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## PROJECT DIRECTORATE OF BIOLOGICAL CONTROL
## BANGALORE

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| Cover | Adults of the syrphid, *Ischiodon scutellaris* |
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CONTENTS

## PREFACE

The All India Co-ordinated Project on Biological Control of Crop Pests and Weeds with its headquarters at Bangalore was established in 1977. Subsequently Project Directorate of Biological Control was formed which started functioning in 1993. Biocontrol based pest management system has been intensified and the economic benefit derived from use of natural enemies to control sugarcane tissue borers, tomato fruit borer and maize stem borer amounts to Rs.4674, Rs.4861 and Rs.699 per hectare, respectively. Biological control of water fern, *Salvinia molesta* using the weevil, *Cyrtobagous salviniae* in Kerala has proved highly successful resulting in clearing the weed mat from the waterways in Kuttanad district and savings of Rs.68 lakhs per annum on labour alone. Similarly biological control of water hyacinth, *Eichhornia crassipes* by using the weevils, *Neochetina eichhorniae, N. bruchi* and the mite, *Orthogalumna terebrantis* has resulted in savings of about Rs.11.2 lakhs per year in Bangalore alone.

Evolution of successful BIPM practices for major crop pests of sugarcane, rice, tobacco, potato, fruits, vegetables, pulses, oil seeds and coconut has led to increased interest in attaining similar successes for other crop pests. To achieve this, a critical analysis has been made and a detailed perspective plan has been prepared for the Project Directorate of Biological Control.

The fifth annual report of the Project Directorate embodies the endeavours of my scientist colleagues for the period from April 1997 to March 1998. 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, 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 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. I thank Dr.N.S.Rao, Senior Scientist (Agri. Entomology) for making all the efforts in bringing out this report.

(S.P.Singh)

## 2. EXECUTIVE SUMMARY

### 2.1 Basic Research

**Project Directorate of Biological Control, Bangalore**

Cultures of thirteen host insects, twenty parasitoids and seven predators were maintained continuously.

Fifty nine cultures of various host insects and 80 cultures of natural enemies were sent to coordinating centres and other research organizations. A formulation of *Trichoderma harzianum* was supplied to six coordinating centres.

*Diglyphus begini*, a parasitoid of *Liriomyza trifolii* was imported from California, successfully quarantined and recoveries made from net house trials. Field releases have been made, but recovery has not been obtained so far.

Studies on the biosystematics of predatory coccinellids covered eleven genera and 30 species under five tribes. Two species belonging to the genera *Pseudoscymnus* Chapin and *Serangium* Blackburn were designated as new.

An acrylic multicellular rearing unit was devised for rearing of *Helicoverpa armigera*. The unit is transparent, indigenous, cheap, amenable to surface sterilisation, durable and provides 80 to 90% survival.

Life cycle parameters of *Ischiodon scutellaris* were assessed under laboratory conditions following a method developed for rearing aphidophagous syrphids with two different larval rearing units.

Studies to identify characters for separating out females of *Campoletis chlorideae* revealed that cocoons with length (L) more than 6.5 mm, weight (W) more than 10.5 mg, L x diameter (D) more than 16.5, L x W more than 70, W x D more than 30, L x W x D more than 180 and W / D more than 4.4 would definitely yield females.

Wing scales of *Helicoverpa armigera* acted as very good preconditioning agent increasing the predatory capacity of the larvae of *Chrysoperla carnea*.

Adults of *Trichogramma chilonis* responded positively to the hexane wash of sunflower buds of different varieties. Highest response (52%) was observed to the bud wash (synomone) of var. Morden.

The endosulfan tolerant strain was capable of parasitising eggs of *H. armigera* immediately after spray of endosulfan to the tune of 56.0% compared to 3.0% by susceptible strain of *T. chilonis* and five days after spray, parasitism and emergence were more in tolerant strain.

Soybean hydrolysed powder based diet (0.2gm) was found to be very effective for *in vitro* rearing of *Chrysoperla carnea*. The feeding potential of *in vitro* reared and *Corcyra* reared *C. carnea* on *H. armigera* eggs and *Aphis gossypii* was found to be good. A semi-synthetic diet based on pig liver paste was promising for rearing *Cheilomenes sexmaculata*.

Gonad-specific viruses from *Helicoverpa armigera* and *Spodoptera litura* have been suspected based on the external manifestation of waxy-plug symptom of the genital system.

Three hundred sunflower rhizospheric bacterial isolates were screened for antagonistic activity against *Sclerotium rolfsii* and PDBC NO. 19 (*Pseudomonas putida* ?) was found to completely inhibit growth of *S. rolfsii* in dual culture.

More than one hundred isolates of *Trichoderma* and *Gliocladium* spp. showing antagonistic potential against pathogenic fungi were isolated from rhizosphere and rhizoplane soil samples.

Among *Trichoderma* species, *T. harzianum* isolate PDBCTH 2 and *Gliocladium virens* among *Gliocladium* isolates gave maximum inhibition of mycelial growth of *S.rolfsii*.

*Steinernema* spp. were isolated from elevation ranges of 107 - 2200 m and were found predominant in sandy loam and clayey loam soils. An isolate PDBCEN 6.11 caused the death of *Plutella xylostella* and *Opisina arenosella* larvae within a day after inoculation and within 2 days in the case of *H. armigera, S. litura* and *C. cephalonica.*

*T. harzianum* PDBCTH2, *T. koningii, G. virens* and *G. deliquescens* were effective against *Meloidogyne incognita* causing 94.5% mortality.

Extensive and intensive field surveys undertaken for parthenium diseases in Karnataka revealed the association of several leafspot / blight pathogens and they included *Alternaria, Colletotrichum, Fusarium, Sclerotium rolfsii, Sclerotinia sclerotiorum* and others. Phyllody caused rampant damage to parthenium plants in many locations. Leaf curl virus also occurred over a large area.

The pre-emergence and post-emergence mycoherbicidal activity studies using *Gliocladium virens* culture filtrates against parthenium revealed that parthenium seed germination and seedling vigour index was reduced to a great extent at different concentrations.

**Indian Agricultural Research Institute, New Delhi**

Seven varieties of *Bacillus thuringiensis* were maintained continuously. Protoxins of two varieties of *B. thuringiensis, viz., kurstaki* and *israelensis* and one isolate BTS 42 (obtained from NRC on Plant Biotechnology, IARI, New Delhi) administered to penultimate instar larvae of *Helicoverpa armigera* resulted in $LD_{50}$ values of 33.01, 195.47 and 22.39/larva for var. *kurstaki, israelensis* and BTS 42, respectively.

**Gobind Vallabh Pant University of Agricultural Sciences and Technology, Pantnagar**

*Gliocladium virens* isolate PI 1 (GV) was found to be a potent antagonist *in vitro* against *Fusarium oxysporum* f.sp. *gladioli* causing gladiolus corm rot and yellows.

*Gliocladium virens* PI 1 (GV) was multiplied on sorghum grains and seven formulations tested against chickpea wilt and root rot complex for their bioefficacy. These were found to improve seedling emergence, plant stand and grain yield of chickpea when used alone or with Vitavax.

*Trichoderma harzianum* isolate-1 (TH 1) is fast growing and heavily sporulating, with excellent antagonistic potential (*in vitro* and *in vivo* conditions) against *Sclerotium rolfsii, Rhizoctonia solani* and *Fusarium solani*, but highly sensitive to carbendazim.

**2.2 Biological suppression of sugarcane pests**

The larval parasitoid, *Cotesia flavipes* was most commonly recorded on *Acigona steniellus* and *Chilo infuscatellus*. *Topobracon* sp. (1.7 - 2.8%) was recorded for the first time on *Scirpophaga excerptalis* larvae. Release of *Trichogramma chilonis* @ 50,000/ha at 10 days interval during May-June proved promising both in the planted and ratoon crops for the control of *C. infuscatellus* and during July - October for the control of *C. auricilius*. Simultaneous releases of *T. chilonis* (50,000/ha at 10 days interval) + *C. flavipes* (10,000/ha at 20 days interval) during July - October proved very promising for the control of *C. auricilius* (PAU).

Peak activity of *Sturmiopsis inferens* on shoot borer at Coimbatore was recorded during January (5.6%) and November (6.1%). The activity of *Cotesia flavipes* was noticed only in August (0.5%). Granulosis virus (GV) of shoot borer was active throughout the year with the peak in August. The fungus *Beauveria brongniartii* was produced on molasses and showed limited ovicidal activity on eggs of white grubs in the laboratory. At a dosage equivalent of $10^{15}$ - $10^{17}$ spores/ha, in pot experiments, *B. brongniartii* caused slightly higher levels of mortality in third instar grubs than in first instar grubs (SBI).

### 2.3 Biological suppression of cotton pests

Biocontrol based IPM (BIPM) evaluated for the control of bollworm complex on cotton was found to reduce boll damage significantly. Egg parasitization by *Trichogramma chilonis* on *Helicoverpa armigera* was highest in BIPM. However, the yield was highest in the PAU spray schedule and was at par with biocontrol+ need based application of insecticides (PAU).

BIPM excelled due to the significant role played by the beneficial insects, which increased through intercropping with groundnut. The seed cotton yield obtained through BIPM strategy was highest (18.27 Q/ha). The incremental cost-benefit ratio (ICBR) in IPM was high (10.07) compared to farmers' practice (1.55) and judicious usage of insecticide (1.59) (ANGRAU).

Bud and boll damage, damage to locules and population of sucking pests were significantly lower in BIPM modules as compared to control. Parasitism due to *Agathis* spp. was extremely high as compared to previous years. The yield in BIPM plots was significantly higher and also gave a higher ICBR than insecticidal treatments and control. Intercropping of maize with cotton enhanced the activity of *Cheilomenes sexmaculata* in BIPM blocks. Studies revealed that maize, *Cassia occidentalis*, parthenium, castor, sunnhemp, marigold, tobacco, etc. harbour various parasitoids / predators of cotton pests (GAU).

### 2.4 Biological suppression of tobacco pests

Sequential sprays of *Bacillus thuringiensis (Bt) kurstaki* @ 1.0 kg/ha and *Spodoptera litura* nuclear polyhedrosis virus (*Sl* NPV) @ 250 LE/ha in tobacco nursery against *S. litura* resulted in a cost-benefit ratio of 1:1.49 as against 1:1.35 in chemical control adopted by nursery growers at Morampudi. BIPM of *Helicoverpa armigera* with *Helicoverpa armigera* nuclear polyhedrosis virus (*Ha* NPV) @ 450 LE/ha and management practices to improve natural enemy activity and crop diversity through erection of bird perches and raising two rows of tagetes around FCV tobacco field reduced the damage by *H. armigera* to 1.30% in comparison to farmers' method (20-30%) (CTRI).

### 2.5 Biological suppression of pulse crop pests

Spray application of *Ha*NPV @ 125 LE/ha + endosulfan 0.035% effectively reduced the larval population of *H. armigera* and increased the yield followed by *Ha*NPV @ 250 LE/ha. Of the *Bt* formulations, Dipel and BTK-II at 1.0 kg/ha were effective against *Helicoverpa* in chickpea (ANGRAU).

Alternate sprays of *Bt* and *Ha*NPV were effective in managing the pod borer complex on pigeon pea (PAU).

**2.6 Biological suppression of insect pests of rice**

Five inundative releases of *Trichogramma japonicum* @ 50,000 / ha / week starting from 30 days after transplanting (DAT) during rabi gave effective control of stem borer (AAU).

Nine simultaneous releases of *T. chilonis* and *T. japonicum* at 10 days interval @ 1,00,000/ha starting from 20 DAT proved very effective for the control of rice stem borer and leaf folder (PAU).

**2.7 Biological suppression of tropical fruit crop pests**

An entomopathogenic fungus, *Paecilomyces farinosus* was isolated from the spiralling whitefly. Outbreak of whitefly *Siphoninus phyllireae* was observed on pomegranate and also the aphelinid parasitoid, *Encarsia azimi*. The oriental mealybug *Planococcus lilacinus* was parasitised up to 60% by the encyrtid, *Tetracnemoidea indica* on pomegranate. *Ooencyrtus papilionis* and *Telenomus* sp. were found on the eggs of pomegranate butterfly *Deudorix isocrates*. The green lacewing *Mallada astur* was predominant on *Aleurodicus dispersus* on guava and about 230 nymphs of spiralling whitefly were consumed by a single larva in 10-12 days. The efficacy of *Cryptolaemus montrouzieri* in controlling the green shield scale *Chloropulvinaria psidii* on guava was demonstrated at Kesthur village near Bangalore (IIHR).

**2.8 Biological suppression of temperate fruit crop pests**

At Solan and Kashmir, *Aphelinus mali* was active from May-December despite low woolly aphid population (Dr.YSPUH & F and SKUAS & T).

Parasitization of San Jose scale by *Aphytis* sp. (*proclia* group) and *Encarsia perniciosi* was recorded at Solan, Shimla and Kulu. *Chilocorus bijugus* larval population was observed from July-August (Dr.YSPUH & F).

**2.9 Biological suppression of vegetable crop pests**

Three species of egg parasitoids were collected from brinjal sphingid, *Acherontia styx* causing in all 64% parasitism. Over 50% egg parasitism by *T. pretiosum* and 30 - 50 % infection of larvae by NPV on fruit borer *H. armigera* in tomato were observed (IIHR).

The mean egg parasitization by *Trichogramma chilonis* on *H. armigera* was 29% in tomato while larval parasitization by *Campoletis chlorideae* was up to 12.5% (Dr.YSPUH &F).

Pea leaf miner, *Chromatomyia horticola* was parasitized by *Diglyphus* sp. on pea (21.1-58%), broccoli (0-15.4%) and sweet pea (0-100%) (Dr. YSPUH & F).

**2.10 Biological suppression of potato pests**

*Apanteles* sp. and *Bracon* sp. were obtained from foliage feeding potato tuber moth larvae. Two hymenopterous parasitoids and a coccinellid predator were obtained from stored potatoes. Four weekly releases of *Copidosoma koehleri* @ 50,000 adults/ha and *Chelonus blackburni* @ 15,000 adults/ha were equally effective in reducing the leaf mines (MPKV).

A laboratory experiment carried out by preparing miniatures of Arnies (20 kg cap.) with only initial releases of parasitoids and application of *B. thuringiensis* and granulosis virus revealed that *Bt* @ 1.0 g/kg tubers was most effective in reducing tuber infestation one month later. *Spodoptera litura* NPV @ 750 LE/ha (=4.5 x $10^{12}$ polyhedral occlusion bodies/ha) was effective causing 87.50% *Spodoptera litura* larval mortality and recording 184.5 q/ha tuber yield. (MPKV).

**2.11 Biological suppression of weeds**

Release of one pair of *Bactra venosana* adults damaged up to 100% of *Cyperus rotundus* in large enclosed cement pots, within a month. The feeding caused reduction in plant growth, tuber weight and regeneration capacity of the damaged tubers. Under field conditions the eggs of *B. venosana* were parasitised heavily by *Trichogrammatoidea bactrae*. Feeding on sunflower leaves caused degeneration of reproductive organs in adults of *Zygogramma bicolorata*. However, when adults fed on sunflower for 15 days were transferred to parthenium, ovarian follicles and testes developed normally (IIHR).

*Z. bicolorata* was found to complete 5 generations in a year. In the field, maximum adult population (1.3 beetles/plant) was observed in June-end, first week of September and mid-October (Dr. YSPUH & F).

Successful control of water hyacinth was achieved in Assam by the exotic weevils *Neochetina eichhorniae* and *N. bruchi* in Disangmukh area of Sibsagar district and less flowering was observed in the remaining water hya
cinth areas of Sibsagar district (AAU).

*N. eichhorniae* and *N. bruchi* have established on water hyacinth. *Zygogramma bicolorata* is widespread on parthenium in Ropar, Nawanshahar and Jalandhar (PAU).

*Orthogalumna terebrantis* has established all over the release sites giving partial suppression of water hyacinth (KAU).

## 3. INTRODUCTION

### 3.1.Brief History

All India Coordinated 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 1988 the Project Coordinator'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 utilization 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 colonized on subabul psyllid. Weevil *Cyrtobagous salviniae* (Origin : Argentina) introduced in 1982 colonized 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 colonized 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 standardized 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* & *Telenomus remus* preferred to parasitize *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. Organizational 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).

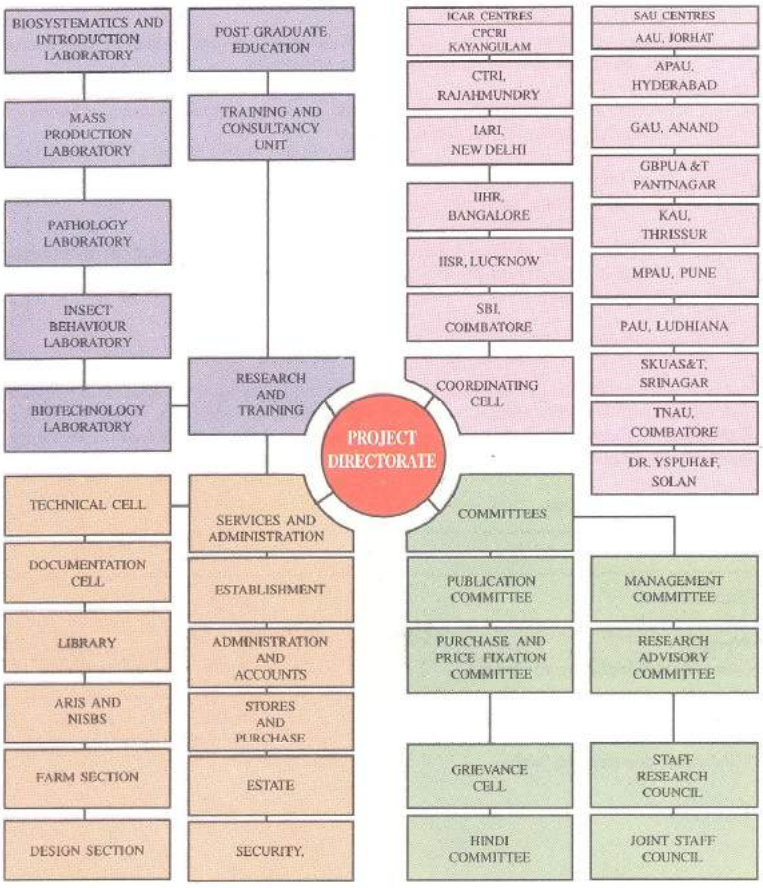
### 3.5. Financial statement

| Head | Plan* | Non-plan | Total |
|---|---|---|---|
| Establishment | 26.10 | 50.03 | 76.13 |
| TA | 03.00 | 01.75 | 04.75 |
| Works | 51.90 | - | 51.90 |
| Other charges including equipments | 25.10 | 05.00 | 30.10 |
| Total | 106.10 | 56.78 | 162.88 |

* Including coordinating centres

# PROJECT DIRECTORATE OF BIOLOGICAL CONTROL
# BANGALORE

## Organisational Chart



**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 | 2.69 | 2.89 |
| ANGRAU, Hyderabad | 2.99 | 3.72 |
| GAU, Anand | 5.12 | 7.15 |
| KAU, Thrissur | 3.15 | 6.33 |
| MPKV, Pune | 2.15 | 3.57 |
| PAU, Ludhiana | 4.37 | 3.70 |
| SKUAS&T, Srinagar | 1.66 | 2.68 |
| TNAU, Coimbatore | 3.42 | 2.74 |
| YSPUH&F, Nauni, Solan | 3.29 | 3.44 |
| 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 upto 31.03.1998 | Posts filled up to 31.03.1998 | vacant positions |
|---|---|---|---|
| **PDBC, Bangalore** | | | |
| Scientific | 25 | 18 | 7 |
| Technical | 21 | 17 | 4 |
| Administrative | 8 | 8 | - |
| Supporting | 6 | 6 | - |

contd..

| Category | Posts sanctioned upto 31.03.1998 | Posts filled up to 31.03.1998 | vacant positions |
|---|---|---|---|
| **SAU-based Centres** | | | |
| Scientific | 15 | 15 | - |
| Technical | 41 | 39 | 2 |
| Administrative | 01 | 01 | - |
| 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 of natural enemies of *Liriomyza trifolii* and laboratory studies on them

*Diglyphus begini* was successfully quarantined. Net house studies on the efficacy of *D. begini* on *L. trifolii* on tomato revealed that the parasitoid could be recovered. Following the successful recovery from net house trial, a field release programme was initiated and the first consignment released on 16-07-1997 for field release in and around Rajanukunte near Bangalore. Five field releases were made but the parasitoid could not be recovered which may be because of frequent insecticidal sprays by the farmers. The sixth release was done on enclosed infested tomato plants. Efforts are still continuing to further field test the parasitoid.

#### 4.1.2 Importation of natural enemies of *Aleurodicus dispersus*

The import permit for *Encarsia haitiensis* from Guam islands was obtained from the Plant Protection Advisor, Government of Indian, New Delhi. Efforts to get the parasitoid from other sources are being continued in addition to the above source.

### 4.1.3. Culturing of spiralling white fly, *Aleurodicus dispersus*

The culture of *A. dispersus* developed properly on canna plants. The initial culture was obtained from shade trees where *A. dispersus* was breeding heavily. Now it is being reared on
seedlings of cotton and a shade plant, *Begonia* sp.

### 4.2. Biosystematic studies on Indian predatory Coccinellidae

### 4.2.1 Taxonomic studies on coccinellids

All the available species belonging to the tribes Chilocorini, Platynaspini and Serangiini covering seven genera were studied and the genitalic characters were illustrated. The genera studied so far include *Chilocorus* Leach, *Curinus* Mulsant, *Exochomus* Redtenbacher, *Brumoides* Chapin, *Platynaspidius* Miyatake and *Serangium* Blackburn. Two species belonging to the genera *Serangium* (predatory on subabul psyllid, *Heteropsylla cubana* Crawford) and *Pseudoscymnus* Chapin (predatory on mango mealybug, *Rastrococcus iceryoides* (Green)) were designated as new. Two genera of Scymnini, *viz.*, *Horniolus* Weise and *Pseudoscymnus* were also studied. Keys are being constructed for these species.

### 4.2.2 Preparation of an annotated checklist of Indian fauna of predatory coccinellids

A checklist to the Indian fauna of predatory coccinellids was completed for most of the genera. For all the genera and species, the most recent combination, the original citation and all the synonyms in chronological order were given. The nature of type material, method of fixation and the type depository were indicated. The distribution of the genera and the species therein was given. All subsequent references of importance pertaining to revisions, redescriptions, distribution, lectotype designations, etc. were provided for all the taxa. Literature search for completing the list is still on.

### 4.2.3 Construction of a national biodiversity database on coccinellids

Literature on various aspects of coccinellid fauna of India is being sorted out for species-wise compilation. A database incorporating the taxonomy, distribution, biology, host range, predatory potential, potential or actual use in the field, etc. for all the species known from India is being created.

## 4.3 Survey for natural enemies

### 4.3.1 Record of predators of *Aphis craccivora*

Field surveys were carried out during 1997 in pulse growing areas of Bangalore, Arsikere, Tumkur and Hassan districts of Karnataka for collection and identification of predatory fauna of *A. craccivora*. Several coccinellid and syrphid predators were collected. *A. craccivora* was recorded almost throughout the year on *Gliricidia maculata* with peaks during January-March and June-August. During June-July it was also observed on *Trigonella foenumgracum* and *Medicago sativa*.

The list of the predators and their activity period indicates that there was a definite sequence in their activity and a number of them preyed upon the aphids at the same time. They were well distributed throughout the study area and in general these predators were more common on *G. maculata*. *G. maculata* appeared to contribute greatly to the season to season carry-over of infestations of *A. craccivora*. It also harboured several other homopteran pests like *Maconellicoccus hirsutus* and *Planococcus citri*. Polyphagous predators like *Cryptolaemus montrouzieri*, *Cheilomenes sexmaculata* and *Scymnus* spp. have other hosts to feed upon in addition to this aphid accounting for more number of predators on *G. maculata* (Table 1).

### 4.3.2 Record of host plants and predators of *Ceroplastodes cajani*

Surveys were carried out in pigeonpea plots during 1997 in and around Bangalore. As the pest occurred twice a year, in summer and rainy season, observations were recorded during both the seasons in two different localities. For each season three plots were surveyed. Three shoots per plant of pigeonpea (var. ES 90) were collected every week, brought to the laboratory and placed in cloth walled aluminium cages (30 x 30 x 30 cm) at weekly interval. Sampling was done on 20 such infested plants. Parasitoids/predators that emerged in each sampling in the cages were collected and counted. Similar sampling procedure was adopted during rainy season. Samples were also collected from different places in Bangalore in both the seasons of both the years. For studying biological parameters and feeding potential, twenty freshly emerged first instar grubs were confined individually in petri dishes. Two hundred nymphs of *C.cajani* along with the twigs of pigeonpea were provided everyday until the emergence and up to death of adult beetles.

Number of scales fed was counted the next day and the dates of moulting into the next instar were recorded. Temperature and humidity in the laboratory varied from 24 °C to 27 °C and 65 to 79 % respectively, during the experiments.

In the present study two new hosts, *viz*., *Solanum anguivi* and *S. hispidium* were

recorded during rainy season on which it was found in association with the mealybug *Coccidohystrix insolita*. During summer it was recorded on *Duranta plumerii* and *Artocarpus heterophyllus* and during winter on *S. trilobatum*, *S. melongena* and *Lycopersicon esculentum* where it was not associated with *C. insolita*. An unidentified aphelinid, an encyrtid and a pteromalid were recorded. The activity of the aphelinid parasitoid was only during rainy season on perennial pigeonpea and the peak population was during July first week-August first week. In summer, encyrtid and pteromalid parasitism was higher during March-May. However, these two parasitoids could not be recovered during rainy season.

Table 1. Record of predators of *Aphis craccivora* in Karnataka

| Predator | Activity period | Crop / Host plant | Stage |
|---|---|---|---|
| *Anegleis cardoni* | May | *Gliricidia maculata* | Adult |
| *Anisolemnia dilatata* | June | *Gliricidia maculata* | Adult |
| | November | Pigeonpea | Adult |
| *Brumoides suturalis* | August - October | Pigeonpea | Adult |
| *Coelophora bissellata* | September - November | Cowpea, lablab | larval & |
| | | *Gliricidia maculata* | adult |
| *Cryptolaemus montrouzieri* | January | *Gliricidia maculata* | Larval & adult |
| *Curinus coeruleus* | May - June | *Gliricidia maculata* | Adult |
| *Hyperaspis maindroni* | June | Cowpea | Adult |
| *Oenopia* sp. | June | *Gliricidia maculata* | Adult |
| *Synonycha grandis* | June - July | *Gliricidia maculata* | Adult |
| *Episyrphus balteatus* | November - December | *Solanum nigrum* | Larval |
| Unidentified | June-July | *Gliricidia maculata* | Larval |
| Cecidomyiid | October - November | Lablab | |

*Scymnus* sp., *Hyperaspis maindroni*, a nitidulid *Cybocephalus* sp., and an unidentified cecidomyiid were recorded during this year in addition to others.

*Curinus coeruleus*, *Rodolia* sp., *Pseudaspidimerus trinotatus* and *Cybocephalus* sp. were recorded during summer, whereas *Scymnus* sp., *Hyperaspis maindroni* and the cecidomyiid were recorded only during rainy season. *Spalgis epius* was the only predator available during both the seasons. *Cybocephalus* sp. occurred only in the early infestation stages (i. e. during last week of December), but *P. trinotatus* and *Rodolia* sp. were recorded in large numbers from January to March with peak during second week of February to first week of March. During this period their population ranged from 10.6 to 21.7 and 11.1 to 35.3 beetles per plant, respectively.

During rainy season, the cecidomyiid was the first predator to occur followed by *Scymnus* sp. and *H. maindroni*. Peak population of these coccinellids occurred in August, when all the plant parts including pods were covered with the coccid. During this period, population of *Scymnus* sp. and *H. maindroni* ranged from 12.9 to 52.4 and 10.6 to 42.8 beetles per plant, respectively (Table 2). *C. coeruleus* occurred only in the fields where *Heteropsylla cubana* infested subabul (*Leucaena leucocephala*) trees were present in the vicinity.

Population of cecidomyiid remained negligible throughout the season. *S. epius* attained high proportions during last week of March and second week of August in summer and rainy season, respectively.

Laboratory studies which were conducted to study the feeding potential and biological parameters of these predators using *C. cajani* as host indicated that the egg incubation period in case of *P. trinotatus* varied from 4 to 6 days. The total larval period varied from 10 to 14 days and the pupal period ranged from 8 to 11 days. A single grub could consume 369.74 $\pm$ 19.53 crawlers during its larval period and 15 to 20 nymphs per day during adult stage. *Scymnus* sp. was relatively less voracious and fed on 289.53 $\pm$ 24.35 crawlers during its larval period of 10 to 11 days. Pupal development was completed in 6 to 7 days. Single adult consumed 12 to 15 nymphs per day and laid 36 to 48 eggs which hatched in 4 to 5 days.

### 4.3.3 Collection of *Campoletis chlorideae* and *Eriborus argenteopilosus* from different agroecosystems

*Helicoverpa armigera* larvae parasitised by *Campoletis chlorideae* were collected from sunflower, pigeonpea, marigold, dolichos, tomato and cotton crop ecosystems and larvae parasitised by *Eriborus argenteopilosus* were collected from sunflower, pigeonpea and dolichos fields. Maximum parasitism by *C. chlorideae* was found on sunflower (6%).

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

### 4.4.1 A multi-cellular larval rearing unit for *Helicoverpa armigera*

Comparisons were made between rearing in multi-cellular trays rearing in diet bottles (4 cm height and 2 cm diameter) with cotton plugs and in plastic louvers (60 x 20cm with 2.5 cm cubical cells) with acrylic sheet base and top.

The diet bottles could hold 7.4 cc of diet, which was not adequate for the total development of the insect. Though 60 to 80 % survival could be obtained, as the capacity of the bottle was less, diet had been provided again and this lead to increased handling of larvae and increased disease incidence. More time and labour was involved in collection of pupae from individual bottles.

Table 2. Population of predators of *Ceroplastodes cajani* during summer and rainy season on ratoon and perennial pigeonpea

| Month/Weeks | Ratoon Pigeonpea | | | Month / Week | Perennial Pigeonpea | | |
|---|---|---|---|---|---|---|---|
| | *Pseudaspi-limerus trinotatus* | *Rodilia sp.* | *Spalgis* epius | | *Scymnus* sp. | *Hyperaspis maindroni* | *Spalgis epius* |
| January I | 1.8±0.50 | 0.4±0.15 | 0.0 | June I | 0.0 | 0.0 | 0.0 |
| II | 3.4±1.27 | 0.6±0.12 | 0.0 | II | 0.0 | 0.0 | 0.0 |
| III | 4.1±2.36 | 1.8±0.41 | 0.0 | III | 0.0 | 0.0 | 0.0 |
| IV | 3.2±0.15 | 4.2±1.82 | 0.0 | IV | 0.0 | 0.4±0.1 | 0.0 |
| V | 6.1±1.27 | 3.1±1.27 | 0.0 | V | 0.8±0.12 | 0.4±0.0 | 0.0 |
| February I | 10.6±5.36 | 11.1±5.22 | 0.0 | JulyI | 3.9±1.80 | 0.0 | 0.0 |
| II | 13.9±1.84 | 21.8±6.91 | 0.0 | II | 2.2±0.30 | 0.0 | 0.0 |
| III | 19.2±10.15 | 35.3±12.15 | 0.0 | III | 6.1±4.10 | 2.1±0.5 | 0.4±0.0 |
| IV | 21.7±12.20 | 17.2±10.20 | 0.4±0.0 | IV | 9.2±2.60 | 4.2±1.2 | 1.2±0.5 |
| March I | 11.3±3.50 | 9.8±7.46 | 1.8±0.15 | August I | 12.9±8.40 | 10.6±5.2 | 2.9±1.2 |
| II | 19.2±1.12 | 4.5±2.3 | 3.5±2.10 | II | 18.2±9.20 | 13.9±10.9 | 4.8±3.2 |
| III | 8.1±0.5 | 0.8±0.10 | 2.8±1.50 | III | 31.9±15.20 | 42.8±13.2 | 3.2±1.1 |
| IV | 3.1±1.2 | 0.00 | 6.9±2.30 | IV | 52.4±10.50 | 10.2±1.9 | 0.3±0.0 |

In the case of louvers, only 20 to 30% survival could be obtained. The major disadvantages of using these louvers were :- a) mortality of larvae due to insufficient aeration and fungus formation, b) the acrylic sheet cover could not prevent the movement of the larvae from one compartment to another leading to cannibalism, c) escape of larvae while transferring in the open louvers, d) each cell could hold only 4.6 cc of diet which was not adequate for complete development, e) as larvae had to be transferred again into fresh diet, this led to increased handling and disease incidence

The multi-cellular rearing unit and its parts are depicted in Figures 2 a and b.

This unit is made up of two exactly fitting separable rectangular acrylic trays (4mm thick) - the outer or basal tray (without compartments) and an inner or upper tray (with compartments). The outer tray is 37 x 32 x 5 cm and the inner tray is 36 x 31 x 5.5 cm. The inner tray is divided into 100 compartments, each compartment measuring 3.5 x 3 x 4.5 cm. At the base of each compartment, a small round hole is provided (9mm diameter). Stacking of trays is possible.

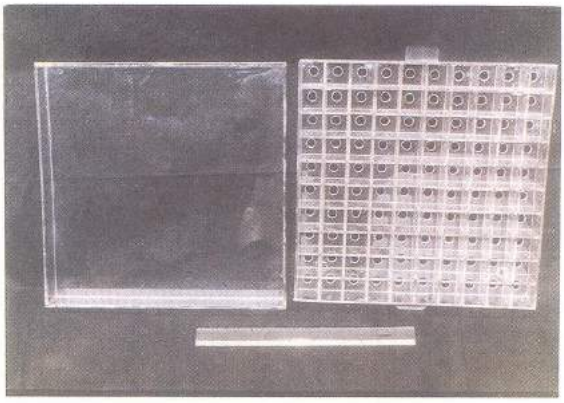
Semi-synthetic diet is prepared and 350 ml of the diet is poured into the outer tray. After the diet solidifies and cools, the inner tray is inverted and placed over the outer tray, with the holes facing upwards. The larvae are transferred individually into the compartments through the holes and plugged with cotton wool. The whole set up is placed in a incubator ($26 \pm 1$°C). After pupation, the upper tray is removed and the pupae collected from the base of the basal tray.

The major advantages of using this tray are - pupation of about 80 to 90% is obtained; the unit is made of indigenous material; the trays are amenable to surface sterilisation and can be re-used; each compartment can hold 12 cc of diet which is sufficient for the total larval development; there is enough moving space for the growing larvae in each compartment; as young larvae are transferred into the tray and pupae are collected, handling is minimum and disease incidence is also negligible, the larvae cannot move from one compartment into another and hence cannibalism can be avoided, escape of larvae was minimum, the cotton plugs can provide enough aeration and hence the problem of moisture accumulation is not encountered, since the trays are transparent, pupal formation and collection is easy and rearing in these trays consume less time and labour.

### 4.4.2 Improved larval and adult rearing methods for *Ischiodon scutellaris*

Adult oviposition cage for syrphid was modified and two different larval rearing units were fabricated. The adults before oviposition were maintained in one litre plastic container and kept under light for an hour every morning, for seven to eight days. They were then shifted to a acrylic sheet cage (30x30x30 cm) with pollen placed on an artificial flower.

(A)



(B)

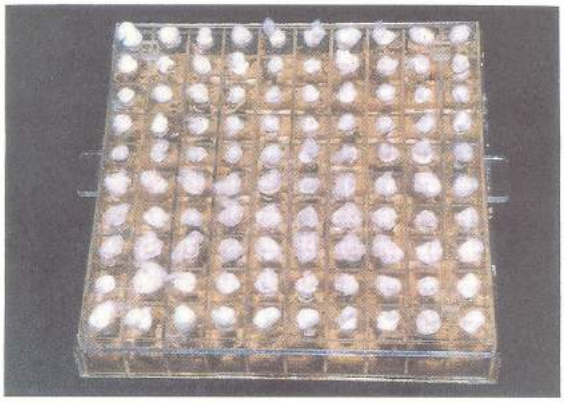


*Fig. 2. Multicellular larval rearing unit*
*(A) comprising two trays*
*(B) multicellular tray inverted over the plan tray*

To stimulate oviposition cowpea seedlings infested with *Aphis craccivora* were provided in the syrphid oviposition cage. Adult female deposited eggs in the aphid colony. Each container with cowpea seedlings could yield about 150 to 300 eggs every alternate day.

Two types of larval rearing units were fabricated.

The first type of unit consisted of two square containers (9.5 x 9.5 x 4 cm) made of polyurethane. The bottom container was used to raise 16 seedlings of cowpea. The container with ventilation window was used for covering the top. Cowpea seedlings were infested with *A. craccivora* adults. Two newly hatched larvae of *Ischiodon scutellaris* were released on each seedling. The larvae completed development in 10 to 12 days. During this period each larva consumed 370.60 $\pm$7.74 aphids. Fully grown larvae pupated in the sand in which seedlings were raised. Pupae were removed from the sand and used for further multiplication.

The advantages in the type I rearing unit were that, larval handling was minimum and aphids could be replenished periodically without escape of syrphid larvae.

The second type of unit consisted of two ventilated polyurethane containers fixed over each other with the help of hinges and a locking hook to form a case (9.5 x 9.5 x 8 cm). Cut pieces of cowpea plant infested with *A. craccivora* were kept in side and seedlings containing syrphid eggs were released. A 4 x 4 cm pad of cotton was placed in a corner at the base of the case or a dried leaf introduced as a pupation substrate. When adequate feeding (2250 to 3000 aphids) was provided around 30 larvae could be reared in the case.

### 4.4.3 Mass rearing of the American serpentine leaf-miner, *Liriomyza trifolii* in the laboratory

A mass multiplication method developed during 1995 - 1997 for the *L. trifolii* using french bean seedling was continued. French bean seedlings were found more suitable than cowpea. Several generations have been reared with reinforcements and rejuvenation with field collected populations.

### 4.4.4 Studies on host suitability of *Corcyra cephalonica* for rearing *Allorhogas pyralophagus* in comparison with *Chilo partellus*

Studies were conducted to find out the host suitability of the laboratory host *C. cephalonica* to rear the mexican parasitoid *Allorhogas pyralophagus*. This parasitoid which is generally reared and maintained on *Chilo partellus* can also be maintained on other laboratory hosts. This possibility was explored by utilising *C. cephalonica* as an alternate factitious host. Larvae of both these hosts were exposed by placing them inside drinking paper straws to the

parasitoids at host : parasitoid ratio of 1:2. The larvae after exposure for 24 hrs. were later examined for number of cocoons formed, adults emerged and sex ratio. The results are presented in Table 3.

The results indicated that *A. pyralophagus* could parasitise *C. cephalonica* also but the adult yield and per cent adult emergence were poor. Though *C. cephalonica* could be used as an alternate host the performance of the parasitoid was not as good as when *C. partellus* was used as a laboratory host.

Table 3. *Allorhogas pyralophagus* emergence from *Corcyra cephalonica* and *Chilo partellus* larvae

| Host larva | No. of cocoons formed / larva | No. of adults emerged | % emergence | Sex ratio |
|---|---|---|---|---|
| *C. partellus* | 26.53 | 25.40 | 95.74 | 1 : 0.89 |
| *C. cephalonica* | 19.50 | 17.88 | 91.67 | 1 : 0.79 |

### 4.4.5 Culturing the promising indigenous natural enemies of *Liriomyza trifolii*

Survey was conducted on cultivated crops around Bangalore and leaf-miner infested leaves of castor, cucurbits, weeds, drumstick, beans and other crops were collected for the emergence of natural enemies. *Chrysonotomyia* sp. was found as a dominant indigenous parasitoid of *L. trifolii* on tomato and castor.

## 4.5 Bioecological studies on natural enemies

### 4.5.1 Population dynamics, host range and biological parameters of *Leucopis* sp. (?) *formosana*

Broad bean, *Vicia faba* was kept under surveillance for incidence of *Aphis craccivora* from germination of the crop till harvest. Ten aphid colonies, each comprising of around 500 aphids, were collected every week, starting from first week of December, 1996. These aphids were reared in the laboratory to record the number of larvae of the chamaemyiid, *Leucopis* sp. (?) *formosana* associated with them. Its biological parameters and host range were also studied.

Population of the chamaemyiid ranged from 6 to 17 per colony of about 500 aphids up to first week of January and it increased to an average of 29.67 during third week of January. A slight decline in its population (18.42 / colony) was recorded in the second week of February but the population increased to around 41.60 per colony by the third week of March. However, its population showed a decline by the first week of April which coincided with a decline in aphid population and maturity of crop.

Egg, larval, pupal and adult periods were 3-4, 10-13, 15-20 and 18-28 days, respectively. Eggs were laid in the aphid colony and each female laid about 13-28 eggs. Single larvae needed 60-80 aphids to reach maturity. The present study revealed that *Leucopis* sp. (?) *formosana* is an important predator of *A. craccivora*, especially during winter when population of other predators is relatively low.

### 4.5.2 Bioecological studies on syrphids in cowpea ecosystem

Studies on abundance of different species of syrphids in cowpea ecosystem were carried out during summer and kharif seasons of 1997. The larval activity of syrphids started from the first week of March and second week of August during summer and kharif season, respectively. During March - May, three species and during August - November four species were recorded.

The peak larval counts of *Paragus yerburiensis, P. serratus* and *Ischiodon scutellaris* were observed from third week of April to second week of May and second week of September to fourth week of September in summer and kharif, respectively. During rainy season, *Dideopsis aegrota* appeared in the fourth week of August and was abundant till the second week of September. *P. serratus, P. yerburiensis* and *I. scutellaris* were active during both the seasons. *I. scutellaris* maintained a relatively higher population density, ranging from 1 to 51 and 2 to 14 larvae per ten plants with peak in the second week of May and 4th week of September when it constituted 78.46 and 45.16 per cent of syrphid population in summer and kharif season, respectively. But its share in the community reached 84.61 and 47.82 per cent at the end of May and third week of September, respectively. High activity of syrphids coincided with peak aphid populations in general.

### 4.5.3 Studies on the fecundity, hatchability, mortality and longevity of *Coelophora bissellata*

During September - November 1997, *A. craccivora* was found to be predated upon by *Coelophora bissellata*. The beetles were collected from the field to observe egg hatchability and mortality during larval stages, larval feeding potential and adult longevity.

Copulated females started ovipositing after 5.80 days. They continued to lay eggs for 44.70 days. Total fecundity varied between 295 and 410 eggs with an average of about 345 eggs per female. On an average 49.54 to 69.08% of the eggs successfully hatched out as grubs.

The daily rate of aphid consumption increased progressively with the larval growth. The maximum number of aphid consumption was found on the penultimate day of larval period and the rate of consumption of aphid decreased on the last day as the larvae entered prepupal stage. The average consumption of aphids by the first, second, third and fourth instar was 14.04, 45.84, 57.06 and 198.05, respectively. Larval duration of first, second, third and fourth instar was 1.80, 2.70, 1.80 and 3.80 days, respectively. The total number of aphids consumed during larval development was 314.976 aphids. The last instar larva was the most voracious.

Mortality during larval stages was between 13 to 26.74%. Adult females lived for 56.80 days and males 51.50 days. Oviposition period was of about 44.70 days.

### 4.5.4 Effect of different aphid hosts on the development of *Ischiodon scutellaris*

Six aphid species *viz.*, *Aphis craccivora*, *A. gossypii*, *A. nerii*, *Lipaphis erysimi*, *Rhopalosiphum maidis* and *Uroleucon compositae* were reared on cowpea, cotton, *Calotropis gigantea*, mustard, maize and safflower, respectively. Developmental period of *I. scutellaris* was recorded by releasing one pair of freshly emerged adults on each of the hosts. Plants were observed each day for oviposition, larval and pupal duration, prey consumption, larval and pupal mortality, pupal weight and adult longevity on each host. The rate of host consumption by larvae of predator was determined by releasing it on known number of aphids.

The developmental period of three larval instars on different hosts ranged from 6.90 to 10.50 days (Figs.3 & 4). *I. scutellaris* took less time on *A. nerii* (6.90 days) and *A. craccivora* (7.80 days) than on *U. compositae* (10.50 days). Larvae of *I. scutellaris* were able to complete development on all the aphid species provided. There was a significant difference in weight of pupa resulting from the larvae reared on different aphid hosts. Larvae reared on *A. gossypii* resulted in light pupa (18.05 mg) which was on par with those reared on *U. compositae* (18.70 mg). Larvae reared on *A. craccivora* resulted in heavier pupae (26.05 mg) followed by those reared on *A. nerii* (23.05 mg). Per cent emergence of adults was only 33.33% and 53.33% in *U. compositae* and *A. gossypii*, respectively, whereas it was 83.33% and 80.00% in *A. craccivora* and *A. nerii*, respectively.

Host consumption rate by the larvae ranged from 33.40 to 54.10 aphids per day. It exhibited strong preference for consumption of *A. nerii* (54.60 aphids / day) and *A. craccivora* (49.20 aphids / day) followed by *R. maidis* (45.10 aphids / day).

**Fig 3 : Influence of *A. craccivora* density on development of *I. scutellaris***

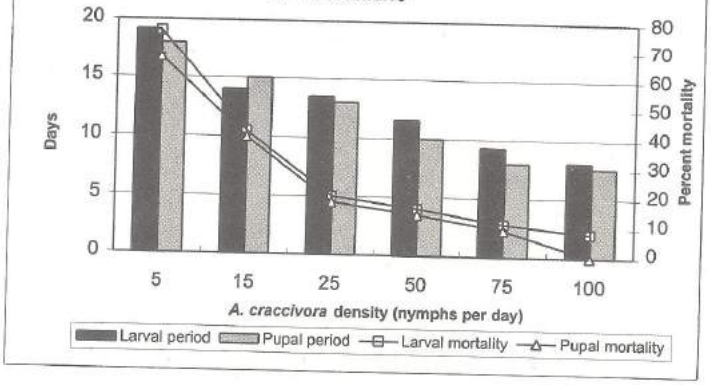
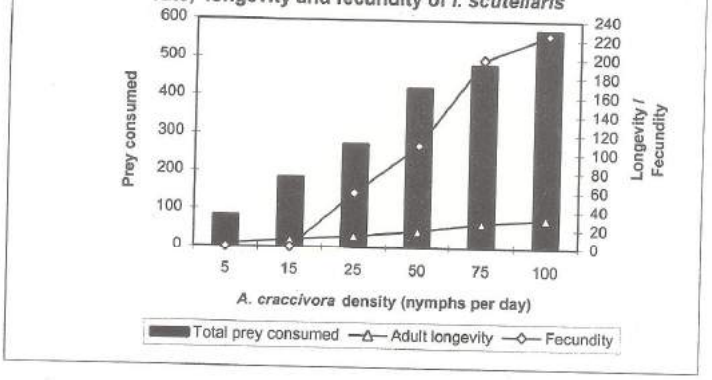



**Fig 4 : Influence of *A. craccivora* density on consumption rate, longevity and fecundity of *I. scutellaris***



### 4.5.5 Influence of different predators of *Aphis craccivora* on different host plants

*A. craccivora* infesting cowpea (*Vigna unguiculata*) and *Gliricidia maculata* collected from field were used for rearing the coccinellids viz., *Coccinella septempunctata, C. transversalis, Scymnus* sp. and syrphids viz., *Ischiodon scutellaris, Paragus serratus* and *P. yerburiensis* and a chamaemyiid, *Leucopis* sp. (?) *formosana* in the laboratory. Mating pairs of the predators (except syrphids and chamaemyiid) were collected from respective hosts and reared from the eggs laid by them in the laboratory. In case of syrphids and chamaemyiid, adults from laboratory cultures were confined to *V. unguiculata* and *G. maculata* and allowed to lay eggs, which were used.

To study the larval mortality fifteen larvae of each predator were confined in a cage with aphid infested shoots and dead larvae recorded daily. The variation in the percentage of larval mortality in the different stages of the predatory larvae feeding on aphids infesting *G. maculata* was observed by rearing the predators up to preceding larval instar on a preferred host (*A. craccivora* on *V. unguiculata*) and then confining them on the former host.

Among the four larval instars of *C. septempunctata* and *C. transversalis*, the percentage of mortality was high in the first two instars, when reared on *A. craccivora* infesting *G. maculata* (Table 4). The mortality rate decreased considerably when the predators attained the third and fourth instar stage. However, the percentage mortality in *Scymnus* sp. was very low even when reared on aphids infesting *G. maculata*. In case of syrphids, *I. scutellaris* showed high mortality in first two instars but mortality decreased after attaining third instar. However, in *P. serratus* and *P. yerburiensis*, percentage mortality was considerably less even in first two instars and percentage of mortality in *Leucopis* sp.(?) *formosana* was nil. The percentage mortality was relatively low in all the predators when reared on the same aphid infesting *V. unguiculata*.

The study of field population of coccinellids and syrphids on *G. maculata* revealed that larval stages of *C. septempunctata, C. transversalis* and *I. scutellaris* were observed occasionally, but larval stages of *P. serratus, P. yerburiensis, Scymnus* sp. and *Leucopis* sp. (?) *formosana* were observed frequently.

It can be concluded that *A. craccivora* infesting *G. maculata* could not be used for feeding / rearing larval stages of *C. septempunctata, C. transversalis* and *I. scutellaris*. However, their late instars and *P. serratus* , *P. yerburiensis, Scymnus* sp. and chamaemyiid could be reared on *Gliricidia* aphid in the absence of *A. craccivora* on *V. unguiculata* itself.

Table 4. Larval mortality in different predators on *Aphis craccivora* infesting *Gliricidia maculata* and *Vigna unguiculata*

| Predator | Larval mortality (%) on *Gliricidia maculata* | | | | Larval mortality (%) on *Vigna unguiculata* | | | |
|---|---|---|---|---|---|---|---|---|
| | Larval instars | | | | Larval instars | | | |
| | I | II | III | IV | I | II | III | IV |
| *Coccinella septempunctata* | 93.33 | 73.33 | 33.33 | 13.33 | 20.00 | 6.66 | 0.00 | 0.00 |
| *C. transversalis* | 86.66 | 46.66 | 20.00 | 6.66 | 13.33 | 6.66 | 0.00 | 0.00 |
| *Scymnus* sp. | 6.66 | 0.00 | 0.00 | 0.00 | 6.66 | 0.00 | 0.00 | 0.00 |
| *Ischiodon scutellaris* | 80.00 | 53.33 | 26.66 | - | 6.66 | 6.66 | 0.00 | - |
| *Paragus serratus* | 6.66 | 0.00 | 0.00 | - | 0.00 | 0.00 | 0.00 | - |
| *P. yerburiensis* | 6.66 | 0.00 | 0.00 | - | 6.66 | 0.00 | 0.00 | - |
| *Leucopis* sp.(?) *formosana* | 0.00 | 0.00 | 0.00 | - | 0.00 | 0.00 | 0.00 | - |

### 4.5.6 Effect of prey density on development and reproduction output of *Ischiodon scutellaris*

The effect of prey number on feeding capacity, development and fecundity of *I. scutellaris* was studied in the laboratory using *Aphis craccivora* as prey. *A. craccivora* was reared on cowpea seedlings and *I. scutellaris* adults were obtained from laboratory culture that had been reared on *A. craccivora* for three generations. Eggs of the predator were kept individually in glass vials (15 x 2.5 cm). After hatching, each larva was provided with a known number of aphid nymphs, viz., 5, 15, 25, 50, 75 and 100 per day until all the larvae pupated. Each treatment was replicated 20 times. The data on the number of aphid nymphs consumed and predator's developmental period (egg to pupation) were recorded at 24 h interval. Fecundity of adults that emerged from 5, 15, 25, 50, 75 and 100 nymph density was recorded.

Adults were held in acrylic sheet cage (30 x 30 x 30 cm) and fed honey and castor pollen daily. Cowpea seedlings infested with *A. craccivora* were kept in the cage for stimulating oviposition. RBD design with one predator, six density levels and 20 observations for each combination was followed. All laboratory studies were conducted at 25 ± 1.5 °C and 55 to 70% RH.

The feeding capacity of *I. scutellaris* larvae when presented with 5 and 15 *A. craccivora* nymphs per day was 89.00 and 88.20 per cent of the nymphs provided, respectively (Fig.5). At low prey density of 5 and 15 aphid nymphs per day, 24.00% larvae were able to pupate out of which 33.00% emerged as adult. However adult longevity was lowest in these treatments (3.10 and 8.00 days, respectively). In the treatments with 25 and 50 aphid nymphs per day, percentage consumption came down to 81.42 and 73.50, respectively. The predator consumed more aphids as prey density increased but the percentage of nymphs consumed declined till the density of 75 aphid nymphs per day. A slight marginal increase in the percentage prey consumed and total prey consumed was observed at the density of 100 nymphs per day. Larval period varied from 19.10 to 8.10 days when larvae were provided 25 and 100 aphid nymphs per day.

*I. scutellaris* larvae given 5 and 15 nymphs per day failed to oviposit, but those provided with 25 and 50 nymphs laid an average of 57.85 and 108.00 eggs, respectively. As the number of prey increased from 75 to 100 nymphs per day, number of eggs laid per female increased from 188.50 to 224.75, respectively.

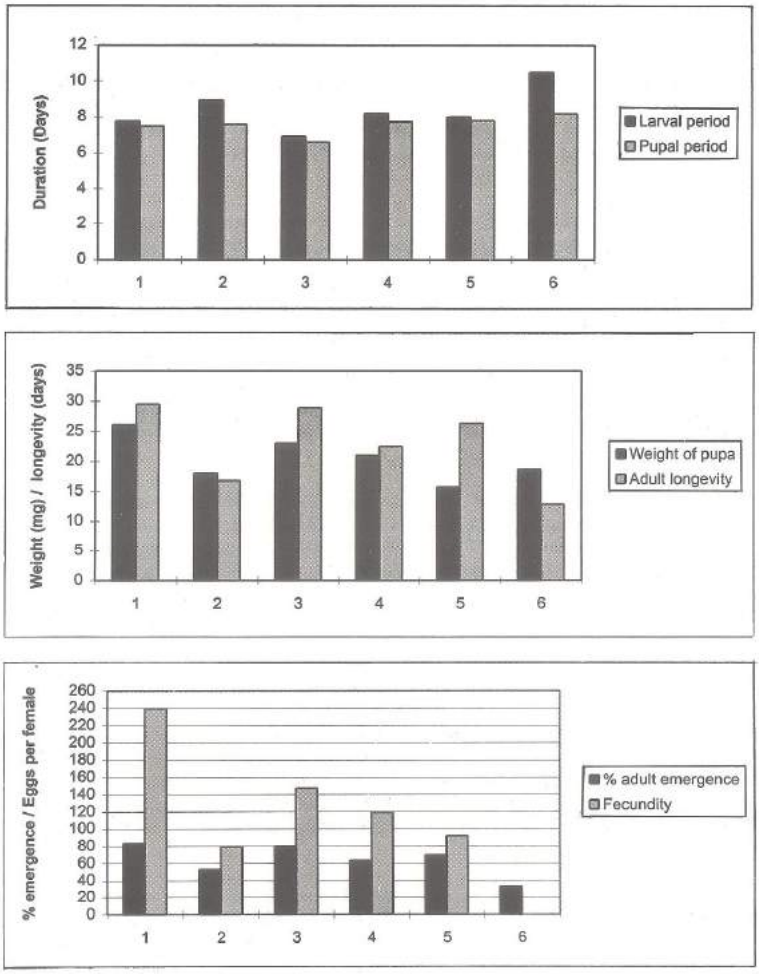
The level of 75 nymphs per day enabled proper development of the immature stages, increased fecundity and longevity of adults, as well as optimized prey use.

### 4.5.7 Effect of types of exposure on parasitism and sex ratio of *Campoletis chlorideae*

Individual exposure method and mass exposure method were tried. Bouquets of castor leaves were made and *Spodoptera litura* larvae (3 to 4 day old) were released on these bouquets in acrylic sheet cages and one mated female parasitoid released into the cage. After 24 hours, the larvae were collected and placed in individual vials with artificial diet. The vials were checked regularly for cocoon formation and adult emergence. This was replicated twenty times.

In the individual exposure method, 3 to 4 - day - old *S. litura* larvae were individually exposed to a mated female of *C. chlorideae*. This was also replicated twenty times.

Individual exposure resulted in 66.36% of the parasitised larvae forming cocoons whereas it was significantly less in the mass exposure method (Table 5). The per cent females among the progeny was 32.78% in the mass exposure method, significantly more than that in the individual exposure method (19.93%).




1 - *A. craccivora*, 2 - *A. gossypii*, 3 - *A. nerii*, 4 - *L. erysimi*, 5 - *R. maidis*, 6 - *U. compositae*

**Fig 5 : Influence of different aphid hosts on development, weight of pupa, adult longevity, emergence and fecundity of Ischiodon scutellaris**

### 4.5.8 Identification of male and female *Campoletis chlorideae* in the cocoon stage

Attempts were made to find out if sex determination of *C. chlorideae* could be done at the cocoon stage. The major parameters which were taken into account were cocoon weight, cocoon diameter (*i.e.* the greatest width) and cocoon length. Various combinations were taken into account for arriving at a size index *viz.*, cocoon length x diameter; cocoon

Table 5. Effect of types of exposure of host larvae to *Campoletis chlorideae* on cocoon production and per cent females produced

| Types of exposure | Cocoon production (%) | Females (%) |
|---|---|---|
| Individual exposure | 66.36 (59.12) | 19.93 (19.77) |
| Mass exposure | 40.16 (39.43) | 32.78 (32.78) |
| CD at P 0.05 | 11.50 | 12.13 |

Figures in parentheses are angular transformed values

length x weight, cocoon weight x diameter, cocoon length x weight x diameter, cocoon length / diameter, cocoon weight / length and cocoon weight / diameter.

Correlation between cocoon weight and cocoon length was significant in males (Fig.6) and non-significant in the case of female cocoons (Table 6).

Table 6. Correlation coefficients indicating the relationships between cocoon weights with cocoon length and diameter

| Parameter | Cocoon diameter | Cocoon length |
|---|---|---|
| Male cocoon weight | 0.0046 | 0.5233* |
| Female cocoon weight | 0.1070 | 0.2775 |

* = significant at P 0.05

Significant differences were observed between male and female cocoons with reference to all the other parameters except cocoon diameter and cocoon length. Except for weight / length where the difference was significant at P 0.05, in the case of all the other parameters the differences were significant at P 0.01.

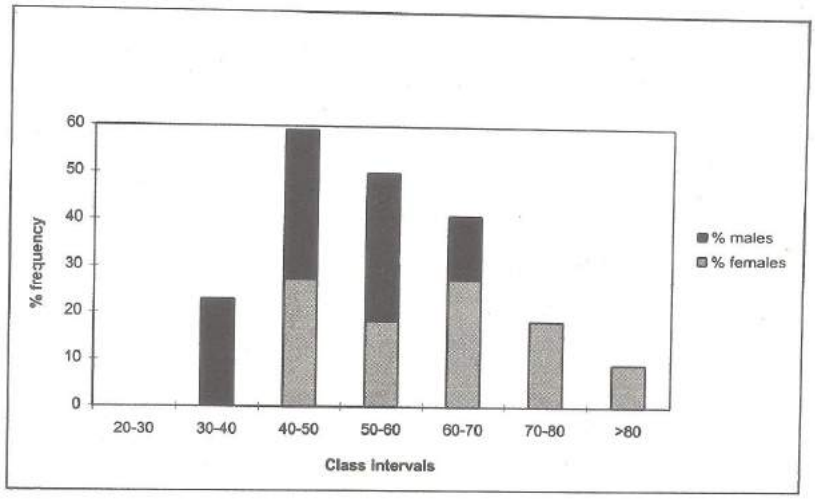



**Fig. 6. Segregation of male and female *C. chlorideae* based on cocoon length x cocoon weight**

Considerable overlap was observed in the size indices of the male and female cocoons. Attempts were made to find out the most suitable parameter (among those which have shown significant differences) which could be utilised for sex determination in *C. chlorideae*. Cocoons with length more than 6.5, weight more than 10.5, length x diameter more than 16.5, length x weight more than 70, weight x diameter more than 30, length x weight x diameter more than 180 and weight / diameter more than 4.4 would definitely yield females (Table 7). When the different size indices were compared, L x W ( 50) and L x W ( 120) proved to be best as among the total female cocoons examined, 72.7% belonged to this category. However, L x W can be chosen, for which only two parameters the length and weight of the cocoon have to be checked and if L x W is 50 the probability of females emerging from such cocoons is more (Fig.7 and Table 7 & 8).

Table 7. Cocoon length, diameter, weight and other size indices of male and female *Campoletis chlorideae*

| Particulars | Male | | Female | | CD (P= 0.05) |
|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | |
| Cocoon (L) | 5.82±0.10 | 4.96- 6.36 | 6.29±0.10 | 5.34-7.00 | 0.28 |
| Cocoon (W) | 8.34±0.24 | 6.58-10.32 | 9.91±0.37 | 7.72-15.47 | 0.89 |
| L x D | 13.27±0.31 | 10.66-15.66 | 14.93±0.42 | 11.91-18.91 | 1.05 |
| L x W | 48.72±1.90 | 33.83-64.29 | 62.56±2.88 | 42.72-108.29 | 6.97 |
| D x W | 19.01±0.60 | 14.67-25.93 | 23.46±1.04 | 17.20-41.30 | 2.44 |
| L x D x W | 111.20±4.76 | 75.43-160.01 | 148.60±8.24 | 92.27-289.13 | 9.22 |
| W x L | 1.43±0.03 | 1.17-1.67 | 1.58±0.05 | 1.56-2.21 | 0.13 |
| W x D | 3.67±0.12 | 2.76-4.91 | 4.21±0.16 | 3.04-5.79 | 0.40 |

L = Length; D = Diameter; W = Weight of cocoons

Table 8. Segregation of female and male *Campoletis chlorideae* based on the size indices of cocoons

| Per cent females among the total number of adults with | | | |
|---|---|---|---|
| Length x Width | | Length x Width x Diameter | |
| >50 | >70 | >120 | > 180 |
| 61.54% | 100% | 62.50% | 100% |

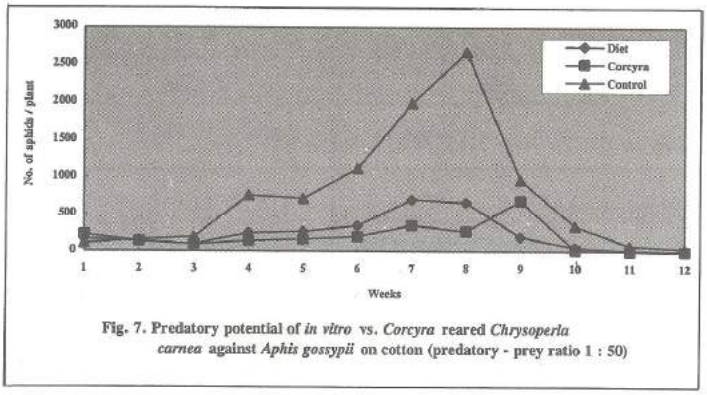



**Fig. 7. Predatory potential of *in vitro* vs. *Corcyra* reared *Chrysoperla carnea* against *Aphis gossypii* on cotton (predatory - prey ratio 1 : 50)**

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

### 4.6.1 Response of *Trichogramma chilonis* to sunflower bud wash in different varieties

The response of egg parasitoid, *Trichogramma chilonis* to the hexane wash of sunflower buds of different varieties, *viz.*, 6D-1, Morden , BSH-1, CMS-234-A, KBSH-1 and RHA-274 was studied. Hexane wash of sunflower buds was prepared by dipping the live buds *in situ* in 5ml of hexane for 30 minutes. In the olfactometer, 10 *T. chilonis* adults were presented with a choice of two air streams, one carrying odour of the sunflower bud (synomone) and the other clean air. Observations were recorded on the movement of the parasitoids towards the source of olfaction. The per cent response to bud wash of different varieties of sunflower was 40, 52, 38, 26, 40, and 40 in 6D-1, Morden, BSH -1, CMS-234-A, KBSH-1 and RHA-274, respectively. Maximum response (52%) was observed to the bud wash of Morden and minimum to CMS-234-A(26%).

### 4.6.2 Tritrophic interaction between *Trichogramma chilonis*, *Helicoverpa armigera* and sunflower varieties

The experiment was conducted to know the influence of the inter-varietal variability of green volatiles in sunflower on parasitisation efficiency of the egg parasitoid, *Trichogramma chilonis*. Fourteen varieties / accessions of sunflower, *viz.*, accession 109, acc.194, acc.244, acc.344, acc.367, acc.410, acc.450, BSH-1, CMS-234-A, EC-68414, EC-68415, GAU-SUF-15, PAC-1091 and TNAU-SUF-7 were evaluated in a Polyhouse using one - day- old *Helicoverpa armigera* eggs. The eggs were placed individually on leaves close to flower buds. One day old adults of *T. chilonis* were released from central point to give equal access to the eggs placed on different varieties for parasitisation. Highest parasitisation was recorded on variety GAU-SUF-15( 6%) followed by PAC-1091 (4%). In general, parasitisation of *H. armigera* eggs by *T. chilonis* on different varieties/accessions of sunflower was quite low.

### 4.6.3 Tritrophic interaction between *Trichogramma chilonis*, *Helicoverpa armigera* and different varieties of chickpea

Four experiments on tritrophic interaction between egg parasitoid, *T. chilonis*, host insect *H. armigera* and four varieties of chickpea were conducted in Polyhouse. Each variety was replicated 10 times with two plants/replication. Ten eggs (one - day - old) of *H. armigera* were placed near flower buds on each plant. One - day - old post mated adults of *T. chilonis* were released. Observations were recorded on per cent parasitization of *H. armigera* on different varieties. The per cent parasitization varied from 4.72 to 10.83 (pooled data). Consistently higher parasitization was obtained on variety BG 256. Other three varieties, *viz.*, JG 315, ICCV 10 and Avrodhi registered 4.72, 5.82 and 5.83 per cent parasitization, respectively (Table 9).

Similarly six varieties of chickpea (Annigri, ICCV 95992, ICCV 93122, ICCV 7, ICC 506, and ICCX 730266-3-4) were evaluated in a polyhouse under multiple choice condition for their influence on the parasitisation efficiency of *H. armigera* eggs by *T.chilonis*. Highest parasitisation (13.12%) was observed on variety ICCV 7.

Observations were also recorded on the trichome density on leaves of different varieties of chickpea (Table 10). The per cent parasitisation of *H. armigera* eggs by *T. chilonis* and mean trichome density on upper and lower sides of chickpea leaves did not show any relation.

### 4.6.4 Tritrophic interaction between *Trichogramma chilonis*, *Helicoverpa armigera* and pigeonpea varieties

Ten experiments on tritrophic interaction between egg parasitoid, *T. chilonis*, host insect *H. armigera* and 11 varieties / hybrids of pigeonpea were conducted in a polyhouse. The varieties tested for synomone interaction were: Bahar, ICPH-8, ICPL-27, ICPL-87, ICPL-151, ICPL-84060, ICPL-84089, ICPL-87119, Manak, PPE 45-2 and UPAS-120. Ten eggs (one - day - old) of *Helicoverpa armigera* were placed on leaves near to flower bud or tender pod. One - day - old mated adult *T. chilonis* parasitoids were released in a ratio of 1:3 (parasitoid : host). The data on per cent parasitization of *H. armigera* eggs on different varieties were recorded on the basis of change in egg colour (black) and also on basis of adult parasitoid emergence (Table 11). Lowest parasitization was observed on ICPL-151 (1.25) and highest (8,25) on ICPL-84060. There was no difference in the general trend, however, based on adult emergence and actual parasitization was also low.

Table 9. Tritrophic interaction between *Trichogramma chilonis*, *Helicoverpa armigera* and chickpea

| Variety | Mean parasitization (%) of *H. armigera* | | | |
|---|---|---|---|---|
| | Exp.I | Exp. II | Exp. III | Exp. IV |
| JG 315 | 5.83 | 1.83 | 6.67 | 4.72 |
| ICCV | 5.83 | 7.50 | 4.16 | 5.82 |
| Avrodhi | 4.16 | 5.83 | 7.50 | 5.83 |
| BG256 | 10.83 | 11.67 | 10.00 | 10.83 |
| CD (P=0.05) | NS | 7.54 | NS | 4.56 |

Table 10. Trichome density on leaves of different varieties of chickpea

| Variety | Upper side of the leaflet | | Lowerside of the leaflet | |
|---|---|---|---|---|
| | Non-Glandular trichomes | Glandular trichomes | Non-Glandular trichomes | Glandular trichomes |
| Annigeri | 92 | 61 | 26 | 13 |
| ICCV 95992 | 49 | 41 | 23 | 12 |
| ICCV 93122 | 55 | 40 | 21 | 12 |
| ICCV 7 | 46 | 29 | 19 | 12 |
| ICC 506 | 92 | 61 | 25 | 7 |
| ICCX 703266-3-4 | 69 | 61 | 47 | 42 |

### 4.6.5 L-tryptophan as an ovipositional attractant for *Chrysoperla carnea*

L-tryptophan and valine either in combination or alone were found to act as good ovipositional attractants for the adults of *Chrysoperla carnea*. A process of oxidation was attempted as a substitute for acid hydrolysis. Different concentrations of hydrogen peroxide were used and their oxidative efficiency studied in terms of *C. carnea* attraction. In wind tunnel studies, the number of adults entering the bait chamber was counted. Highest number of adults (7.80 - 8.20) was recorded in higher dose of 3 or 5 ml hydrogen peroxide one day after oxidation and in lower dose seven days after oxidation.

The process of oxidation and its attractiveness to the adults of *Chrysoperla carnea* was studied in multiple choice tests. The kairomone treated brown papers were hung on the inner top side of the container ( 30 X 30 X 30 cm) and 70 adults were released inside the chamber. The number of adults visiting each paper was recorded for 30 minutes. Each treatment was replicated 10 times. In multiple choice tests also 3 and 5 ml of hydrogen peroxide 1 or 2 days after oxidation recorded highest number of adults (12.5 - 14.5) visiting the filter paper.

The ovipositonal response of the adults of *C. carnea* to the oxidised L-tryptophan was studied in the multiple choice tests. The number of eggs laid on papers sprayed with L-tryptophan 1-2 days after oxidation with higher dose of 3 and 5 ml hydrogen peroxide (27.4 - 51.0) was more than others. The results indicate that 3 and 5 ml of hydrogen peroxide elicited higher behavioural response and egg laying 1 or 2 days after oxidation.

Table 11.Tritrophic interaction between *Trichogramma chilonis*, *Helicoverpa armigera* and pigeonpea varieties

| Variety/ Accession | Mean egg Parasiti zation (%) | Mean egg Parasitiza- tion (%) | Variety/ Accession | Mean egg parasiti- zation(%) | Mean egg parasiti- zation(%) |
|---|---|---|---|---|---|
| Bahar | 6.50 | 4.50 | ICPL-84089 | 3.00 | 2.50 |
| ICPH-8 | 7.00 | 4.25 | ICPL- 87119 | 2.75 | 1.75 |
| ICPL-27 | 7.00 | 3.50 | Manak | 4 .00 | 3.25 |
| ICPL-87 | 6.00 | 3.50 | PPE-45-2 | 7.25 | 4.50 |
| ICPL-151 | 1.25 | 0.75 | UPAS-120 | 5.75 | 4.00 |
| ICPL-84060 | 8.25 | 4.50 | | | |

Another experiment was conducted to find the use of L-tryptophan in the open conditions. The results showed that L- tryptophan is very effective in the open conditions, registering more number of eggs (15.6/ 20 plants) compared to control (1.22 /20 plants).

### 4.6.6 Kairomonal formulation for the larvae of *Chrysoperla carnea*

Formulations of kairomone based on the scales of *Helicoverpa armigera* were sprayed on caged cotton, tomato and sunflower plants and predation by *C.carnea* larvae was monitored. On cotton the number of *Helicoverpa armigera* eggs consumed (66.5%) in kairomone treated plants was more than in control plants. However, phytotoxic symptoms were noticed. In sunflower the number of eggs consumed was less (45.4%) than in control plants, but no phytotoxic symptoms were noticed. On tomato plants though no phytotoxiciy was observed, predation was also negligible (10.7%).

Amongst several kairomone formulations based on the wing scales, egg washings and abdominal tips tested for their efficiency in preconditioning the larvae before release on cotton plants, the scale extract of *H. armigera* recorded highest predation (65.17%) followed by the egg washing (34.50%) and washings of abdominal tip (33.40).

### 4.6.7 Studies on the kairomonal attraction of *Chilo partellus* frass to *Cotesia flavipes*

The parasitoid *C. flavipes* is attracted to the frass of *C. partellus*. The kairomonal activity of the extract of this frass was investigated by taking methanol extracts of the frass. The extract was taken utilising 1.0 g of the frass in one litre. This extract was placed at one end of the olfactometer and the females released at the other end with a blank at the third end of the tube.

Results of the studies on the frass extracts (1.0 g/l) revealed that the females of *C. flavipes* were readily attracted to the kairomonal extract.

### 4.7 Artificial diets for host insects

#### 4.7.1 Synthesis of diets for *Plutella xylostella*

Attempts were made to synthesise modified artificial diets for *P. xylostella*. Larvae (2-3 days old) were transferred to the modified cabbage based semi-synthetic diet and studies on different growth parameters showed that the egg period lasted 3 - 4 days, larval period 10-18 days and pupal period 4 - 6 days. Per cent pupation and adult emergence was 24 and 12, respectively. The pupal weight was 0.00246 - 0.00728 g.

#### 4.7.2 Evaluation of diet for *Opisina arenosella*

Diet suggested by Jayanth and Sudha Nagarkatti, 1981 for *O. arenosella* was evaluated. *O. arenosella* was reared on the diet for two generations. The freshly hatched larvae were allowed to feed on coconut leaves for 12 days and then transferred to the diet. The per cent pupation and adult emergence were 36.1 and 36 respectively. Simultaneously, the culture was also maintained on coconut leaves at the production level of 600 eggs/day. The larval period was observed to be slightly longer when reared on artificial diet.

#### 4.7.3 Evaluation of diet for *Spodoptera litura*

*S. litura* was reared on cabbage leaf based diet. Newly hatched larvae were fed on cabbage leaves for 9 days and then transferred to the artificial diet. Studies on duration of various stages showed that the egg, larval and pupal periods were 3, 17 and 10.2 days, respectively. Per cent pupation and female adult emergence was 96 and 70, respectively. The adult longevity was 9.0 days with average number of fertile eggs laid being 478.

### 4.8 Artificial diets for natural enemies

#### 4.8.1 Synthesis of new diet for *in vitro* rearing of *Chrysoperla carnea*

Among the several diets tested for *in vitro* rearing of *C. carnea*, hydrolysed soybean diet (D6) was found to be the best with reference to increased pupation (85%) and adult emergence (71%) ( Table 12). On this diet *C. carnea* was reared continuously for ten generations. Besides these, *C. carnea* was also reared for ten generations on *Spodoptera* abdomen powder based diet as a standard semi-synthetic diet and the per cent pupation, adult emergence and fecundity per generation (Table 13) were 26, 9 and 98 eggs/female, respectively.

### 4.8.2 Evaluation of *in vitro* reared *Chrysoperla carnea*

After rearing *C. carnea* on soybean hydrolysed powder based diet for ten generations a study was conducted to test the predatory potential of *in vitro* and *Corcyra* reared *C. carnea* against cotton aphid *Aphis gossypii*. Cotton plants (var.DCH 132) were infested by releasing the aphids in three different densities 50, 100 and 200/ plant. Two-day-old larvae of *C. carnea* were released weekly as per the densities of aphids ( 1: 50, 1: 100 and 1:200). The number of aphids/ plant was observed weekly till harvest of the crop.

At 1 : 50 predator-prey ratio, there was a significant difference in aphid population in diet and *Corcyra* reared *C. carnea* . The mean aphid population/ plant in diet reared was 240.14 which was significantly different from *Corcyra* reared (138.8/ plant). There was also significant difference in aphid population between diet reared and control and *Corcyra* reared and control(762.43) (Table 14). At 1: 100 predator-prey ratio there was significant difference in diet reared and control and *Corcyra* and control (762.51). At 1: 200 predator-prey ratio there was significant difference among diet (432.21) and *C. cephalonica* (204.28), diet and control (762.510) and *C. cephalonica* and control. Over all the mean aphid population per plant was less at 1:50 ratio ( Fig. 8).

An experiment was conducted to test the feeding potential of *in vitro* and *Corcyra* reared *C. carnea* on *Helicoverpa armigera* in the laboratory. The number of eggs consumed per larvae was recorded daily till pupation stage. There was no significant difference between diet and *Corcyra* reared *C. carnea* ( Table 15). Hydrolysed soybean based diet was thus found to be promising and could be used for the *in vitro* production of *C. carnea* (Table 16).

### 4.8.3 A semi-synthetic diet for *Cheilomenes sexmaculata*

Egg batches of *C. sexmaculata* were obtained from the stock culture maintained on *Aphis craccivora*. The diet ingredients were mixed in a beaker(15x7cm) and placed in a water bath (50° C). On heating, agar agar (80 mg)was added to the diet. Droplets of the diet were placed on polythene sheets. Fresh droplets were provided every day to the larvae. Observations were made on the duration of development of larvae, pupae, pupation(%), adult emergence(%), adult weight(mg) and longevity(days) of the adults. Freshly emerged adults were cultured in pairs in a transparent plastic jar (11x7cm). The experiment was replicated ten times under CRD.

Table 12. Evaluation of various diets for mass rearing the larvae of *Chrysoperla carnea*

| Diet | Larval duration (day) | Pupatin (%) | Pupal Duration (day) | Cocoon weight (mg) | Adult emergence (%) | Fecundity | Longevity (days) |
|---|---|---|---|---|---|---|---|
| D1 | 32.17 | 10.00 (18.29) | 7.67 | 3.47 | 2.50 (8.84) | 12 | 27.0 |
| D2 | 19.00 | 31.80 (34.24) | 7.67 | 3.87 | 13.00 (21.07) | 132 | 45.0 |
| D3 | 19.40 | 38.17 (30.07) | 12.50 | 3.88 | 13.10 (21.06) | 50 | 32.0 |
| D4 | 17.20 | 31.67 (64.73) | 7.62 | 4.47 | 56.17 (48.55) | 160 | 50.3 |
| D5 | 17.07 | 75.80 (60.64) | 8.17 | 3.40 | 49.17 (44.52) | 103 | 41.4 |
| D6 | 14.57 | 84.50 (66.88) | 7.45 | 4.23 | 71.00 (57.46) | 440 | 56.0 |
| D7 | 29.03 | 49.17 (44.52) | 10.80 | 4.07 | 32.50 (34.66) | 338 | 69.0 |
| D8 | 25.05 | 57.10 (49.06) | 10.18 | 4.15 | 39.00 (38.62) | 259 | 68.0 |
| D9 | 21.75 | 88.33 (70.05) | 8.28 | 4.32 | 58.50 (41.92) | 433 | 74.0 |
| D10 | 29.07 | 67.17 (55.25) | 10.48 | 3.92 | 38.80 (38.49) | 355 | 67.0 |
| D11 | 16.77 | 82.00 (65.08) | 7.63 | 3.88 | 57.83 (49.54) | 98 | 48.4 |
| D12 | 20.50 | 58.67 (50.03) | 10.88 | 4.00 | 12.67 (20.57) | 184 | 77.0 |
| D13 | 35.05 | 11.25 (19.58) | 11.08 | 3.78 | 20.00 (26.50) | 184 | 86.0 |
| D14 | 32.05 | 45.00 (42.11) | 12.83 | 3.93 | 27.50 (31.56) | 125 | 69.0 |
| D15 | 38.90 | 55.17 (47.98) | 9.50 | 3.98 | 6.00 (13.86) | 125 | 13.0 |
| D16 | 33.00 | 43.00 (40.95) | 9.08 | 4.08 | 8.00 (16.24) | 140 | 42.0 |
| D17 | 9.00 | 86.00 (68.05) | 6.50 | 8.90 | 79.30 (63.02) | 448 | 85.0 |
| CD (P=0.05) | 2.58 | (4.23) | 0.65 | 0.25 | (3.60) | | |

Table 13. Development of *Chrysoperla carnea* on *Spodoptera litura* abdomen diet

| GENERATIONS F6 to F10 | | |
|---|---|---|
| Growth-parameters | Range | Mean |
| Larval period (days) | 20.5 - 29.0 | 25.5 |
| Pupation (%) | 20-65 | 48 |
| Pupal period (days) | 7-8.7 | 8.04 |
| Pupal wt. (mg) | 3-4.1 | 3.62 |
| Adult emergence (%) | 6-52 | 19.6 |
| Fecundity (Nos./ ) | 98-149 | 114 |
| Longevity (in days) | 39-50 | 43.4 |
| Sex-ratio ( / ) | 1.2:1-3:1 | 1.76:1 |

Table 14. Aphid numbers in cotton where diet reared *Chrysoperla carnea* and *Corcyra cephalonica* were released (Predator - Prey ratio 1: 50)

| Week | Diet reared *C. carnea* released | *Corcyra* reared *C. carnea* released | Control | Week | Diet reared *C. carnea* released | *Corcyra* reared *C. carnea* released | Control |
|---|---|---|---|---|---|---|---|
| 1 | 169 | 222 | 110 | 7 | 700 | 352 | 1991 |
| 2 | 138 | 136 | 156 | 8 | 660 | 271 | 2678 |
| 3 | 95 | 93 | 193 | 9 | 197 | 685 | 967 |
| 4 | 245 | 140 | 757 | 10 | 53 | 23 | 344 |
| 5 | 266 | 161 | 718 | 11 | 11 | 3 | 79 |
| 6 | 344 | 198 | 1117 | 12 | 3 | 3 | 37 |
| Mean | 240.14 | 138.8 | 762.43 | | | | |

**t test**

| t-Test: Two-sample Assuming Unequal Variances | Diet & *Corcyra* | Diet & Control | Corcyra & Control |
|---|---|---|---|
| t stat | 2.859 | 4.610 | 5.645 |
| t critical tw | 1.972 | 1.977 | 1.9791 |

Table 15. Number of *Helicoverpa armigera* eggs consumed by *Chrysoperla carnea* and *Corcyra cephalonica*

| Day | Diet reared *C. carnea* | *Corcyra* reared *C. carnea* | Day | Diet reared *C. carnea* | *Corcyra* reared *C. carnea* |
|---|---|---|---|---|---|
| 1 | 5.9 | 6.7 | 6 | 26.6 | 26.6 |
| 2 | 6.0 | 3.9 | 7 | 43.4 | 43.3 |
| 3 | 26.3 | 24.4 | 8 | 97.7 | 97.0 |
| 4 | 28.8 | 33.2 | 9 | 148.6 | 148.8 |
| 5 | 12.1 | 21.8 | 10 | 27.4 | 51.3 |
| Mean | 42.28 | 45.4 | | | |

**t-Test: Two sample Assuming Unequal variances**

t stat : 0.50448; t critical tw 1.97201

Table 16. Development of *Chrysoperla carnea* on hydrolysed soybean diet

| GENERATIONS F7 to F10 | | |
|---|---|---|
| Growth parameters | Range | Mean |
| Larval period | 18.0-19.7 | 18.65 |
| Pupation (%) | 61-84 | 72.75 |
| Pupal period (days) | 7.0-7.7 | 7.45 |
| Pupal wt. (mg) | 4.2-4.4 | 4.32 |
| Adult emergence(%) | 45-70 | 54.5 |
| Fecundity (Nos./ ) | 155-241 | 202.5 |
| Longevity (in days) | 32-40 | 38.25 |
| Sex-ratio | 1.8:1-1:1.3 | 1.4:1 |

In all the treatments, larval feeding was noticed on the diets, while pupation was observed in varying degrees (Table 17). The larval period of *C. sexmaculata* reared on the diet was significantly longer (13.8 - 18.00 days ) than that reared on aphids (7.2 days). The per cent pupation in all the larvae fed on semi-synthetic diets was significantly lower (3.54%) than the control (88%). However, among the semi-synthetic diets, pigliver plus egg yolk based diet (Diet E) proved to be good. Heavier adults (6.8mg) emerged from the larvae fed on the diet E,

but still it was significantly less than that of the control (10.3mg). Longevity of the adult beetles reared on various diets ranged from 11.0 to 76.0 days. Among diets, adult beetles lived longer on diet E (42.0 days) which was significantly less than that of the beetles reared on aphids (76.0 days). Fecundity of the adults reared on diet E was 19 eggs/female when compared to adults reared on aphids (403 eggs/female).

Table 17. Development of *Cheilomenes sexmaculata* on semi-synthetic diets

| Diet | Larval period (days) | Pupal period (days) | Pupation (%) | Adult emergence (%) | Adult weight (mg) | Adult longevity (days) |
|---|---|---|---|---|---|---|
| A | 18.00 | 3.50 | 4.00 | 4.00 | 3.90 | 11.00 |
| B | 15.00 | 3.50 | 3.00 | 3.00 | 4.10 | 14.00 |
| C | 14.50 | 3.50 | 9.00 | 5.00 | 4.40 | 15.00 |
| D | 17.45[a] | 3.55[b] | 20.00 (26.27)[c] | 17.00 (23.98)[c] | 5.10[c] | 15.00[c] |
| E | 13.80[b] | 4.00[a] | 54.00 (47.36)[b] | 47.00 (43.27)[b] | 6.80[b] | 42.00[b] |
| F | 7.20[a] | 4.40[a] | 88.00 (69.94)[c] | 81.00 (64.40)[a] | 10.30[a] | 76.00[a] |
| CD (P=0.05) | 1.6123 | 0.4547 | 4.3647 | 4.9700 | 0.0017 | 5.1411 |

Figures in parentheses are angular transformed values; Figures followed by same letter are not significantly different

### 4.9 Development of resistant / tolerant strains of *Trichogramma chilonis*

#### 4.9.1 Development of endosulfan tolerant strain of *Trichogramma chilonis*

This study was started in 1989-90 and is being continued. In the resistance / tolerance study 21 generations were passed and during the year, 8 exposures were given at the dosage of 1.75ml of endosulfan / litre of water and reached 254th generation at the present dosage level of 1.75ml/litre. From F 234 to 254 generations, the test insects were exposed to 1.75 ml/l. Initially 95% mortality (after 6hrs.) and very low parasitisation (2%) occurred. By F254 generation mortality reduced to 50% after 6 hrs. and parasitism improved to 95 per cent. Then the test insects were shifted to 2 ml / litre (255th generation) and the mortality was 100% and the parasitisation 30%.

By exposing *T. chilonis* adults to endosulfan for 300 generations including last at 0.07% concentration parasitism obtained was 100% and mortality 80% after 6 hours of constant exposure (Table 18).

Table 18. Exposure of *Trichogramma chilonis* adults to endosulfan

| Generation | Dosages | Mortality after 6 hours (%) | Parasitism (%) |
|---|---|---|---|
| 280 | 2 ml / lit. | 95 | 40 |
| 290 | 2 ml / lit. | 90 | 70 |
| 300 | 2 ml / lit. | 80 | 100 |

### 4.9.2 Comparative toxicity studies of susceptible and endosulfan tolerant strains of *Trichogramma chilonis*

Studies were carried out on effect of endosulfan (0.07%) on parasitising ability of tolerant strain and susceptible strain. Endosulfan (0.07%) was sprayed in the vial (15 x 2.5 cm size) and shade dried. Adults were released in the vial along with egg card. The data was recorded after 6 and 24 hr of constant exposure on per cent mortality and parasitism. Experiment was replicated 10 times.

In tolerant strain of endosulfan about 20.0 per cent adults survived after 6 hours of constant exposure but in susceptible strain more than 95.0 per cent adults died even within 30 minutes of exposure and 100.0 per cent in 6 hours of constant exposure (Table 19). The parasitism by susceptible strain was less than 10.0 per cent whereas it was 100.0 per cent by tolerant strain.

Table 19. Comparative toxicity study of susceptible and tolerant strains of *Trichogramma chilonis*

| Strain | Adult mortality (%) | | Parasitism (%) |
|---|---|---|---|
| | 6 hr | 24 hr | 24 hr |
| *T. chilonis* tolerant strain | 80.0 | 100.0 | 100.0 |
| *T. chilonis* susceptible strain | 100.0 | 100.0 | 10.0 |

### 4.9.3 Net house trial with tolerant and susceptible strains of *Trichogramma chilonis*

The experiment was conducted on potted cotton plants sprayed with endosulfan (0.07%). *Helicoverpa armigera* eggs were placed on cotton plants sprayed with endosulfan @ 10 eggs per plant. *T. chilonis* adults were released on these plants immediately after spray and 1, 2, 3, 4, and 5 days after spray. Eggs were collected after 24 hours and were observed for parasitisation and emergence of parasitoids. In control, *H. armigera* eggs were not exposed to parasitoids to know mortality due to pesticide spray.

It is evident from the trial that tolerant strain was capable of parasitising the eggs of *H. armigera* even immediately after spray of endosulfan to the tune of 56.0% compared to 3.0% by susceptible strain and parasitoids emerged successfully from the host eggs (Table 20).

Table 20. Net house trial with tolerant and susceptible strains of *Trichogramma chilonis* on cotton against *Helicoverpa armigera*

| Days after spray | Parasitism (%) | | Emergence (%) | | Mortality of eggs (%) | | |
|---|---|---|---|---|---|---|---|
| | Tolerant | Susceptible | Tolerant | Susceptible | Tole-rant | Sus-ceptible | Control |
| 0 | 56.0 | 3.0 | 95.0 | 0.0 | 44.0 | 97.0 | 100.0 |
| 1 | 78.0 | 18.0 | 97.0 | 60.0 | 20.0 | 79.0 | 97.0 |
| 2 | 88.0 | 20.0 | 95.0 | 78.0 | 10.0 | 62.0 | 72.0 |
| 3 | 88.0 | 68.0 | 94.0 | 81.0 | 12.0 | 11.0 | 68.0 |
| 4 | 86.0 | 58.0 | 94.0 | 79.0 | 2.0 | 3.0 | 28.0 |
| 5 | 83.0 | 62.0 | 91.0 | 89.0 | 0.0 | 0.0 | 0.0 |

Five days after spray parasitism and emergence was significantly more in tolerant strain. In control plants, where parasitoids were not released, egg mortality declined after 2 days of spray. Total egg mortality two days after spray was 98.0 and 82.0 per cent in tolerant and susceptible strain. Results proved that tolerant strain can be utilised in the field even immediately after spray and combined application can give better suppression of *H. armigera* on cotton.

### 4.9.4 Study on tolerance breakdown in endosulfan tolerant *Trichogramma chilonis* strain

The experiment was conducted by keeping tolerant strain without exposure to endosulfan for up to 10 generations. Emerging adults were exposed to *C. cephalonica* eggs. Adults thus

obtained were exposed to endosulfan 0.07% after 2, 4, 6, 8, and 10 generations without exposure. Data on parasitism and per cent mortality after 6 and 24 hours was recorded.

Tolerant strain of *T. chilonis* maintains tolerance level for up to 4 generations without being exposed to endosulfan (Table 21). However, after a gap of four generations if this strain is again exposed to endosulfan for 2 generations it regains its lost tolerance. Therefore, it is advisable to maintain a part of the nucleus culture with constant exposure to endosulfan and in case of mass production of this strain, a part of the culture should be exposed to endosulfan twice after every four generations.

### 4.9.5 Comparative toxicity of endosulfan on immature stages of tolerant strains of *Trichogramma chilonis*

Studies were carried out on immature stages by exposing host eggs parasitised by *T. chilonis* (both tolerant and susceptible strains) to endosulfan. The eggs were exposed when parasitoids were in different developmental stages, i.e. egg, larval and pupal stages. The prepared solution of endosulfan was sprayed over parasitised eggs and subsequently data on parasitism and adult emergence recorded and compared with unsprayed parasitised eggs.

Table 21. Tolerance breakdown study of *Trichogramma chilonis* strain

| Generation gap | Adult mortality (%) | | Parasitism (%) |
|---|---|---|---|
| | 6 hr | 24 hr | |
| 2 | 80.0 | 100.0 | 95.0 |
| 4 | 85.0 | 100.0 | 80.0 |
| 6 | 90.0 | 100.0 | 50.0 |
| 8 | 95.0 | 100.0 | 25.0 |
| 10 | 100.0 | 100.0 | 10.0 |

Survival of immature stages of tolerant strain was significantly more than susceptible strain. Greatest mortality occurred when parasitoids were in egg stage (50.0 %) in tolerant strain, however, emergence was less when parasitised host eggs were treated during pupal stage (Table 22). Hence immature stage of tolerant strain can also withstand the pesticide load.

### 4.9.6 Development of high temperature tolerant strain of *Trichogramma chilonis*

The experiment was initited by exposing host eggs to *T. chilonis* from temperature ranging from 30 to 35°C in BOD incubator in two different humidity ranges, i.e. 35 and 70%.

Table 22. Endosulfan toxicity to tolerant and susceptible strains of *Trichogramma chilonis*

| Treatment | Mortality (%) | | | Adult emergence (%) | | |
|---|---|---|---|---|---|---|
| | Egg | Larval | Pupal | Egg | Larval | Pupal |
| Endosulfan tolerant strain (sprayed) | 50.0 | 10.0 | 10.0 | 95.0 | 85.0 | 70.0 |
| Unsprayed | 5.0 | 5.0 | 5.0 | 95.0 | 95.0 | 95.0 |
| Susceptible strain (sprayed) | 80.0 | 65.0 | 60.0 | 60.0 | 35.0 | 12.0 |
| Unsprayed | 5.0 | 5.0 | 5.0 | 95.0 | 95.0 | 95.0 |

Parasitism in < 32 °C was more than 90.0 per cent and parasitoids also survived for more than 4 days while at 35 °C both parasitism and adult survival was very low to get sufficient culture for continuous breeding. At 33 °C, five generations have been passed and parasitoids are showing adaptability to this temperature.

## 4.10 Studies on Insect Pathogens

### 4.10.1 Survey for insect pathogens

A gonad specific virus from *Helicoverpa armigera* and *Spodoptera litura* has been suspected based on the external manifestation of waxy-plug symptom of the genital system.

### 4.10.2 Cross infectivity test with granulosis virus (GV) of *Plutella xylostella*

Cross infectivity tests were conducted with GV of *Plutella xylostella* against *Helicoverpa armigera*, *Spodoptera litura*, *Corcyra cephalonica*, *Crocidolomia binotalis*, *Helluta undalis*, *Sesamia inferens*, *Chilo partellus*, *Opisina arenosella*, *Ergolis merione* and *Trichoplusia ni* at 250 LE concentration and none of them was found susceptible.

### 4.10.3 Safety test with granulosis virus (GV) of *Plutella xylostella*

Studies to test the safety of the GV of *P. xylostella* against the predators viz., *Chrysoperla carnea*, *Chilocorus nigrita* and *Cryptolaemus montrouzieri* and parasitoids like *Apanteles plutellae* and *Trichogramma* sp. which were fed GV alone with respective host materials viz., *Corcyra cephalonica*, *Hemiberlesia lataniae* and *Planococcus citri* and honey initiated and found that the virus is safe to predators and parasitoids tested.

## 4.11 Studies on fungal and bacterial antagonists

### 4.11.1 Biological control of root/collar rot of sunflower

The effect of various antagonistic fungi from the culture collection against *Sclerotium rolfsii* was tested *in vitro* to study the potential of these antagonists in controlling root/collar rot of sunflower seedlings under greenhouse conditions.

Fourteen isolates of *Trichoderma* and *Gliocladium* species were tested *in vitro*. Two isolates of *T. viride*, four isolates of *T. harzianum* , one each of *T. hamatum*, *T. koningii*, *T. polysporum*, *G. virens*, *G. deliquescens* and *G. roseum* inhibited mycelial growth of the pathogen significantly (Table 23). Among *Trichoderma* species, *T. harzianum* isolate PDBCTH 2 gave 61.4 per cent inhibition of mycelial growth followed by PDBCTH 8 (55.2%) and PDBCTH 7 (54.9%). Among *Gliocladium* isolates, *G. virens* gave maximum inhibition (39.9%) of mycelial growth. Suppression of sclerotial production by the antagonists ranged from 31.8 to 97.8 %. Complete inhibition of sclerotial germination was obtained with the culture filtrates of *T. harzianum* (PDBCTH 2, 7 and 8) , *T. pseudokoningii* and *G. deliquescens*.

The three *T. harzianum* isolates and the *T. viride* isolate (PDBCTV 4) were superior under greenhouse conditions with PDBCTH 8 showing maximum disease control (66.8%) and even superior to the fungicide, Captan (Table 24). *G. deliquescens* gave maximum (55.7%) disease control among *Gliocladium* spp.

### 4.11.2 Evaluation of various liquid media for mass production of *Trichoderma harzianum* by fermentation technology and development of formulations

Three liquid media *viz.*, potato dextrose broth (PDB), V-8 juice and molasses-yeast medium (MYM) were tried for mass production of *T. harzianum* in a laboratory scale fermenter. Maximum biomass (1224 mg) was obtained in PDB 96 h after fermentation (Table 25). Viable propagules were high in PDB and MYM. PDB gave maximum propagules followed by MYM. Though PDB gave maximum yield of biomass, the production of viable propagules was almost equal in PDB and MYM after 72 h of fermentation. MYM being cheaper, will be a better alternative for mass production of *T. harzianum*. Fermentation for 72 h would be sufficient for obtaining optimum biomass and viable propagules.

Wet fermenter biomass of *T. harzianum* was used for developing talc, gypsum, vermiculite-wheat bran, 3 pesta granule combinations and alginate prill based formulations. The fungus survived for 45 days in gypsum formulation and for 60 days in talc and alginate prills at room temperature (Table 26). Viable propagules were detected only in vermiculite-wheat bran and pesta granules (wheat flour) 90 days after storage at room temperature.

Table 23. Inhibition of mycelial growth and sclerotial production of *Sclerotum rolfsii* by different fungal antagonists

| Antagonist | Per cent inhibition* | Per cent reduction in sclerotial production |
|---|---|---|
| *T. viride* (ITCC 1433) | 32.5(34.8) | 92.1(73.7) |
| *T. viride* (PDBCTV 4) | 37.2(37.6) | 86.6(68.5) |
| *T. harzianum* (ITCC 2895) | 51.7(45.9) | 84.5(66.8) |
| *T. harzianum* (PDBCTH 2) | 61.4(51.6) | 94.2(76.0) |
| *T. harzianum* (PDBCTH 7) | 54.9(47.8) | 94.1(75.6) |
| *T. harzianum* (PDBCTH 8) | 55.2(48.0) | 97.8(81.5) |
| *T. hamatum* (ITCC 2084) | 39.6(39.0) | 84.1(66.5) |
| *T. koningii* (ITCC 2170) | 39.1(38.7) | 86.8(68.7) |
| *T. pseudokoningii* (ITCC 3694) | 23.9(29.2) | 80.9(64.2) |
| *T. polysporum* (ITCC 3761) | 11.4(19.7) | 31.8(34.3) |
| *G. virens* (ITCC 4177) | 39.9(39.2) | 73.3(58.9) |
| *G. deliquescens* (ITCC 3450) | 38.5(38.4) | 69.9(56.7) |
| *G. roseum* (ITCC 4176) | 31.9(34.4) | 84.6(66.9) |
| *G. cantenulatum* | 1.1(6.0) | 58.6(49.9) |
| Control | 0.0(0.0) | 0.0(0.0) |
| C.D. at 5% | 0.79 | 1.77 |

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

Table 24. Effect of *Trichoderma* and *Gliocladium* spp. on root/collar rot incidence

| Antagonist | Per cent inhibition* | Per cent reduction in sclerotial production |
|---|---|---|
| *T. viride* (ITCC 1433) | 38.1(38.1) | 42.0 |
| *T. viride* (PDBCTV 4) | 15.3(22.7) | 65.4 |
| *T. harzianum* (ITCC 2895) | 34.4(35.8) | 45.5 |
| *T. harzianum* (PDBCTH 2) | 18.3(25.2) | 61.6 |
| *T. harzianum* (PDBCTH 7) | 14.6(22.3) | 66.0 |
| *T. harzianum* (PDBCTH 8) | 14.4(21.8) | 66.8 |
| *T. hamatum* (ITCC 2084) | 50.0(35.2) | 46.4 |
| *T. koningii* (ITCC 2170) | 32.8(34.8) | 47.0 |
| *T. pseudokoningii* (ITCC 3694) | 30.5(33.4) | 49.1 |
| *T. polysporum* (ITCC 3761) | 49.0(44.4) | 32.4 |
| *G. virens* (ITCC 4177) | 50.0(33.8) | 48.6 |
| *G. deliquescens* (ITCC 3450) | 23.9(29.1) | 55.7 |
| *G. roseum* (ITCC 4176) | 41.3(39.9) | 39.3 |
| *G. catenulatum* (ITCC 3058 | 41.3(39.9) | 39.3 |
| Control I (*S. rolfsii* alone) | 82.9(65.7) | |
| Control II (Captan and *S. rolfsii*) | 20.8(26.8) | 59.2 |
| C.D. at 5% | 10.34 | |

* Average of four replications; Figures in parentheses are angular transformed values

### 4.11.3 Biological control of *Gladiolus* corm rot and yellows

A survey of Tarai area in Uttar Pradesh was conducted to collect gladiolus corm rot and yellows infected plant samples. Isolations were made from these samples and pathogenicity proved. *Fusarium oxysporum* f.sp. *gladioli* (Massey) Snyder and Hansen was found to be causal agent of this disease. *Gliocladium virens* isolate PI 1 (GV) was found to be a potent antagonist against the pathogen *in vitro*. Different treatments involving GV alone and/or Vitavax, applied as dry bulb or suspension treatment were compared under green house and at farmers' field. Introduction of the GV to infection court through corm proved to be effective against the disease. GV alone or in combination with Vitavax significantly reduced disease incidence under green house conditions. However, in farmers' field, corm treatment with GV + Vitavax was found to be most effective in reducing disease incidence and thereby improving plant stand (Table 27).

Table 25. Biomass production of *Trichoderma harzianum* in different liquid media

| Fermentation | Biomass dry wt. (mg/100 ml) | | | Population of Trichoderma (cfu. x $10^7$/g) | | |
|---|---|---|---|---|---|---|
| | Molasses | PDB | V-8 | Mollasses | PDB | V-8 |
| 24 | 436.3 | 739.3 | 483.3 | 3.3 | 10.0 | 7.8 |
| 48 | 730.0 | 945.3 | 780.6 | 12.0 | 15.2 | 14.8 |
| 72 | 884.3 | 1093.0 | 945.0 | 29.4 | 30.3 | 24.2 |
| 96 | 945.3 | 1224.0 | 1073.6 | 31.0 | 32.5 | 25.1 |
| C.D. at 5% | 31.0 | 42.4 | 55.9 | 1.8 | 3.7 | 1.5 |

### 4.11.4 Comparison of different formulations of *Gliocladium virens*

*Gliocladium virens* PI 1 (GV) was multiplied on sorghum grains. Seven formulations *viz*., GV + clay soil, GV + multani soil, GV + calcium carbonate, GV + calcium sulphate, GV + talcum powder, GV + carboxyl methylcellulose (CMC), GV + boric acid were made and tested against chickpea wilt and root rot complex for their bioefficacy. All formulating agents, except boric acid, were compatible with GV. Boric acid inhibited spore germination of the antagonist. All the formulations, except with calcium carbonate, significantly improved the seedling emergence, plant stand and grain yield of chickpea when used alone or in combination with Vitavax. GV + CMC formulation was most effective.

Table 26. Shelf life of *Trichoderma harzianum* in different formulations at room temperature

| Formulation | Population of *Trichoderma* ((cfu. x $10^7$/g) (days after storage | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 15 | 30 | 45 | 60 | 75 | 90 | Mean |
| Talc | 36.0 | 27.6 | 12.6 | 9.0 | 6.0 | 0.0 | 0.0 | 13.0 |
| Vermiculite-wheat bran | 27.6 | 196.6 | 248.3 | 196.3 | 11.0 | 28.6 | 3.0 | 115.8 |
| Pesta granules (wheat flour) | 47.3 | 92.3 | 101.3 | 89.3 | 68.3 | 48.3 | 29.3 | 68.0 |
| Pesta granules (wheat flour-bentonite) | 41.3 | 48.6 | 51.0 | 42.0 | 40.6 | 6.3 | 4.0 | 33.4 |
| Pesta granules (wheat flour-kaolin) | 55.3 | 59.3 | 65.6 | 47.6 | 39.3 | 24.3 | 10.6 | 43.1 |
| Alginate prills | 25.3 | 22.3 | 11.6 | 6.3 | 2.3 | 0.0 | 0.0 | 9.7 |
| Gypsum | 36.0 | 32.3 | 8.3 | 4.6 | 0.0 | 0.0 | 0.0 | 11.6 |
| Mean | 38.4 | 68.4 | 71.2 | 56.4 | 38.1 | 15.3 | 6.7 | |

C.D. at 5% Formulations = 3.5 Days of storage = 3.5 Interaction = 9.2

Table 27. Management of *Fusarium* corm rot and yellow of gladiolus in field

| Treatment | Just after emergence | | At flowering | |
|---|---|---|---|---|
| | Plant stand (x $10^4$ ha) | Increase in emergence | Plant stand (x $10^4$ ha) | Increase in stand (%) |
| GV | 31.66b | 25.24 | 30.67b | 51.80 |
| Vitavax | 32.33b | 28.35 | 30.33b | 50.47 |
| GV + Vitavax* | 33.00b | 31.04 | 32.00bc | 59.13 |
| GV + Vitavax** | 34.00b | 35.17 | 33.67bc | 67.26 |
| Check | 25.33a | - | 20.33a | - |

Means in a column followed by different letter(s) are significantly different
* Corm dressing treatment (@ 1.0g GV spore powder + 1.0 g Vitavax per kg corm)
** Suspension dip treatment @ $10^7$ conidia of GV per ml + 0.1 % g Vitavax)

### 4.11.5 Improvement of *Trichoderma harzianum* by protoplast fusion

*Trichoderma harzianum* isolate-1 (TH 1) is a fast growing, heavily sporulating isolate with excellent antagonistic potential (both under *in vitro* and *in vivo* conditions) against *Sclerotium rofsii, Rhizoctonia solani* and *Fusarium solani*. However, it is highly sensitive to carbendazim fungicide. *T. harzianum* isolate-3 (TH 3) is inferior to TH 1 in all other characteristics except that it can tolerate carbendazim upto 5 g/l. In order to develop a strain with high antagonistic potential and ability to tolerate carbendazim attempts were made to develop a methodology for protoplast isolation and purification from TH 1 and TH 3. The optimum parameters like temperature (28°C), pH (5.5), parent medium (young mycelia), growth medium (PDY synthetic medium), osmotic stabilizer (sorbitol 0.6 M + NaC1 0.7M)), buffer system (STS), age (24 h) and amount (40 mg/ml enzyme mixture of mycelium) and incubation period (24 h) were worked out. The concentration of lytic enzyme mixture for protoplast isolation was : Novozym 234 5 mg/ml; Novozym 237 5 mg/ml; Driselase 5 mg/ml and Cellulase R-10 5 mg/ml in 0.7 M NaC1 and 0.6 M sorbitol. The protoplasts suspended in STS buffer were viable for 3 weeks. For regeneration of protoplasts, PDA supplemented with 10 percent sucrose was most suitable. Protoplasts of TH 3 exhibited higher regeneration capacity (0.4%) than TH 1 (0.35%).

### 4.11.6 Isolation and evaluation of antagonistic bacteria

Rhizospheric soil samples were collected from different regions of Karnataka. Special emphasis was laid on collecting soils from sites where sunflower was raised during that year and also where root/collar infection was/is noticed. Healthy plants were chosen at random and rhizospheric soil isolated.

### 4.11.7 Evaluation of antagonistic bacteria

Three hundred rhizospheric isolates of bacteria were tested for antagonistic activity against *Sclerotium rolfsii*. The fungus grew very slowly on PAF and NA. However on PDA, profuse growth was obtained. A modified media wherein *S. rolfsii* growing on PDA and the test antagonist growing either on PAF or NA in the same plate was developed to screen the antagonists. This assay was found to be most practical to screen for antagonists inhibiting *S. rolfsii*. Four different media *viz*., a) Potato Dextrose agar (PDA), b) Nutrient Agar (NA), c) Dual Media containing PDA for fungal growth and *Pseudomonas* Agar for bacterial growth (DM) and d) Dual Media with ferric iron substitution for *Pseudomonas* agar (DMF+) were used to screen the isolates. Eleven isolates were found to be antagonistic to *S. rolfsii*. The selected isolates were also screened for HCN production.

### *a) In vitro* antagonism

Growth inhibition (in) was calculated by comparing with control plates containing the fungal pathogen alone. PDBC NO. 19 (*P. putida* ?) was the most effective and completely inhibited growth of *S. rolfsii* in dual culture in DM supplemented with glycine (Table 28). All the others were either strong or moderate in antagonistic activity.

HCN production was determined using standard procedure and the isolates were scored as either strong, moderate or weak. Isolate Nos. 1, 7, 19 and 23 reacted strongly and isolates 12, 14, 15, 8 and 26 showed moderate reaction. Isolate no. 8 was weak and no. 28 did not react. Though a correlation was seen between HCN production and antagonism, isolate no. 28 showed good antagonistic activity despite being negative for HCN production.

The isolates selected based on *in vitro* antagonistic assay were PDBC No.1 (*Pseudomonas fluorescens*), PDBC No.2 (*P. fluorescens*), PDBC Nos. 7, 8, 12, 14, 15, 19, 23, 26, and 28.

Table 28. Growth inhibition of *Sclerotium rolfsii* by PDBC bacterial isolates in dual culture

| Isolate (*Pseudomonas fluorescens*) | HCN Production | Growth inhibition of *Sclerotium rolfsii*(mm) | | | |
|---|---|---|---|---|---|
| | | DM | DMF+ | NA | PDA |
| PDBC NO. 1 | +++ | 35 | 25 | 23 | 0 |
| PDBC NO. 2 | + | 21 | 11 | 12 | 9 |
| PDBC NO. 7 | +++ | 43 | 23 | 30 | 1 |
| PDBC NO. 8 | ++ | 27 | 12 | 6 | 0 |
| PDBC NO. 12 | ++ | 45 | 40 | 32 | 0 |
| PDBC NO. 14 | ++ | 31 | 27 | 20 | 0 |
| PDBC NO. 15 | ++ | 37 | 30 | 27 | 8 |
| PDBC NO. 19 | +++ | 79 | 63 | 59 | 6 |
| PDBC NO. 23 | +++ | 59 | 59 | 47 | 4 |
| PDBC NO. 26 | ++ | 40 | 43 | 17 | 0 |
| PDBC NO. 28 | - | 33 | 39 | 16 | 1 |
| Control | | 80 | 80 | 70 | 90 |
| CD (P=0.01) | | 13.20** | 13.50** | 12.21** | 3.71** |

DM = *Pseudomonas* agar (fluorescens) + potato dextrose agar; DMF+ = DM + ferric chloride, NA = nutrient agar; PDA = potato dextrose agar; HCN prodn. : +++ = strong; ++ = moderate; + or - weak or no reaction

### b) Sclerotial Germination Inhibition Assay

An *in vitro* assay was undertaken to evaluate the isolates for sclerotial germination inhibition. Washed bacterial cell as well as culture filtrates were assayed. The media used were *Pseudomonas* Agar (for fluorescein) with glycine and Nutrient Agar. Incubation in cell suspension for 1hr or 24hr did not alter the germination percentage of sclerotia, except in cell suspensions of isolate Nos. 8, 12, 14, 19 and 23 grown in PAF where the germination.

Table 29. Effect of washed cell suspension on germination of sclerotia of *Sclerotium rolfsii*

| Isolates *(Pseudomonas fluorescens)* | Per cent germination of sclerotia | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Incubation (NA) (days) | | | | Incubation (PAF) (days) | | | |
| | 1 | 24 | 7 | 28 | 1 | 24 | 7 | 28 |
| PDBC NO. 1 | 100 (90) | 80(64) | 63 (53) | 33 (35) | 97(84) | 77(61) | 46(43) | 25(30) |
| PDBC NO. 2 | 100 (90) | 90(75) | 77 (61) | 37 (37) | 100(90) | 87(72) | 56(47) | 17(24) |
| PDBC NO. 7 | 100 (90) | 97(84) | 73 (60) | 30 (32) | 100(90) | 85(71) | 69(56) | 15(23) |
| PDBC NO. 8 | 100 (90) | 93(78) | 73 (60) | 41 (39) | 93(78) | 48(44) | 23(29) | 10(19) |
| PDBC NO. 12 | 99 (84) | 97(84) | 57 (49) | 55 (48) | 97(84) | 63(53) | 31(34) | 12(21) |
| PDBC NO. 14 | 100 (90) | 77(62) | 63 (53) | 48 (44) | 100(90) | 56(49) | 69(56) | 27(30) |
| PDBC NO. 15 | 100 (90) | 97(84) | 50 (45) | 78 (62) | 93(78) | 90(75) | 35(37) | 23(29) |
| PDBC NO. 19 | 100 (90) | 87(72) | 47 (43) | 37 (37) | 90(75) | 37(37) | 21(27) | 23(29) |
| PDBC NO. 23 | 100 (90) | 90(75) | 70 (57) | 48 (44) | 100(90) | 43(41) | 31(34) | 8(16) |
| PDBC NO. 26 | 100 (90) | 100(90) | 100(90) | 67 (55) | 90(75) | 97(84) | 50(45) | 40(39) |
| PDBC NO. 28 | 100 (90) | 100(90) | 93(78) | 85 (68) | 100(90) | 80(64) | 40(39) | 57(46) |
| Control | 100(90) | 100(90) | 100(90) | 100(90) | 100(90) | 100(90) | 100(90) | 100(90) |
| CD (P=0.05) | - | 16.8 | 13.6 | 9.9 | 12.2 | 13.7 | 5.5 | 4.7 |

Figures in parentheses are angular transformations

Culture filtrates (filter sterilized) of the isolates were assayed for inhibition ability of sclerotia. The results (Table 30) indicated that incubation of sclerotia for 1hr in culture filtrates obtained from cells grown in NA resulted in 21 to 69 % reduction in germination except in PDBC NO. 14, 15 and 26, where the germination was not affected.

Table 30. Inhibition of germination of sclerotia by bacterial culture filtrates

| Isolates (*Pseudomonas fluorescens*) | Germination of sclerotia (per cent) and Incubation duration | | | |
|---|---|---|---|---|
| | NA | | PAF | |
| | 1 hr | 24 hr | 1 hr | 24 hr |
| PDBC NO. 1 | 52 (46) | 0 | 27 (31) | 0 |
| PDBC NO. 2 | 67 (55) | 0 | 50 (45) | 0 |
| PDBC NO. 7 | 69 (56) | 0 | 67 (55) | 0 |
| PDBC NO. 8 | 29 (32) | 0 | 25 (30) | 0 |
| PDBC NO. 12 | 31 (34) | 0 | 25 (30) | 0 |
| PDBC NO. 14 | 96 (80) | 19 | 89 (72) | 0 |
| PDBC NO. 15 | 92 (73) | 19 | 77 (61) | 0 |
| PDBC NO. 19 | 31 (34) | 0 | 25 (30) | 0 |
| PDBC NO. 23 | 21 (27) | 0 | 21 (27) | 0 |
| PDBC NO. 26 | 100 (90) | 25 | 96 (80) | 0 |
| PDBC NO. 28 | 23 (29) | 0 | 19 (26) | 0 |
| Control | 100 | 100 | 100 | 100 |
| CD (P=0.05) | 6.64 | - | 10.75 | - |

Figures in parentheses are angular transformed values

### 4.12 Studies on entomophilic nematodes

#### 4.12.1 Isolation and identification of entomophilic nematodes

Intensive surveys were made to collect soil samples in Andhra Pradesh, Assam, Delhi, Himachal Pradesh, Karnataka, Kerala, Sikkim, Tamil Nadu, Uttar Pradesh, and West Bengal. Out of 243 soil samples collected from different states 13 samples were found to be positive to entomophilic nematodes. The soil samples from different vegetations were analyzed for the existence of entomophilic nematodes and the samples from pulses, vegetables, fruit trees and spices have yielded entomophilic nematodes (Table 31).

Information on the type of soil, elevation, and annual median rainfall of the locations from which the soil samples were collected was also recorded. *Steinernema* spp. have been isolated from the localities with an elevation range of 107m - 2200m . The annual median rainfall in

these localities ranged between 714mm and 923mm . *Steinernema* sp. was found to occur in sandy loam and clayey loam soils. *Heterorhabditis* spp. was isolated from soils collected from Delhi and Hyderabad , where the elevation was found to be 107m and 545m , annual rainfall 714.2mm and 764.4 mm and the soil type clayey loam and gravelly loam, respectively. There was no correlation between occurrence of either of the species of entomophilic nematodes and the elevation, annual rainfall and type of soil.

The collected entomophilic nematodes were fixed in TAF and processed by slow glycerin method. Permanent slides made were utilized for morphometric analysis of infective juveniles and males, which are important for identification.

Table 31. Crops found positive to entomophilic nematodes

| Crops | Number of samples collected | Samples positive | Crops | Number of Samples collected | Samples positive |
|---|---|---|---|---|---|
| Cereals | 14 | - | Spices | 19 | 2 |
| Millets | 12 | - | Narcotics | 4 | - |
| Pulses | 16 | 2 | Fibre crops | 1 | - |
| Oilseeds | 10 | - | Plantation crops | 7 | - |
| Vegetables | 40 | 1 | Ornamentals | 3 | - |
| Tuber crops | 25 | - | Forest | 6 | - |
| Fruits | 56 | 3 | Others | 31 | 5 |

### 4.12.2 Bioefficacy of certain isolates of *Steinernema* spp. against some common insect species

Three isolates viz., PDBCEN 6.11, PDBCEN 6.2 and PDBCEN 13.1, from Devanahalli, Adigenalli and Madurai, respectively were tested for bioefficacy against larvae of *Corcyra cephalonica, Helicoverpa armigera, Spodoptera litura, Plutella xylostella, and Opisina arenosella* in the laboratory by petri dish method. PDBCEN 6.11 caused the death of *P. xylostella* and *O. arenosella* larvae within a day after inoculation and within 2 days in case of *H. armigera, S. litura* and *C. cephalonica.* In case of PDBCEN 6.2 mortality of *P. xylostella* larvae occurred within a day and within 2 days in case of other four species, whereas PDBCEN 13.1 isolate killed *O. arenosella* within a day after inoculation and within 2 days in other insects. The isolate PDBCEN 6.11 was found to be most effective against *P. xylostella* and *O. arenosella*, PDBCEN 6.2 against *P. xylostella* and PDBCEN 13.1 against *O. arenosella.*

### 4.12.3 Efficacy of *Steinernema* spp. against *Chilo partellus* on maize in pot culture

Pot culture experiment was conducted to find out the efficacy of *Steinernema* spp. against *Chilo partellus* on maize. *C. partellus* @ 20 larvae/pot were introduced into 20 days old maize plants grown in pots. After getting heavy infestation, the IJs of *Steinernema* spp. were mixed with 6% liquid paraffin and sprayed over the foliage of maize plants. The treatments were 500 IJs/pot, 1000 IJs/pot and check (water). The occurrence of *C. partellus* was less in pots sprayed with 1000 IJs compared to pots sprayed with 500 IJs.

Number of galleries formed was minimum (6) at 1000 IJs/pot compared to 13 in check and 11 in pot sprayed with 500 IJs/pot. Pupation of larvae was reduced to 2 in 1000 IJs/pot. The tunnel length was also minimised in the treated plants (Table 32).

Table 32. Efficacy of *Steinernema* spp. against *Chilo partellus* on maize in pot culture (Mean of 10 replications)

| Dosage | Number of galleries | Number of host larvae recorded | Number of host pupae | Length of tunnel (cm) recorded | Plant height (cm) |
|---|---|---|---|---|---|
| 500 IJ / pot | 11 | 5 | - | 5.5 | 44.32 |
| 1000 IJ / pot | 6 | 1 | 2 | 12.58 | 31.25 |
| 0 (Control) | 13 | 4 | 7 | 28.45 | 23.50 |

### 4.13 Studies on nematophagous fungi and bacteria

#### 4.13.1 Effect of fungal spore suspension against *Meloidogyne incognita*

The effectiveness of four fungi *viz.*, *Trichoderma harzianum* PDBCTH2, *T. koningii*, *Gliocladium virens* and *G. deliquescens* was tested against *M. incognita* in vials containing soil. The spore suspension ($10^{-3}$ and $10^{-6}$) and nematodes @ 200 juveniles were introduced into the vials and kept for 48 hr and soil samples were processed for nematode extraction.

All the fungi were effective in killing the nematodes (Table 33). The maximum (97%) mortality was recorded in *T koningii* and it significantly differed from others. This was followed by *T. harzianum* (94.75%) in $10^{-3}$ spore suspension and it was on par with *G. deliquescens* (94.5%).

### 4.13.2 Effect of fungal spore suspension against *Meloidogyne javanica*

All the fungi were found to be effective against *Meloidogyne javanica* in soil. Maximum mortality of nematodes was recorded in *T. koningii* (89%) and it significantly differed from other treatments followed by *T. harzianum* (80%) at $10^{-3}$ spore suspension level. The same trend was observed at $10^{-6}$ spore suspension level (Table 34).

Table 33. Effect of fungal spore suspension against *Meloidogyne incognita*

| Treatments | Percent mortality of juveniles after 48 hrs* | |
|---|---|---|
| | $10^{-3}$ | $10^{-6}$ |
| *Gliocladium virens* | 91.00 (72.84) | 83.50 (66.17) |
| *G.deliquescens* | 94.50 (76.71) | 88.25 (70.09) |
| *Trichoderma harzianum* | 94.75 (76.80) | 94.75 (76.80) |
| *T.koningii* | 97.00 (81.47) | 93.75 (75.73) |
| Control | 20.00 (26.01) | 16.25 (23.58) |
| CD (P=0.05) | 6.97 | 4.17 |

* Mean of four replications; Figures in parentheses are transformed values

Table 34. Effect of fungal spore suspension against *Meloidogyne javanica*

| Treatments | Per cent mortality of juveniles after 48 hrs* | |
|---|---|---|
| | $10^{-3}$ | $10^{-6}$ |
| *Gliocladium virens* | 71.75 (61.88) | 60.00 (50.74) |
| *G. deliquescens* | 78.50 (62.49) | 53.75 (47.16) |
| *Trichoderma harzianum* | 80.00 (63.52) | 67.00 (55.16) |
| *T.koningii* | 89.00 (70.66) | 84.25 (66.77) |
| Control | 19.50 (26.11) | 21.75 (27.78) |
| CD (P=0.05) | 3.56 | 5.29 |

* Mean of four replications; Figures in parentheses are transformed values

### 4.13.3 Nematotoxic effect of different fungi against *Meloidogyne incognita* on sunflower

A pot culture experiment was conducted to find out the nematotoxic effect of different fungi *viz.*, seven *Trichoderma* isolates and two *Gliocladium* spp. against *M. incognita* on sunflower. The fungi were cultured in PDA medium. Both fungi @ 10 gm biomass and nematodes @ 1000 juveniles/pot were inoculated simultaneously in one-week-old sunflower seedlings.

Inoculation of fungi to sunflower showed increased plant height. The maximum plant height was recorded in *T. harzianum* ITTC (78.87 cm) and it was significantly superior followed by *T. koningii* (74.07 cm). The maximum root weight was recorded in *G. virens* (5.43 gm) followed by *G. deliquescens* (5.17 gm). Among the fungi *T. viride* PDBCTV4 recorded 1.43 gm and was on par with *T. harzianum* PDBCTH8 (Table 35).

Table 35. Nematoxic effect of different fungi against *Meloidogyne incognita* on sunflower

| Treatment | Plant height (cm)* | Root weight (g)* | No. galls/ root* | No. egg masses/g root* | Nematode population/ 200 g soil* |
|---|---|---|---|---|---|
| Nematode alone | 61.40 | 2.43 | 175.00 | 103.33 | 330.00 |
| *Trichoderma harzianum* ITCC | 78.87 | 4.03 | 65.00 | 33.00 | 216.67 |
| *T.harzianum* PDBCTH7 | 60.40 | 2.57 | 43.33 | 26.33 | 156.67 |
| *T.viride* ITCC | 62.83 | 3.40 | 133.33 | 85.33 | 256.67 |
| *T.viride* PDBCTV4 | 62.67 | 1.43 | 71.67 | 32.67 | 166.67 |
| *T.harzianum* PDBCTH8 | 38.17 | 1.83 | 43.67 | 23.67 | 163.33 |
| *T.koningii* ITCC | 74.07 | 4.93 | 148.33 | 75.00 | 236.67 |
| *T.pseudokoningii* ITCC | 69.50 | 2.13 | 81.67 | 44.67 | 186.67 |
| *Gliocladium* virens | 67.03 | 5.43 | 33.33 | 15.00 | 86.67 |
| *G.deliquescens* | 72.10 | 5.17 | 57.67 | 17.67 | 120.00 |
| CD (P=0.05) | 9.11 | 1.79 | 18.67 | 25.08 | 46.71 |

* Mean of three replications

There was a drastic reduction of galls/root system when plants were inoculated with any of the fungi. Among the fungi *G. virens* recorded the lowest (33.33 galls/root), followed by *T. harzianum* PDBCTH7 (43.33). *T.koningii* ITCC recorded the highest of 148.33 galls/ root. The maximum egg masses /gm root was recorded in nematode alone treatment and a reduction in

egg masses was noticed by inoculation of fungi. *G. virens* recorded the lowest (15.00 egg masses/ gm root) followed by *G. deliquescens* (17.67). *T. viride* ITTC isolate recorded highest (85.33) egg masses/g root. *G. virens* and *G. deliquescens* recorded minimum nematode population i.e. 86.67 and 120.00, respectively. *T. viride* ITTC isolate recorded highest population (256.67) and was effective in reducing the nematode populations.

### 4.14 Studies on weed pathogens

#### 4.14.1 Survey and identification of *Parthenium* weed pathogens

Extensive and intensive field surveys were undertaken for parthenium diseases in Bangalore Urban, Bangalore Rural, Mandya, Mysore, Dharwad, Bidar, Gulbarga, Raichur, Bellary and Chitradurga districts of Karnataka State. Samples of diseased parthenium were collected and observations made during field surveys from January to December. Disease symptoms that were targeted include various stem and leaf spots; blights; lesions; mildews and other major categories of pathogenic damage.

The procedure suggested by Hanlin (1982), with suitable modifications, was used for isolation and purification of fungi and bacteria from diseased samples. Infected lesions were cut into small pieces ( 1 $cm^2$) and were surface-disinfected by submersion in a bleach: ethanol: water (10:10:80) solution for 2 minutes. The sterilized pieces were dried between two sterile filter papers and plated on a suitable agar medium such as potato dextrose agar (PDA) amended with streptomycin sulphate ( for suspected fungi) or nutrient agar (NA) (for bacteria). Pure cultures of fungal isolates and bacteria were obtained. The microbes after purification were identified to genus level.

All the fungal and bacterial cultures in axenic form were maintained in a refrigerator at ca.4°C. Sub-culturing was done as and when needed. The obligate parasites were maintained in the greenhouse in the host plants. Pathogenicity tests were done and the pathogens reisolated from the infected plant parts.

Surveys revealed the occurrence of a wide variety of microbiota associated with parthenium (Table 36). Powdery mildew was observed in all the districts visited. The causal organism (*Oidium parthenii* ?) was tested for its pathogenicity towards *Tagetes* sp. (marigold). Its negative reaction to the ornamental plant confirmed to some extent that the pathogen was not *Erysiphe cichoracearum*.

Mysore district was found to be abundant with parthenium pathogens. A large number of leaf spot/blight pathogens were collected from Hunsur town and surrounding villages during

August. Initial isolations revealed the association of various genera such as *Alternaria*, *Colletotrichum*, *Fusarium* and others. *Sclerotium rolfsii* and *Sclerotinia sclerotiorum* were the other fungi found there. Phyllody was commonly observed in many locations with rampant damage to parthenium plants. Leaf curl was the viral disease seen occurring over a large area.

Table 36. Occurrence of pathogens on parthenium in Karnataka

| District | Period (1997) | Pathogens |
|---|---|---|
| Bangalore Urban | January-December | *Sclerotium rolfsii*, *Sclerotinia sclerotiorum*, *Fusarium pallidoroseum*, *Pestalotia* sp., *Oidium parthenii*, an unidentified bacterium, MLO's, viruses |
| Bangalore Rural | January- December | All the above and *Alternaria* spp., *Colletotrichum* spp., viruses |
| Mandya | August | All the above |
| Mysore | August | An unidentified fungal pathogens |
| Bidar | September | All the above |
| Gulbarga | September | Three unidentified fungal pathogens |
| Raichur | September | Two unidentified fungal pathogens |
| Bellary | September | One unidentified fungal pathogen |
| Dharwad | October | Two unidentified fungal pathogens |
| Chitradurga | December | Three unidentified fungal pathogens |

### 4.14.2 Evaluation of *Sclerotium rolfsii* as a mycoherbicide

*Sclerotium rolfsii* was originally isolated from parthenium plants showing collar rot and wilt symptoms in Hebbal area of Bangalore. The isolate was assayed for pathogenicity and virulence and maintained on potato dextrose agar (PDA) for further use.

Preliminary studies were conducted for assessing the effect of different inoculum concentrations of the pathogen on parthenium plants. Plants were raised in 15-cm plastic pots. Mature sclerotia were harvested from 30-day-old cultures of *S. rolfsii* and used for inoculation on a month old parthenium plants at the rate of 1, 2, 3, 4, and 5 sclerotia per plant. Symptom development was observed daily and the percentage mortality recorded on the sixth day when all the plants inoculated with the highest concentration of the pathogen were dead.

Studies on the effect of varying numbers of sclerotia applied per plant on the mortality of parthenium showed that the treated plants showed no major foliar changes in the form of

yellowing, all the plants applied with 4 and 5 sclerotia started drooping from the fourth day and collapsed on the sixth day. Three sclerotia per plant were not sufficient to achieve completertality of parthenium.

### 4.14.3 Studies on the mycoherbicidal properties of *Gliocladium virens*

*Gliocladium virens* (ITCC 4177) was grown in a special nutrient broth consisting of sucrose (300 g/L), ammonium nitrate (3 g/L), magnesium sulphate (2 g/L) and potassium dihydrogen phosphate (2 g/L). The final pH of the medium was adjusted to below 7.0. Sporeless culture filtrate was obtained after incubation for 15 days. The culture filtrate (100%) was diluted with sterile distilled water to get different concentrations viz. 10, 20, 30, 40, 50, 60, 70, 80 and 90 % (v/v). Sterile distilled water served as control.

#### a) Pre-emergence effect

Parthenium seeds obtained from natural populations were soaked in various concentrations of *G. virens* culture filtrate for 6 h. Treated seeds were either placed on moist blotters in petri dishes or sown in sterile soil in small pots. After incubation for 3 weeks, the percentage of germination, root length (mm) and shoot length (mm) were measured. Seedling vigour index was arrived at by using the following formula.

Seedling vigour index = (Root length + Shoot length) x Germination percentage

The culture filtrate at a minimum concentration of 70 per cent was effective in checking parthenium seed germination. Similarly, the root and shoot lengths drastically affected with 50 per cent concentration of the filtrate produced radicles suggesting the deleterious effect of the metabolites produced by *G. virens* especially towards root development. Because of the effect on both root and shoot development, the ultimate seedling vigour index was reduced to a great extent.

Germination was slightly more affected when the seeds were sown in soil. Because of this the root and shoot lengths and the eventual seedling vigour also suffered correspondingly. The pronounced effect on the emerging radicles suggests the rhizogenic toxicity of *G. virens* culture filtrate on parthenium.

#### b) Post-emergence effect

All the concentrations were applied to pots consisting 10-15-day-old seedlings in such a manner that the root region of the plants was sufficiently moistened. 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 100% concentration.

*G. virens* culture filtrate showed post-emergence root necrosis when young seedlings of parthenium were treated with varying concentrations. On the third day of treatment, undiluted filtrate exhibited the maximum effect killing all the seedlings. Among themselves, all the treatments tested showed significant differences in their post-emergence herbicidal activity towards parthenium.

## 4.15 Cultures of host insects /natural enemies /nematodes / antagonists /pathogens

### 4.15.1 Host cultures

4.15.1 Insects

*Helicoverpa armigera, Spodoptera litura, Plutella xylostella, Opisina arenosella, Chilo partellus, Phthorimaea operculella, Corcyra cephalonica, Aphis craccivora, Ferrisia virgata, Maconellicoccus hirsutus, Planococcus citri, P. lilacinus* and *Hemiberlesia lataniae* were maintained continuously for several generations and used for rearing natural enemies and the experiments underway.

### 4.15.2 Culture of natural enemies

4.15.2.1 Parasitoids

Cultures of *Campoletis chlorideae, Eriborus argenteopilosus, Chelonus blackburni, Allorhogas pyralophagus, Cotesia flavipes, Copidosoma koehleri, Telenomus remus, Leptomastix dactylopii* and 11 species of trichogrammatids are maintained.

4.15.2.2 Predators

Cultures of *Cheilomenes sexmaculata, Coccinella septempunctata, Ischiodon scutellaris, Cryptolaemus montrouzieri, Scymnus coccivora, Chilocorus nigrita* and *Chrysoperla carnea* are maintained.

4.15.2.3 Insect pathogens

Multiplication of nuclear polyhedrosis viruses of *H. armigera* and *S. litura* and granulosis virus of *P. xylostella* using their respective hosts is continued.

Seven varieties of *Bacillus thuringiensis viz., aizawai, entomocidus, galleriae, israelensis, kurstaki, sotto* and *thuringiensis* were maintained at Indian Agricultural Research Institute, New Delhi, a coordinating centre of PDBC.

### 4.16 Shipment of host insects and natural enemies

During the reporting period, 59 cultures of various host insects and 80 cultures of natural enemies were maintained and sent to coordinating centres and other research organizations as nucleus cultures to facilitate their multiplication and establishment. Formulation of *Trichoderma harzianum*, a biocontrol agent was supplied to 6 coordinating centres to test its efficacy against chickpea and lentil wilt and root rot complex by G.B.Pant University of Agriculture & Technology, Pantnagar.

### 4.17 Software development for identifying and suggesting BIPM

Cotton crop was chosen to develop an Expert System. The spotted bollworm, *Earias vittella*; spiny bollworm, *Earias insulana*; pink bollworm, *Pectinophora gossypiella*; cotton bollworm, *Helicoverpa armigera*; jassid, *Amrasca biguttula biguttula*; Aphid, *Aphis gossypii*; thrip, *Scirtothrips dorsalis*; whitefly, *Bemisia tabaci*; semilooper, *Anomis flava*; cotton grey weevil, *Myllocerus undecimpustulatus*; red cotton bug, *Dysdercus cingulatus*; dusky cotton bug, *Oxycarenus laetus*; cotton leafroller, *Sylepta derogata*; mite, *Tetranychus telarius*; tobacco caterpillar, *Spodoptera litura* and stem weevil, *Pempherulus affinis* were identified as serious pests.

Information on the nature of damage, different symptoms and observations for identification of the pest was collected from the literature and from the cotton experts. The relevant information was modified to codes to suit the programme (software). Control measures for these pests on cotton crop, as suggested by the experts in the relevant field were computerised and then the software (Expert System) was developed. After many trial runs, when the programme was bug free, it was compiled and an executable file created. The executable programme was tried under DOS, Windows 3.11 and Windows 95 environments. It was found that in all the three environments it was working satisfactorily. Installation disks were developed and are ready for distribution.

## 4.18. BIOLOGICAL SUPPRESSION OF SUGARCANE PESTS

**Punjab Agricultural University, Ludhiana**

### 4.18.1 Survey and seasonal fluctuation studies on natural enemies of sugarcane borers

The survey and seasonal fluctuation studies on natural enemies of sugarcane borers were carried out at farmers' fields near Phillaur (Jalandhar District) at fortnightly interval from July to December 1997. Eggs, larvae and pupae of the borers were collected and reared in the laboratory for emergence of the natural enemies and/or the next stage of the pest.

The observations showed that the egg parasitoids of *Chilo infuscatellus* were active from second fortnight of April to first fortnight of July. The extent of parasitization was 4.5 to 7.4% by *Trichogramma chilonis* and 4.2-8.6% by *T. chilotraeae*. The larval parasitoid, *Cotesia flavipes* was observed from April to July and the parasitization varied from 1.7 to 5.5 per cent. An unidentified braconid was also observed causing 1.4 to 2.3 per cent parasitization during April-May. No pupal parasitoid was observed.

The eggs of the top borer, *Scirpophaga excerptalis* were available from July to September. The egg parasitoid, *Telenomus dignoides* was the most important and was recorded during April - July causing 4.8 to 25.0 per cent parasitization. The larval parasitoids were active throughout the season (April to November) of which *Glyptomorpha nicevillei* was the most common (1.9 to 20.0%). *Isotima javensis* was recorded during June - August (3.3 -10.3 %), while *Rhaconotus scirpophagae* was observed during July - October (4.8 to 13.0%). One larval parasitoid, *Topobracon* sp. was recorded for the first time in Punjab during August - October, though the parasitization was 1.7 to 2.8 per cent only. No pupal parasitoid was recorded.

No egg and pupal parasitoids were observed on gurdaspur borer, *Acigona steniellus* during this period. The larval parasitoid *C. flavipes* was the most predominant species inflicting 2.2 to 7.1 per cent parasitization during July - October. *G. nicevillei* was recorded during August-September (2.2 to 3.5%), while *R. signipennis* (0.9%) was recorded in September.

No pupal parasitoid of *C. auricilius* was observed while larval parasitoids were active during April - November. *C. flavipes* was observed during April - October (2.2 to 7.7% ) while *Sturmiopsis inferens* was observed from May to November (4.4 to 10.5%). *G. nicevillei* was observed only during October (3.8%).

### 4.18.2 Field studies on *Trichogramma chilonis* against tissue borers

**Control of early shoot borer, *Chilo infuscatellus***

The experiment for the control of *C. infuscatellus* was carried out on the planted and ratoon crops of sugarcane at Regional Research Station, Kheri, Sangrur. The egg parasitoid, *T. chilonis* was released 6 times @ 50,000/ha at 10 days interval during May-June. The parasitoid releases were compared with insecticide applications and control (Table 37). The plot size was 16 m x 23 m in case of plant crop (var. Co 1148) and 16 m x 9 m in ratoon crop (var. CoJ 82) with 4 replications. The incidence of the early shoot borer was recorded in July.

The incidence of the borer in plant crop was significantly lower (2.96%) in the plots where *T. chilonis* was released. The damage in insecticide treated plots was on par with control.

Table 37. Biological suppression of early shoot borer, *Chilo infuscatellus*

| Treatment | Per cent incidence | |
|---|---|---|
| | Plant crop | Ratoon crop |
| BHC @ 5.0 l/ha | 5.52 (13.56) | * |
| Chlorpyriphos 925 ml/ha (20-05-1997) | 4.65 (12.32) | 1.36 ( 6.57) |
| *T. chilonis* @ 50,000/ha at 10 days interval (May-June) | 2.96 ( 9.86) | 1.68 ( 7.26) |
| Cartap 4 G @ 1.0 kg a.i./ha | 5.76 (13.86) | * |
| BHC dust @ 18.75 kg/ha (29-04-1997) | * | 2.35 ( 8.49) |
| Imidacloprid @ 500 g/ha (12-06-1997) | * | 1.10 ( 6.02) |
| Control | 5.17 (13.13) | 3.76 (11.06) |
| CD (P = 0.05) | (2.24) | (2.98) |

Figures in parentheses are arcsine transformed; * Treatment not included in the experiment

In ratoon crop (Table 37), the damage in treated plots except BHC dust was significantly lower than control. The lowest damage (1.10%) was recorded in imidacloprid but was on par with parasitoid release, chlorpyriphos spray and BHC dust application.

**Control of stalk borer, *Chilo auricilius***

The experiment on the evaluation of *T. chilonis* for the control of stalk borer, *Chilo auricilius* was carried out at Regional Research Station, Kheri (Sangrur District) on

planted crop (var. CoJ 82) and the ratoon crop (var. CoJ 83) with plot size of 17 x 9 m and 15 x 9m, respectively. The releases of *T. chilonis* alone and in combination withinsecticide sprays were given as indicated in Table 38. The incidence of the stalk borer was recorded in December on the basis of 50 canes per plot. In the ratoon crop, the incidence of stalk borer in treated plots was significantly lower than control. However, in the planted crop, the incidence was very high, but significantly lower in the release/treated plots. The releases of egg parasitoid, *T. chilonis* alone or in combination with insecticides proved equally effective in reducing the pest incidence.

### 4.18.3 Demonstration of the effectiveness of *Trichogramma chilonis* for the control of sugarcane stalk borer, *Chilo auricilius*

To demonstrate the efficacy of *T. chilonis* for the control of stalk borer, four locations, *viz.*, Shekhupura (Ludhiana), Nagar & Jalowal (Jalandhar) and Barnala (Sangrur) were selected. The plot size was 2 ha at Shekhupura and Nagar, 1 ha at Jalowal and 8 ha at Barnala. The plot size of the control was one ha at all the locations. At Shekhupura and Nagar, adult parasitoids were also released in two and one hectare plots. For this purpose, 4.0 cc eggs of *Corcyra cephalonica* were parasitized by *T. chilonis*. One day after parasitization the eggs were transferred equally in 100 gelatin capsules. When adult parasitoids were about to emerge, these capsules were stored in the refrigerator in polythene bags. At the time of release, these capsules were opened at 100 spots in the field for equal distribution. The incidence of the stalk borer was recorded during November on the basis of 100 canes each from 5 spots in each plot. Recovery tests were carried out at Shekhupura and Nagar during August - October by exposing

Table 38. Biological suppression of stalk borer, *Chilo auricilius* in sugarcane

| Treatment | Per cent incidence | |
|---|---|---|
| | Ratoon Crop | Planted crop* |
| Release of *T. chilonis* (May-October) 9 times @ 50,000/ha at 10 days interval | 1.62 | 25.3 (30.21) |
| Chlorpyriphos spray @ 1250 ml/ha (20.5.97) + releases of *T. chilonis* (July-October) | 1.37 | 23.7 (29.10) |
| Monocrotophos spray @ 1250 ml/ha (20.5.97) + release of *T. chilonis* (July-October) | 1.75 | 25.5 (30.37) |
| Control | 4.75 | 65.3 (53.92) |
| CD (P=0.05) | 1.96 | (8.49) |

* Figures in parentheses are *arcsine* transformed values

5 egg clusters of *Chilo auricilius* for 24-48 hrs. The cards were brought to the laboratory for observations.

The incidence of the stalk borer in fields with 'tricho-cards' ranged from 7.1 to 16.6 per cent as compared to 13.6 to 34.8 per cent in the control. The borer incidence, when adult parasitoids were released, was 8.8 to 9.4 per cent. The mean borer incidence was 9.1 and 13.5 per cent in release fields as compared to control (39.3%). The parasitoid was recovered at both the locations during September and October in the release fields.

**4.18.4. Field studies on *Cotesia flavipes* against early shoot borer and stalk borer**

The experiment for the evaluation of *Cotesia flavipes* alone and in combination with *T. chilonis* was carried out at two locations, *viz.*, Mauli (Kapurthala) and Jalowal (Jalandhar). At Mauli there were four treatments *viz.*, *C. flavipes* (single release), *C. flavipes* (five releases), *T. chilonis* (10 days interval during July - October), *T. chilonis* (July - October) + *C. flavipes* (September - October) and control. At Jalowal, the five treatments were *C. flavipes* (September - October), *T. chilonis* (July - October), *T. chilonis* + *C. flavipes*, *T. chilonis* (July - August) + *C. flavipes* (September - October), and control. The data was recorded at monthly interval during July - October at Mauli and once in November at Jalowal on the basis of 5 units of 50 canes each.

At Mauli (Jalandhar) the incidence in release fields was lower than control in all the months. The final incidence during November was lowest (8.4%) in plots where *T. chilonis* and *C. flavipes* were released, followed by 10.8 per cent in plots where releases of *T. chilonis* alone were made. Single release of *C. flavipes* was not effective. At Mauli, larval parasitism was recorded in all the treatments and it was higher (8.0%) in plots where *C. flavipes* was released five times at 20-days interval. Egg parasitism was recorded in the plots where *T. chilonis* was released 11 times during July - October. However, at Jalowal all the treatments were equally effective and better than control.

**Sugarcane Breeding Institute, Coimbatore**

**4.18.5 Seasonal fluctuations of shoot borer parasitoids**

Shoot borer parasitoids were monitored at Coimbatore from January to December 1997 by collecting larvae at monthly intervals and examining in the laboratory. *Sturmiopsis inferens* was active almost throughout the year at moderate levels. Two peaks of parasitism were noticed in January (5.6%) and November (6.1%). In the remaining months, parasitism varied from 0.0 to 1.9%. *Cotesia flavipes* was noticed in August (0.5%) only.

### 4.18.6 Seasonal fluctuations of granulosis virus (GV) of shoot borer

Seasonal incidence of GV of shoot borer was monitored during January-December 1997. GV was active throughout the year, the incidence appeared to be higher during January-June whereas it appeared to be more or less uniform in the remaining months, except August which showed the overall peak of 23.09%.

### 4.18.7 Studies on *Beauveria brongniartii*

The fungus was mass cultured on moist sorghum grains in empty saline bottles. In preliminary studies, molasses was found to be a suitable alternative medium for the fungus. The fungus was bioassayed against eggs of white grub in the laboratory at $10^6$ to $10^9$ spores/5 ml of suspension added to eggs placed in soil in small plastic containers (Table 39). Per cent hatching was slightly reduced in treated eggs indicating limited ovicidal activity. The treated eggs also showed limited infection by the fungus. However, these differences were not significant ($P>0.05$).

Table 39. Bioassay of *Beauveria brongniartii* against eggs of white grubs in the laboratory

| No. of spores/5 ml of suspension | % hatching of eggs[#a] | % infection due to fungus[#b] |
|---|---|---|
| $10^6$ | 45.0(42.1)a | 7.5(2.3)a |
| $10^7$ | 67.5(59.0)a | 2.3(1.3)a |
| $10^8$ | 62.5(52.3)a | 0.0(0.7)a |
| $10^9$ | 52.5(46.4)a | 2.3(1.3)a |
| Control | 75.0(62.8)a | 0.0(0.7)a |

# Four replications of 10 eggs each; Figures in parentheses are [a]arcsine or [b]$(x+0.5)^{1/2}$ transformations; values followed by the same letter are not significantly different ($P>0.05$) by DMRT.

The fungus was evaluated against first instar grubs in pots at a concentration of $10^7$-$10^{10}$ spores/pot ($10^{13}$ - $10^{16}$ spores/ha). Infection rates at these concentrations, observed from 30 to 100 days after treatment (DAT), were not significantly different from one another (Table 40).

Table 40. Evaluation of *Beauveria brongniartii* against first instar white grubs in pot culture

| Spores / pot (Spores/ha) | % infection due to fungus #a |
|---|---|
| $10^{7}$ ($10^{13}$) | 3.6 (1.5) a |
| $10^{8}$ ($10^{14}$) | 0.0 (0.7) a |
| $10^{9}$ ($10^{15}$) | 10.7 (2.7) a |
| $10^{10}$ ($10^{16}$) | 3.6 (1.5) a |
| Control | 0.0 (0.7) a |

# Four replications of seven grubs each; [a] Figures in parentheses are $(x+0.5)^{1/2}$ transformations; Means followed by the same letter are not significantly different ($P>0.05$)

When the fungus was evaluated against third instar grubs in pot culture at $10^{8}$-$10^{11}$ spores/pot ($10^{14}$-$10^{17}$ spores/ha), infection rates at higher concentrations ($10^{16}$ and $10^{17}$ spores/ha) were significantly higher than those at lower concentrations. The infection rates were higher than those noticed in first instar grubs for similar concentrations.

## 4.19 BIOLOGICAL SUPPRESSION OF COTTON PESTS

**Acharya N.G.Ranga Agricultural University, Hyderabad**

### 4.19.1 Development of biocontrol based IPM

A field trial was laid out at Regional Agricultural Research Station, Lam (Guntur) with L-604 variety in an area of 4000 $m^2$. There were four treatments *viz.*, BIPM, conventional method of control (farmers' practice), judicious usage of insecticides and an untreated plot to serve as control.

In BIPM treatment cotton was intercropped with cluster beans, cowpea and soybean, while sole cotton crop was sown for the other treatments.

The BIPM treatment plot received seed treatment with carbofuran, application of carbofuran granules @ 1.0 kg a.i/ha at 15 days after sowing, inundative releases of *Trichogramma chilonis* @ 1,50,000 and *Chrysoperla carnea* @ 50,000/ha at 60 days after sowing and spray application of neem seed kernel extract (NSKE) 5% at 115 days, *Ha*NPV + endosulfan at 125 days and Dipel @ 2.0 kg/ha at 140 days after sowing.

In the conventional method insecticidal sprays were given 16 times at weekly interval. The insecticides sprayed were oxydemeton methyl, monocrotophos, endosulfan + sesamum

oil, chlorpyriphos + sesamum oil, monocrotophos + Dipel, endosulfan + Dithane M-45, profenphos, endosulfan + *Ha*NPV, Dipel and Acephate.

The treatment involving judicious usage of insecticides received spray application of oxydemeton methyl, monocrotophos, endosulfan + sesamum oil, chlorpyriphos + sesamum oil, monocrotophos + Dipel, endosulfan + Dithane M-45, endosulfan + *Ha*NPV and Dipel, 12 times on need basis.

The observations on the population of sucking pests, *viz.*, jassids, aphids and whiteflies were recorded on 10 plants selected at random from lower, middle and upper regions of the plant. The data on the incidence of *Helicoverpa armigera* in terms of eggs, larvae and also damaged squares and bolls were recorded from 10 plants from each treatment. The population of natural enemies was also recorded on 10 plants in each treatment.

The results presented in Table 41 reveal that the population of whiteflies was low in BIPM treatment and was on par with judicious usage of insecticides treatment, while same level of population was observed in Farmer's practice and high level in control plot. The population level of jassids in BIPM practice was low and more or less of same level as in judicious usage of insecticides when compared to control plot. Lowest aphid population was recorded in judicious usage of insecticides followed by IPM treatment.

The egg population of *H. armigera* in BIPM and control plot was at the same level, while in farmer's practice and judicious usage of insecticide, it was very high. The build up of larval population was very low in BIPM practice and high in farmer's practice. The larval population in farmer's practice and control plot was higher. In respect of damage to squares and bolls, lowest damage was recorded in BIPM treatment.

The presence of predatory fauna (coccinellids, spiders and chrysopids) was significantly high in BIPM treatment.

The cotton yield obtained through BIPM strategy (18.3 q/ha) was low when compared to that of conventional method (23.8 q/ha). However, the incremental cost benefit ratio (ICBR) was high in BIPM practice (10.07), as compared to farmers' practice (1.55) and judicious usage of insecticides (1.59). The BIPM practice thus excelled due to the significant role played by the beneficial insects which could be increased through intercropping and avoiding insecticidal treatments.

Table 41. Effect of microbial agents against *Helicoverpa armigera* in chickpea

| Treatment | Pretreatment larval population per 5 plants | Mean larval population per 10 plants (10 days after spray) | | | Mean pod damage (%) | Yield for 5 plants (g) |
|---|---|---|---|---|---|---|
| | | I | II | III | | |
| NPV @ 250 LE/ha | 7.67 | 5.00 (12.56) | 12.67 (20.69) | 7.33 (15.60) | 9.08 (17.45) | 70.00 |
| NPV @ 125 LE/ha | 6.00 | 5.60 (12.51) | 15.00 (22.75) | 4.67 (12.46) | 8.91 (17.29) | 70.00 |
| Endosulfan 0.07% | 6.67 | 5.00 (12.88) | 7.30 (15.60) | 4.67 (12.28) | 5.9 (13.94) | 71.67 |
| Endosulfan 0.035% | 6.00 | 6.33 (14.53) | 7.00 (15.17) | 4.00 (11.32) | 5.63 (12.93) | 58.33 |
| *Btk*-I @ 1 kg/ha | 9.00 | 5.33 (13.27) | 4.30 (11.75) | 2.00 (7.95) | 5.23 (13.19) | 85.00 |
| *Btk*-II @ 1 kg/ha | 7.00 | 5.67 (13.75) | 4.00 (11.28) | 4.30 (11.89) | 5.21 (13.02) | 70.00 |
| *Btt* @ kg/ha | 7.67 | 7.67 (16.07) | 6.30 (14.51) | 10.67 (18.45) | 8.39 (16.73) | 58.33 |
| Dipel @ 1kg/ha | 6.67 | 8.33 (16.45) | 7.30 (15.65) | 8.00 (16.36) | 6.90 (15.24) | 113.33 |
| NPV @ 125 LE/ ha +Endosulfan 0.035% | 7.67 | 8.00 (16.37) | 8.67 (17.11) | 6.00 (13.91) | 5.65 (13.71) | 78.33 |
| NPV @ 250 LE/ha + *Btk*-II @ 1 kg/ha | 10.67 | 6.00 (14.07) | 10.33 (18.47) | 4.3 (11.89) | 5.02 (12.85) | 73.33 |
| Control | 11.00 | 16.00 (23.29) | 18.67 (25.60) | 11.67 (19.96) | 13.86 (21.82) | 26.67 |
| C.D. at 5% | 4.42 NS | 4.65 S | 3.82 S | 4.24 S | 3.20 S | 28.34 S |

Figures in parentheses are the transformed values

**Gujarat Agricultural University, Anand**

**4.19.2 Evaluation of BIPM module on cotton Hybrid-8**

To evaluate the efficacy of BIPM module against pest complex in Hybrid Cotton-8 an experiment was laid out in completely randomized block design with the following four treatments replicating 10 times. The variety used was H-8 with a spacing of 120x60 cm in a plot size of 0.2 ha.

BIPM Module-1

Mechanical collection of bollworm infested parts and putting them in wire screen cage; random planting of maize ( @ 5 % of plants); need based application of oxydemeton methyl (0.05%) during early part of the season i.e. 30 days after germination; three releases of *Chrysoperla carnea* @ 10,000 larvae (2-3 days old)/ha/week synchronising with the appearance of the pests; eight releases of *Trichogramma chilonis* each @ 1,50,000 per ha/week synchronising with the appearance of the pest and need based application of *Ha*NPV ($2x10^9$ POB/ml).

BIPM Module-2

Mechanical collection of bollworm infested parts and putting them in wire screen cage; random planting of maize ( @ 5 % of plants); need based application of oxydemeton methyl (0.05%) 30 days after germination; three releases of *Chrysoperla carnea* @ 10,000 larvae (2-3 days old)/ha/week synchronising with the appearance of the pests; eight releases of *Trichogramma chilonis* each @ 1,50,000 per ha/week synchronising with the appearance of the pest; need based application of *Ha*NPV ($2x10^9$ POB/ml); need based application of monocrotophos 0.03 % and endosulfan 0.07 % after 8th release of *T. chilonis*.

Insecticidal Module

Monocrotophos (0.036%), oxydemeton methyl (0.030%), endosulfan (0.70%), monocrotophos (0.036%), endosulfan (0.70%) and monocrotophos (0.036%) (As per GAU recommendation).

Control Untreated

The entire plot (0.2 h) was divided into 10 subplots. From each subplot 5 plants were selected at random and tagged. The observations on population of aphid, jassid, whiteflies and thrips were recorded on the tagged plants at fortnightly interval. In case of bollworms, healthy and damaged buds / bolls were counted from each tagged plant to find out extent of damage. To record the egg/ larval parasitism, immature stages were collected every fortnight under different treatments and were kept individually in glass vials.

Number of predators like *Chrysoperla carnea* (immature stages), *Cheilomenes sexmaculata* (eggs, larvae, pupae and adults), *Geocoris* sp. (adults), spiders and staphylinids, etc., were also recorded on the tagged plants.

Results revealed that the bud and boll damage was significantly lower in BIPM module I and II. The bud damage in BIPM module I and II was found to be 7.24 and 6.01% per cent whereas boll damage was 8.16 and 7.04%, respectively. The bud and boll damage in untreated plot was 19.45 and 21.68%, respectively (Table 42).

The bollworm damage to locules was also significantly low in BIPM blocks. The damage due to *Earias vittella* in BIPM-1, BIPM-2 and insecticide treated plot was found to be 6.86, 6.32 and 10.55% and damage due to *Pectinophora gossypiella* in these treatments was 24.76, 23.11, and 31.79%, respectively (Table 43).

The population of sucking pests was also significantly lower in BIPM modules as compared to control. The releases of *Chrysoperla carnea* gave significantly better protection against aphids, jassids and whiteflies. The population of aphids, jassids and white flies in BIPM module I was 38.19, 2.61 and 3.97 per 15 leaves, in BIPM module II, 37.44, 5.40 and 4.57 per 15 leaves and in insecticide treated plot, 186.70,7.94 and 6.02 per 15 leaves, respectively. Since BIPM plots received fewer sprays of chemical insecticides many of the bio-agents were conserved. The noteworthy among them were *Aleiodes aligarhensi, T. chilonis* and *Agathis*, which caused 19.62, 28.98 and 36.11% parasitism, respectively, in BIPM module I and 17.94, 27.30 and 41.67% parasitism, respectively, in BIPM module II. Further , it was noted that parasitism due to *Agathis* was more compared to the previous years. Amongst the predators recorded, *Chrysoperla, Cheilomenes*, *Geocoris* and staphylinids were 91.2,44.6, 20 and 3.25 per 25 plants in BIPM module I and 83.4, 47.2, 18.5 and 3.4 per 25 plants in BIPM module II, respectively. Observations further revealed that *H. armigera* appeared in insignificant numbers.

Population of natural enemies was greatly hampered due to application of insecticides as per GAU recommendation. The per cent parasitism by *A. aligarhensi* and *T. chilonis* and *Agathis* was found to be 14.77, 10.58 and 31.15% only. The count of *Chrysoperla,*

*Cheilomenes*, *Geocoris* and staphylinids was 25.3, 25.2, 13.5 and 3.4 per 25 plants, respectively. The effect of BIPM was also reflected in the yield. The yield in BIPM-1 and BIPM-2 was 26.25 and 26.47 q/h which was significantly superior to control (18.05 q/h).

Further, it was observed that intercropping of maize with cotton enhanced the activity of *C. sexmaculata* in cotton crop in BIPM blocks. The natural enemies like *Aleiodes*, *Agathis*, *Apantetes*, etc. after recording the incidence were released in the same BIPM block. Thus, both the IPM modules proved effective against cotton pests giving higher ICBR (Tables 44 & 45).

Table 42. Population of different pests and yield in different treatments

| Treatment | Population (numbers) | | | Extent of damage due to *Earias vitella* (%) | | Yield (q/ha) |
|---|---|---|---|---|---|---|
| | Jassids | Aphids | White-flied | Bud damage | Boll damage | |
| BIPM Module 1 | 2.57 (2.61) | 6.26 (38.19) | 2.23 (3.97) | 15.61 (7.24) | 16.60 (8.16) | 26.25 |
| BIPM Module 2 | 2.53 (5.40) | 6.20 (37.44) | 2.36 (4.57) | 14.18 (6.00) | 15.39 (7.04) | 26.47 |
| Insecticidal Module | 2.99 (7.94) | 13.70 (186.70) | 2.65 (6.02) | 23.26 (15.59) | 24.29 (16.92) | 21.19 |
| Control | 3.05 (8.90) | 17.20 (294.84) | 3.02 (8.12) | 26.17 (19.45) | 27.75 (21.68) | 18.05 |
| CD at 5% | | | | | | |
| T | 0.227 | 0.898 | 0.199 | 1.499 | 1.095 | 2.82 |
| P | 0.301 | 1.434 | 0.229 | 2.927 | 1.756 | NS |
| TP | NS | 2.868 | 0.458 | 5.855 | 3.513 | 21.80 |

Figures in parenthesis are retransformed value of $\sqrt{x+1}$

4.19.3 **Standardisation of release technology for *Trichogramma chilonis***

Releases of adult *T. chilonis* were found significantly effective over the release of 100 bits and 200 bits of 'Tricho cards'. The per cent damage to squares and boll was found to be 10.47 and 9.60, respectively, in the plots where adults were released. The yield obtained from above plot was also significantly higher (25.58 q/h) than the rest of the treatments.

Table 43. Extent of leaf and locule damage

| Treatments | Per cent damage by | | Leaf roller | | |
|---|---|---|---|---|---|
| | *Earias vittella* | *Pectinophora gossypiella* | Infestation (%) | Parasitization (%) | |
| | | | | *Apanteles* sp. | Unidentified parasitoid |
| BIPM-1 | 15.18 (6.86) | 29.80 (24.70) | 16.00 | 12.77 | 4.26 |
| BIPM-2 | 14.56 (6.32) | 28.73 (23.11) | 20.00 | 12.63 | 0.00 |
| Insecticides | 18.95 (10.55) | 34.32 (31.79) | 34.00 | 9.23 | 3.08 |
| Control | 27.62 (10.55) | 37.07 (36.34) | 10.00 | 9.88 | 2.47 |
| C.D. at 5% | 3.46 | 2.618 | - | | |

Table 44. Economics of treatments

| Treatment | Details | No.of releases or spray | Total quantity used/ha | Cost of insecticide/ bioagents (in lakh Rs.) | Labour charges (Rs.) | Overall cost (Rs.) |
|---|---|---|---|---|---|---|
| IPM I | Mechanical removal | - | - | - | 152 | 152 |
| | *Chrysoperla* | 3 | 0.30 lakh | 66.68 @ 222.28/lakh | 19 | 85.68 |
| | *Trichogramma* | 8 | 12 lakh | 859.68/ 926.36 @ 71.64/lakh | 152 | 101.68 |
| | | | | 926.36 | 323 | 1249.36 |
| IPM II | Mechanical removal | - | - | - | 152 | 152 |
| | *Chrysoperla* | 3 | 0.30 lakh | 66.68 @ 222.28/ lakh | 19 | 85.68 |
| | *Trichogramma* | 8 | 12 lakh | 859.68/ 926.36 @ 71.64/lakh | 152 | 1011.68 |
| | Endosulfan | 1 | 2 lit. | 534 @ 267/lit | 57 | 591 |
| | | | | 1460.36 | 380 | 1840.36 |

| Treatment | Details | No.of releases or spray | Total quantity used/ha | Cost of insecticide/ bioagents (in lakh Rs.) | Labour charges (Rs.) | Overall cost (Rs.) |
|---|---|---|---|---|---|---|
| Need based insecticide application | Oxydemeton methyl | 1 | 1 lit | 307.50 @ 307.50/lit | 57 | 364.50 |
| | Endosulfan | 3 | 6 lit | 1602 @ 267/lit | 171 | 1773 |
| | Monocrotophos | 3 | 3 lit | 1230 @ 410.lit | 171 | 1701 |
| | | | | 3139.40 | 399 | 3538.50 |

Table 45. Economics and ICBR

| Treatment | Yield kg/ha | Increase in yield (kg/ha) | Gross Income | Cost of treatment | Net income | ICBR |
|---|---|---|---|---|---|---|
| IPM I | 2625 | 820 | 18459 @ Rs.450/20 kg | 1246.36 | 1720.64 | 1:13.77 |
| IPM II | 2647 | 842 | Rs.18945 @ Rs.450/20 kg | 1840.36 | 17104.64 | 1:9.29 |
| | | | | 1840.36 | 17104.64 | 1:9.29 |
| Insecticide | 2119 | 314 | 7065 | 3538.50 | 3526.50 | 1:0.99 |
| Control | 1805 | - | - | - | - | - |

**Punjab Agricultural University, Ludhiana**

**4.19.4 Evaluation of biocontrol-based IPM module**

The experiment on the evaluation of biocontrol based module was laid out at the Regional Research Station, Bathinda. The plot size was 0.4 ha for each of the treatment.

BIPM module-I

Two sprays of oxydemeton methyl in the first fortnight of August at weekly interval as need-based application for the control of sucking pests; release of *Trichogramma chilonis* @

1,50,000 per ha per week during July - October; release of *C. carnea* @ 10,000 per ha on the appearance of sucking pests; one spray of oxydemeton methyl in 1st week of September and NPV spray @ 500 LE per ha on the appearance of *Helicoverpa armigera*.

BIPM module-II

Two sprays of monocrotophos in the first fortnight of August at weekly interval as need-based application for the control of sucking pests; release of *C. carnea* @ 10,000 per ha on the appearance of sucking pests; eight releases of *T. chilonis* @ 1,50,000 per ha per week during July - October and need-based application of insecticides for the control of bollworms during September-October (Four sprays at weekly interval, with oxydemeton methyl, quinalphos, triazophos and chlorpyriphos in that order).

PAU spray schedule

Nine sprays at weekly interval, starting with monocrotophos in the first week of August, followed by monocrotophos, fenvalerate, quinalphos, oxydemeton methyl, chlorpyriphos, triazophos, chlorpyriphos and monocrotophos.

Control

Two sprays of oxydemeton methyl in the first fortnight of August at weekly interval and one spray in the first week of September as need-based application for the control of sucking pests.

Weekly observations were taken on the population of sucking pests (jassid, white fly and thrips) on 30 randomly selected plants. Bollworm damage was assessed by observing 100 randomly selected bolls at fortnightly intervals. For assessing egg parasitism, at least 25 eggs of *H. armigera* were collected and observed in the laboratory. Seed cotton yield was also recorded at the time of harvest.

The observations showed that mean populations of the cotton jassid and whiteflies were lower in PAU spray schedule than control.

The mean damage on green bolls in control was significantly higher (33.5%) than all other treatments. The lowest incidence (10.3%) was recorded in PAU spray schedule and was on par with BIPM module-II (13%), but was significantly lower than that in BIPM module-I. Per cent parasitization of the eggs of *H. armigera* was higher in biocontrol on all the dates of observation (Table 46). The natural parasitization in control was higher than that in the BIPM module and PAU spray schedule.

The cotton seed yield in PAU spray schedule (16.90 q/ha) and BIPM module-II (14.53 q/ha) were on par. The seed cotton yield in BIPM module-I was 13.03 q/ha and is on par with control. Biocontrol also helped in increasing the yield to 13.03 q/ha as against 10.4 q in control, although the difference was non-significant.

Table 46. Evaluation of BIPM on cotton

| Treatment | Mean per cent damage of green bolls | Mean per cent parasitization of *H. armigera* eggs | Yield (q/ha) |
|---|---|---|---|
| PAU spray schedule | 10.3 (17.23) | 0.8 | 16.90 |
| BIPM Module I | 18.8 (24.40) | 15.7 | 13.03 |
| BIPM Module II | 13.2 (19.81) | 1.7 | 14.53 |
| Control | 33.5 (35.26) | 9.4 | 10.40 |
| CD (P=0.05) | (4.96) | - | 2.75 |

Figures in parentheses are arc sin transformed values

**4.19.5 Standardization of release technology for *Trichogramma chilonis***

The experiment on the standardization of release technology for *T. chilonis* was conducted at the Regional Research Station, Bathinda. Three methods of release of *T. chilonis* @ 1,50,000 per week during July - October were tested. The methods tested were one hundred strips of 'tricho-cards' per ha; two hundred strips of 'tricho-cards' per ha and release of adults as 'tricho-capsules'. The plot size was 0.1 ha. The data on the incidence of bollworms was recorded at fortnightly interval. The eggs of *H. armigera* were collected to observe the per cent parasitization. The seed cotton yield was recorded on whole plot basis.

The mean damage to green bolls (16.0 to 23.0%) was lower in the release fields as compared to control (33.5%) (Table 47). The parasitization of the eggs of *H .armigera* was highest (20.7%) in the plots where adults were released. The highest yield (14.8 q/ha) was obtained from the plots where adults were released followed by 13.5 q/ha in the plots where Tricho-cards were distributed at 200 spots/ha.

**4.19.6 Parasitoids of eggs of *Helicoverpa armigera***

Eggs of *H. armigera* were collected from cotton fields in the districts of Bathinda, Mansa and Sangrur during October, 1997. The eggs were observed in the laboratory for the emergence of the parasitoids and the data showed that 25.83 and 38.0 per cent eggs were parasitized by *Trichogramma* sp. from the eggs collected from Taam Kot (Mansa) and Rampura (Bathinda).

Table 47. Evaluation of the efficacy of releasing different stages of *Trichogramma chilonis* against bollworm complex of cotton

| Method of release* | Mean per cent green bolls damaged | Per cent parasitization of *H. armigera* eggs | Yield (q/ha) |
|---|---|---|---|
| 100 strips | 23.0 | 2.7 | 12.6 |
| 200 strips | 19.0 | 5.5 | 13.5 |
| Adults | 16.0 | 20.7 | 14.8 |
| Control | 33.5 | 9.4 | 10.4 |

Three sprays of oxydemeton methyl @ 750 ml/ha were given for the control of sucking pests in all the plots on 5th, 8th August and 4th September 1997.

## 4.20 BIOLOGICAL SUPPRESSION OF TOBACCO PESTS

**Central Tobacco Research Institute, Rajahmundry**

### 4.20.1 Evaluation of *Bacillus thuringiensis* var. *kurstaki* and *Sl*NPV against *Spodoptera litura* in tobacco nursery

The experiment was laid out in a farmer's field in Morampudi commercial tobacco nursery. Commencing from fourth week after germination biopesticides were sprayed in a sequence at weekly interval on fourteen tobacco nursery beds with an area of 15 sq.m. each (*Sl*NPV 250 LE/ha followed by *B.t.k.* 1.0 kg/ha; *Sl*NPV 250 LE/ha, *B.t.k.* 1.0 kg/ha and *Sl*NPV 250 LE/ha).

Similarly the farmers' method of control was tested in fourteen tobacco nursery beds with an area of 15 $m^2$ each. The seven insecticidal sprays were given at weekly intervals commencing with monocrotophos @ 2.0 l/ha followed by monocrotophos @ 2.0 l/ha, methomyl @ 3.0 l/ha, methomyl @ 3.0 l/ha, chlorpyriphos @ 2.5 l/ha, chlorpyriphos @ 2.5 l/ha and acephate @ 1 kg/ha. Observations were recorded on number of seedlings damaged and total number of transplantable seedlings before and after each spray, in one square metre area per nursery bed (Table 48).

Sequential sprays of *Sl*NPV and *B.t. kurstaki* were statistically on par with application of chemical pesticides in case of percentage of seedlings damaged per one sq.m. area (Table 48). 35,00,000 seedlings yield was obtained in biopesticides plot whereas 32,00,000 seedlings were harvested from farmers' method.

Table 48. Management of *Spodoptera litura* with *Bacillus thuringiensis* var. *kurstaki* and *Spodoptera litura* nuclear polyhedrosis virus in tobacco nurseries

| No. of bed | Percentage seedlings damaged | | Z-value | No. of bed | Percentage seedlings damaged | | Z-value |
|---|---|---|---|---|---|---|---|
| | BIPM | Farmer's method | | | BIPM | Farmer's method | |
| 1. | 3.22 | 10.42 | -0.756 | 8. | 16.21 | 12.80 | 0.256 |
| 2. | 4.33 | 11.35 | -0.691 | 9. | 5.96 | 9.92 | -0.388 |
| 3. | 7.80 | 23.64 | 1.151 | 10. | 7.50 | 10.13 | -0.245 |
| 4. | 3.07 | 16.04 | -1.167 | 11. | 7.28 | 13.48 | -0.538 |
| 5. | 7.83 | 17.15 | -0.746 | 12. | 7.94 | 12.77 | -0.419 |
| 6. | 3.21 | 14.04 | -1.021 | 13. | 11.96 | 9.31 | 0.227 |
| 7. | 7.80 | 11.53 | -0.334 | 14. | 7.79 | 13.21 | -0.468 |

The net returns and cost-benefit ratio for BIPM were worked out at Rs.76,783 and 1:1.49 whereas the farmer's method realised a net return of Rs.55,426 with a cost-benefit ratio of 1:1.35 (Table 49).

### 4.20.2 Biointensive IPM of *Helicoverpa armigera* in planted crop

The experiment was conducted in an area of 0.5 ha each for BIPM and chemical control. Before planting tobacco two rows of marigold (*Tagetes erecta*) plants were raised to serve as trap crop for *Helicoverpa* and refuge for natural enemies. The following BIPM practices were tried.

i. 10 bird perches were erected at 30 DAP
ii. One spray of *Ha*NPV 450 LE was applied at 40 DAP
iii. Hand picking of larvae was done at 50 DAP.

The following chemical control practices were adopted:

i. One spray of endosulfan 25% 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.

Table 49. Cost-benefit ratio for management of *Spodoptera litura* in tobacco nursery

| Particulars | BIPM (Rs/ha) | Chemical control (farmers' method) (Rs./ha) |
|---|---|---|
| Cost of plant protection for *S. litura* | 3050 | 4407 |
| Cost of fungicides | 16000 | 16000 |
| Land rent | 40000 | 40000 |
| Labour charges | 85000 | 85000 |
| Fertilizers | 12500 | 12500 |
| Seedlings obtained | 3500000 | 3200000 |
| Gross returns (Av. rate of seedlings Rs.400/6000 seedlings) | 233333 | 213333 |
| Gross expenditure | 156550 | 157907 |
| Net returns | 76783 | 55426 |
| C.B. Ratio | 1:1.49 | 1:1.35 |

Observations were recorded on all 10,040 tobacco plants in 0.4 ha each in BIPM block, chemical control block and a distant farmer's check on number of larvae per plant and number of plants damaged (Table 50). Observations on number of natural enemies and number of larvae on 100 tagetes plants were also recorded in BIPM block (Table.14).

The data presented in Table 50 showed that the percentage plants infested by *H. armigera* was 0.5, 0.51 & 0.51 at 30 days, 0.8, 0.75 & 14.9 at 40 days, 1.30, 1.31 and 20.3 at 50 days in BIPM, chemical control and farmers method of control, respectively. While the population of *H. armigera* was kept under check in IPM plot by birds, natural enemies and *Ha*NPV, in chemical control insecticides at 10 days intervals helped in keeping the population at low.

*Helicoverpa* population on 100 tagetes plants at 30,40 and 50 days was more than on tobacco (Table 51), indicating that tagetes served as a trap crop and prevented *Helicoverpa* from migrating to tobacco. It also served as a reservoir of natural enemies such as preying mantids, spiders and wasps. Crows, myna and black drongo played a key role in bringing down the population of *Helicoverpa* in BIPM plot.

### 4.20.3 Evaluation of bird perches in tobacco nursery against *Spodoptera litura*

In Morampudi, in one hectare tobacco nursery 10 T - shaped bird perches made of bamboo were erected (3 ft. high). Another 10 bird perches made of dried castor plants were

Table 50. Plant damage and *Helicoverpa armigera* larval population at 50 days after planting

| Total No.of plants | Days after planting | BIPM | | Chemical control | | Farmer's method | |
|---|---|---|---|---|---|---|---|
| | | Plants damaged | No.of larvae | Plants damaged | No.of larvae | Plants damaged | No. of larvae |
| 10040 | 30 | 50(0.50) | 50 | 55(0.55) | 55 | 51(0.51) | 50 |
| | 40 | 80(0.80) | 25 | 75(0.75) | 70 | 1500(14.9) | 1300 |
| | 50 | 130(1.30) | 70 | 131(1.31) | 130 | 2040(20.3) | 2650 |

Figures in parentheses indicate % of plants damaged

Table 51. Population of *Helicoverpa armigera* and natural enemies*

| Days after | *Helicoverpa armigera* | Natural enemies | | |
|---|---|---|---|---|
| | | Preying mantis | Wasps | Spiders |
| 30 | 42 | - | - | - |
| 40 | 49 | 1 | 4 | 3 |
| 50 | 84 | 8 | 7 | 15 |

* on 100 marigold plants

erected in another one hectare area. In both the plots diurnal birds did not visit the perches because the larvae hide during day time under the tobacco canopy. However birds were actively seeking the larvae only when there was pulling of seedlings. Even this activity was discouraged when farmers sprayed chemicals immediately after each pulling to kill the exposed *S. litura* larvae. Around the nurseries several trees served as nesting and roosting places for the birds that visit the nursery. At the end of the nursery season birds like crows and myna were found feeding *S. litura* larvae crawling on the ground.

## 4.21. BIOLOGICAL SUPPRESSION OF PULSE CROP PESTS

**Acharya N.G.Ranga Agricultural University, Hyderabad**

### 4.21.1 Effectiveness of *Ha*NPV and *B.t.* formulations against *Helicoverpa armigera* in chickpea

A field trial was conducted with chickpea (var.: Annegiri) comprising 11 treatments viz., *Ha*NPV @ 250 LE/ha, *Ha*NPV @ 125 LE/ha, endosulfan (0.07%), endosulfan (0.035%), *Btk*-I, *Btk*-II, *Btt* and Dipel @ 1.0 kg/ha, *Ha*NPV @ 125 LE/ha + endosulfan (0.035%), *Ha*NPV @ 250 LE/ha + *Btk* II @ 1.0 kg/ha and control (unsprayed), replicating thrice with a plot size of 50 $m^2$. All the treatments were given in the evening hours starting from noticing the incidence of *H. armigera* in the field. Jaggery 0.5% and Ranipal 0.1% were added to *Ha*NPV before spraying. Spray application of these treatments were given for four and three rounds, respectively, starting from noticing the incidence in the experimental plots. Observations were recorded on the population of larvae and the number of pods and pods damaged by the larvae from 10 plants/treatment selected at random before and 10 days after each spray application and the yield at harvest were recorded.

Initially the larval population was very high and 10 days after first round of spraying it was significantly reduced in all the treatments (Table 52). Among the treatments, *Btk*-I, *Ha*NPV @ 250 LE/ha and endosulfan (0.07%) were found better in reducing larval population. After the subsequent two spray applications, *Btk*-I, *Btk*-II and *Ha*NPV @ 250 LE/ha were found to reduce *H. armigera* population.

With regard to the per cent pod damage, all the treatments were significantly superior to control. *Btk* I (5.21%), *Btk* II (5.25%) and *Ha*NPV @ 250 LE/ha + *Btk* I (5.02%) were found better and were on par with endosulfan.

In respect of yield, significant differences were recorded between the treatments. Highest yield was with Dipel (113.11 gm/5 plants), followed by BTK-I (85 gm/5 plants).

Considering the overall performance of the treatments, spray application of *Ha*NPV @ 125 LE/ha + endosulfan 0.035% was found to be superior in all respects. Among the *Bt* formulations, Dipel and *Btk*-II at 1.0 kg/ha were found to be the best.

**Punjab Agricultural University, Ludhiana**

### 4.21.2 Biocontrol based management of pod borer complex on pigeon pea

The experiment on the management of pod borer complex was conducted in farmer's field at Boparai (Ludhiana). The experiment was conducted in a randomized block design with four replications and a plot size of 100 $m^2$. Different combinations of *Ha*NPV, *Bacillus thuringiensis* (*Bt*), Neem seed kernel extract (NSKE) and an insecticide (endosulfan) were tested. First spray was given at flower initiation and subsequent three sprays were given at 10 days interval except in endosulfan, where 3 sprays were given at 15 days interval. The data on the pod damage was recorded on the basis of 10 plants in each plot near maturity. The data on the seed yield was recorded on whole plot basis.

All the treatment combinations except NSKE-*Bt*-*Ha*NPV *Bt* showed significantly lower pod damage (Table 53). The lowest damage (5.9%) was recorded with 3 sprays of endosulfan. Among different biocontrol combinations, the lowest damage (11.6%) was recorded in plots where alternate sprays of *Bt* and *Ha*NPV were given but it was on par with the remaining combinations except NSKE-*Bt*-*Ha*NPV-*Bt*. The yield was significantly higher than control in all the treatments except NSKE-*Bt*-*Ha*NPV-*Bt*. The highest yield (14.32 q/ha) was obtained from the plots treated with endosulfan and on par with all other treatments except NSKE-*Bt*-*Ha*NPV-*Bt*.

Table 52. Effect of microbial agents against *Helicoverpa armigera* in chickpea

| Treatment | Pretreatment larval population per 5 plants | Mean larval population per 10 plants (10 days after spray) | | | Mean pod damage(%) | Yield for 5 plants |
|---|---|---|---|---|---|---|
| | | I | II | III | | |
| *Ha*NPV @ 250 LE/ha | 7.67 | 5.00(12.56) | 12.67(20.69) | 7.33(15.60) | 9.08(17.45) | 70.00 |
| *Ha*NPV @ 125 LE/ha | 6.00 | 5.60(12.51) | 15.00(22.75) | 4.67(12.46) | 8.91(17.29) | 70.00 |
| Endosulfan 0.07% | 6.67 | 5.00(12.88) | 7.30(15.60) | 4.67(12.28) | 5.9(13.94) | 71.67 |
| Endosulfan 0.035% | 6.00 | 6.33(14.53) | 7.00(15.17) | 4.00(11.32) | 5.63(12.93) | 58.33 |
| *Btk*-I @ 1 kg/ha | 9.00 | 5.33(13.27) | 4.30(11.75) | 2.00(7.95) | 5.23(13.19) | 85.00 |
| *Btk*-II @ 1 kg/ha | 7.00 | 5.67(13.75) | 4.00(11.28) | 4.30(11.89) | 5.21(13.02) | 70.00 |
| *Btt* @ 1 kg/ha | 7.67 | 7.67(16.07) | 6.30(14.51) | 10.67(18.45) | 8.39(16.73) | 58.33 |
| Dipel @ 1kg/ha | 6.67 | 8.33(16.45) | 7.30(15.65) | 8.00(16.36) | 6.90(15.24) | 113.33 |
| *Ha*NPV @ 125 LE/ha +endosulfan 0.035% | 7.67 | 8.00(16.37) | 8.67(17.11) | 6.00(13.91) | 5.65(13.71) | 78.33 |
| *Ha*NPV @ 250 LE/ha + *Btk*-II @ 1 kg/ha | 10.67 | 6.0(14.07) | 10.33(18.47) | 4.3(11.89) | 5.02(12.85) | 73.33 |
| Control | 11.00 | 16.00(23.29) | 18.67(25.60) | 11.67(19.96) | 13.86(21.82) | 26.67 |
| CD (P=0.05) | 4.42 | 4.65 | 3.82 | 4.24 | 3.20 | 28.34 |

**Tamil Nadu Agricultural University, Coimbatore**

4.21.3 Effect of *Bt* formulations against pod borers in pigeonpea

A field experiment was conducted with pigeonpea (var.Co5) with five *Bt* formulations, endosulfan 0.07% and a control. The results (Table 54) indicate that all the *Bt* formulations tested were superior to control but were on par with endosulfan (0.07%) in respect of pod borer incidence at 105-140 days after sowing whereas there was no significant difference at 79-90 days. Endosulfan applied plot recorded higher yield followed by Biobit and *Btk* which were on par.

Table 53. Efficacy of different combinations of biopesticides for the control of pod borer complex of pigeon pea

| Treatment* | Mean pod** infestation (%) | Grain yield (q/ha) |
|---|---|---|
| *Bt-Ha*NPV-*Bt-Ha*NPV | 11.6(19.79) | 12.91 |
| *Bt-Ha*NPV-endosulfan-*Bt* | 13.3(21.01) | 12.44 |
| Endosulfan-*Bt-Ha*NPV-*Bt* | 16.6(23.96) | 11.54 |
| NSKE-*Bt-Ha*NPV-*Bt* | 19.9(26.41) | 8.58 |
| Endosulfan | 5.9(13.97) | 14.32 |
| Control | 24.1(29.34) | 8.09 |
| CD (P=0.05) | (4.58) | 3.05 |

* Four sprays at 10 days interval except endosulfan treatment in which 3 sprays at 15 days interval were given at flower initiation on 13.10.1997.

** Five days after last spray; Mean of 4 replications.

Dosages: *Ha*NPV=1.5x10$^{12}$ POB/ha, *Bt* (Dipel 8 L)=1.0 l/ha, Endosulfan=350g a.i/ha and NSKE=5%

4.21.4 **Effect of *Trichogramma chilonis* and *Ha*NPV on *Heliothis armigera* on pigeonpea**

A field experiment was laid out during summer 1997 with the following treatments on pigeonpea (var. Co 5).

i. *T. chilonis* released three times at 1,00,000/ha
ii. *T. chilonis* released three times at 50,000 /ha
iii. Spraying two rounds of *Ha*NPV at 250 LE/ha
iv. Spraying two rounds of *Ha*NPV at 125 LE/ha

v. Spraying *Ha*NPV at 125 LE and releases of *T. chilonis* at 50,000/ha
vi. Endosulfan spraying (two rounds)
vii. Control

The plots treated with *T. chilonis* either at 1,00,000 (or) 50,000 and plot sprayed with *Ha*NPV at 250 or 125 LE/ha were superior to control at 150 DAS but on par with endosulfan applied on 120 and 140 DAS. All the biocontrol plots were better than insecticide applied and control plots (Table 55). However, endosulfan treated plot recorded the highest yield and was superior to other treatments.

Table 54. Evaluation of *Bacillus thuringiensis* formulations against *Helicoverpa armigera* in pigeonpea

| Treatments | Live larvae | Pod borer damage (%)-day after sowing | | | | Yield kg/ha |
|---|---|---|---|---|---|---|
| | | 90 | 105 | 120 | 140 | |
| Bio Bit (1.0 kg/ha) | 0.7 | 2.6 | $3.1^{c}$ | $7.40^{b}$ | $17.10^{b}$ | $393^{d}$ |
| Delfin (1 kg/ha) | 1.1 | 2.8 | $4.9^{b}$ | $8.80^{b}$ | $16.3^{bc}$ | $360^{c}$ |
| Dipel (1 kg/ha) | 0.8 | 2.6 | $5.7^{bc}$ | $8.40^{b}$ | $17.6^{b}$ | $325^{b}$ |
| Agree (1 kg/ha) | 0.9 | 2.9 | $5.4^{bc}$ | $7.1^{b}$ | $18.9^{b}$ | $358^{c}$ |
| BTK (1 kg/ha) | 0.9 | 3.1 | $6.2^{b}$ | $9.0^{b}$ | $14.7^{bc}$ | $422^{d}$ |
| Endosulfan 0.07 | 0.8 | 3.0 | $6.3^{b}$ | $8.0^{b}$ | $12.3^{c}$ | $508^{e}$ |
| Control | 1.2 | 3.0 | $12.5^{a}$ | $27.8^{a}$ | $28.8^{a}$ | $253^{a}$ |

Table 55. Evaluation of biocontrol agents against *Helicoverpa armigera* on pigeonpea

| Treatments | Live larvae | Pod borer damage (%)-day after sowing | | | | Yield kg/ha |
|---|---|---|---|---|---|---|
| | | 90 | 105 | 120 | 140 | |
| *T. chilonis* 1.0 lakh/ha | $0.37^{ab}$ | $1.53^{d}$ | $3.33^{c}$ | $5.43^{c}$ | $18.20^{b}$ | $362^{cd}$ |
| *T. chilonis* 0.5 lakh/ha | $0.20^{b}$ | $1.83^{cd}$ | $4.13^{c}$ | $8.70^{cd}$ | $14.93^{cd}$ | $337^{c}$ |
| *Ha*NPV 250 LE/ha | $0.60^{ab}$ | $2.53^{cd}$ | $4.57^{c}$ | $8.47^{cd}$ | $16.73^{bc}$ | $310^{bc}$ |
| *Ha*NPV 125 LE/ha | $0.83^{a}$ | $2.97^{bc}$ | $4.83^{c}$ | $9.73^{c}$ | $19.37^{b}$ | $267^{ab}$ |
| *Ha*NPV 125 LE + 0.5 lakh *T. chilonis* | $0.67^{ab}$ | $3.77^{b}$ | $8.20^{b}$ | $12.83^{b}$ | $19.67^{b}$ | $412^{d}$ |
| Endosulfan 0.07 | $0.30^{ab}$ | $1.77^{cd}$ | $3.43^{c}$ | $7.33^{d}$ | $12.67^{d}$ | $507^{e}$ |
| Control | $0.90^{a}$ | $8.47^{a}$ | $11.17^{a}$ | $20.00^{a}$ | $25.00^{a}$ | $243^{a}$ |

Figures with the same superscript are not significantly different

## 4.22 BIOLOGICAL SUPPRESSION OF RICE PESTS

### Assam Agricultural University, Jorhat

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

The experiment was conducted during rabi 1997 in farmers' field at Kakajan (Assam). The inundative releases of *T. japonicum* and *T. chilonis* were made @ 50,000/ha/week.

The parasitoids were released 30 days after transplanting. The observations on dead hearts were taken at seven days interval and a pre-harvest count of white ear head was taken to assess the infestation of stem borer in the advanced stage of the crop. The dead heart per cent was lowest (2.63) at five weeks after release, in *T. japonicum* + insecticide treatment, followed by that in *T. japonicum* released plot (3.62) (Table 56 & 57). The white ear head formation was 2.44% in *T. japonicum* released plot against 5.89% in the unreleased plot.

Table 56. Evaluation of *Trichogramma japonicum* against yellow stem borer of rice

| Treatment | Pre-released dead heart(%) | % Dead heart at weekly intervals | | | | | White ear head (%) |
|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | |
| *T. japonicum* | 13.80 | 10.47 | 4.49 | 5.93 | 5.50 | 3.62 | 2.44 |
| *T. japonicum* + insecticide | 14.30 | 14.12 | 4.76 | 7.61 | 4.07 | 2.63 | 3.86 |
| Insecticide | 14.78 | 18.05 | 9.07 | 11.72 | 7.43 | 9.70 | 4.86 |
| Control | 18.00 | 18.05 | 15.90 | 14.28 | 10.58 | 12.90 | 5.89 |

The per cent dead heart was lowest (1.04) at five weeks after release in *T. chilonis* released plot (Table 57), followed by that in *T. chilonis* + insecticide treated plot (1.62).

Table 57. Evaluation of *Trichogramma chilonis* against and *Scirpophaga incertulas*

| Treatment | Per cent dead heart at weekly intervals (after release) | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| *T. chilonis* | 4.26 | 1.77 | 1.64 | 2.08 | 1.04 |
| Insecticide + *T.chilonis* | 4.35 | 1.74 | 1.60 | 1.69 | 1.62 |
| Insecticide | 4.58 | 2.55 | 4.46 | 6.57 | 2.24 |
| Control | 5.98 | 3.41 | 3.94 | 8.49 | 2.99 |

### 4.22.2 Field evaluation of *Trichogramma japonicum*, *T. chilonis* and *Bacillus thuringiensis* against rice stem borer and leaf folder

This experiment was conducted in farmers' field at Kakajan during Kharif 1997. In this experiment *T. japonicum* @ 50,000/ha and *T. chilonis* @ 50,000/ha were simultaneously released at weekly intervals. The releases of the two species of *Trichogramma* were also made @ 1,00,000/ha simultaneously at weekly intervals. *Bt* application (Delfin) against leaf folder and a need based spray of insecticide were also given. The dead heart per cent was lowest (2.59) at two weeks after release of T. japonicum + T. chilonis @ 1,00,000 / ha followed by T. japonicum + T. chilonis @ 50,000 / ha (2.70). Dead heart per cent ranged from 4.96 to 6.30% in the unreleased plot (Table 58 & 59). There was no difference between the release rates 50,000/ha and 1,00,000/ha in checking the dead heart. The infestation of leaf folder during *Kharif* 1997 was very low in the control plot and hence no difference could be detected between released and unreleased plots.

Table 58. Evaluation of integrated use of *Trichogramma japonicum* and *T. chilonis* against rice stem borer

| Treatment | Pre-released percent of dead heart | Mean infestation (% Dead heart at weekly intervals | | | | White ear heads (%) |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | |
| *T. japonicum* + *T. chilonis* @ 50,000/ha | 2.43 | 2.89 | 2.70 | 2.96 | 2.99 | 5.21 |
| *T. japonicum* + *T. chilonis* @ 1,00,000/ha | 3.28 | 2.82 | 2.59 | 2.85 | 3.15 | 4.70 |
| Need based insecticide application | 3.37 | 2.79 | 2.72 | 3.89 | 3.01 | 4.40 |
| Control | 4.87 | 6.30 | 6.20 | 6.28 | 4.96 | 6.18 |
| CD (P=0.05) | 1.26 | 1.35 | 0.94 | 1.26 | 0.81 | 0.83 |

### 4.22.3 Field recoveries of *Trichogramma japonicum*

To study the field recovery of *T.japonicum* adult moths of yellow stem borer were collected and used to obtain egg masses. The egg masses along with the leaves were stapled on the leaves of rice plants in the parasitoid released plots. The egg masses were allowed to remain in the field for 24 h for parasitisation. The egg masses were then kept in the laboratory for the emergence of parasitoid. The percent recovery of *T. japonicum* during kharif season was 30%.

Table 59.Evaluation of *Trichogramma japonicum*, *T. chilonis* and *Bacillus thuringiensis* against rice leaf folder

| Treatment | Pre-released percent of LFDL | Mean infestation (% LFDL) at weekly interval | | | | White ear heads (%) |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | |
| *T. japonicum* + *T. chilonis* @ 50,000/ha | 2.94 | 2.89 | 2.50 | 2.75 | 2.32 | 4040 |
| *T. japonicum* + *T. chilonis* @ 1,00,000/ha | 3.28 | 2.82 | 2.49 | 2.90 | 3.11 | 3820 |
| *Bt* (Delfin) | 3.81 | 3.34 | 3.26 | 2.33 | 2.34 | 3845 |
| Insecticide protection | 3.37 | 3.04 | 2.41 | 3.49 | 2.75 | 3860 |
| Control | 4.00 | 2.94 | 3.17 | 3.36 | 2.86 | 3510 |
| CD (P=0.05) | NS | NS | NS | 0.76 | NS | - |

(LFDL : Leaf folder damaged leaves)

**4.22.4 Evaluation of Biocontrol based IPM**

The evaluation of BIPM in rice was conducted during kharif 1997 in farmer's field at Kakajan. The release of *Trichogramma* @ 50,000/ha could check the formation of dead hearts (Table 60 & 61). The percentage of dead hearts was 3.21% in the released plot against 6.03% in the control plot, which was effective in the 4th week after the field release of the parasitoid. The white ear head population was also lower in the released plot (4.23) than in the control plot (7.99%). The leaf folder population during *Kharif* 1997 was very low (below 5%). Hence BIPM could not be evaluated against rice leaf folder.

Table 60. Effect of biocontrol based IPM on the incidence of rice stem borer

| Treatment | Pre-release percent of dead heart | Mean percent Dead heart at weekly interval | | | | % White ear heads |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | |
| Biocontrol | 4.58 | 3.39 | 6.15 | 3.21 | 3.50 | 4.23 |
| Chemical Control | 4.10 | 5.94 | 6.46 | 4.31 | 4.86 | 5.86 |
| Control | 6.03 | 5.77 | 7.70 | 6.73 | 5.97 | 7.99 |
| CD (P=0.05) | NS | 0.71 | NS | 0.64 | 1.67 | 1.35 |

Table 61. Effect of biocontrol based IPM on the incidence of leaf folder

| Treatment | Pre-released percent of LFDL | Mean percent of LFDL at weekly intervals | | | | Yield (kg/ha) |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | |
| Biocontrol | 2.75 | 3.63 | 2.38 | 1.89 | 1.40 | 4031 |
| Chemical control | 3.23 | 3.50 | 2.47 | 1.53 | 1.33 | 3925 |
| Control | 4.11 | 3.83 | 3.12 | 2.27 | 2.36 | 3813 |
| CD (P=0.05) | 0.97 | NS | 0.41 | NS | 0.30 | - |

**4.22.5 Survey and quantification of natural enemy complex in rice**

Weekly observations were taken at three locations (Research Farm, Kakajan and Charingia) on the population build up of natural enemies of rice insect pests. The observations were recorded from tillering stage (first week of August) to grain ripening stage (second week of November). Population of spiders, insect predators and parasitoids (Hymenoptera, Odonata, Coleoptera, Diptera, Orthoptera and Dictyoptera) were recorded once a week from selected paddy fields by visual and sweep net methods. The collected spiders/other predators were identified and preserved (Table 62).

Table 62. List of natural enemies recorded from the rice ecosystem of Jorhat district

| Natural enemy | Abundance | Period of activity |
|---|---|---|
| Spider | | |
| *Lycosa pseudoannulata* (Lycosidae:Araneae) | **** | Kharif season |
| *Tetragnatha* sp. (Tetragnathidae:Araneae) | **** | Kharif season |
| *Oxyopes shweta* (Oxyopidae:Araneae) | **** | Kharif season |
| *Zygoballua pashanensis* (Salticidae:Araneae) | *** | Kharif season |
| *Neoscona theisi* (Araneidae:Araneae) | ** | 1st to 3rd week of October |
| *Argiope catenulata* (Araneidae:Arancae) | * | 2nd to 4th week of September |
| Hymenoptera (12) | | |
| *Cotesia flavipes* (Braconidae) | *** | 2nd week of August to 2nd week of Sept. |

| | | |
|---|---|---|
| *Tetrastichus* sp. (Eulophidae) | **** | 4th week of August to 1st week of October |
| *Telenomus* sp. (Scelionidae) | **** | 4th week of August to 1st week of October |
| Odonata (8) | | |
| *Agriocnemis pygmaea* (Coenagrionidae) | *** | Kharif season |
| *A. famina famina* (Coenagrionidae) | *** | Kharif season |
| Coleoptera (7) | | |
| *Coccinella transversalis* (Coccinellidae) | *** | Kharif season |
| *Cheilomenes sexmaculata* (Coccinellidae) | *** | Kharif season |
| *Illeis confusa* (Coccinellidae) | * | 2nd-4th week of August |
| *Oenopia* sp. (Coccinellidae) | * | 2nd - 3rd week of August |
| *Micraspis discolor* (Coccinellidae) | **** | 2nd week of August<br>2nd week of September |
| *Harmonia octomaculata* (Coccinellidae) | ** | 3rd week of August to 1st week of sept. |
| Indet. beetle (Staphylinidae) | *** | 4th week of August to 3rd week of sept. |
| Orthoptera (1) | | |
| *Conocephalus longipennis* (Tettigoniidae) | ** | 2nd - 4th week of August |

| | | |
|---|---|---|
| Dictyoptera (1) | | |
| *Mantis religiosa* | ** | 4th week of August to 2nd week of sept. |

**** Highly abundant; *** Moderately abundant; ** Less abundant; * Rare

**Kerala Agricultural University, Vellanikkara**

**4.22.6 Survey and quantification of natural enemy complex in rice**

In Thrissur district two locations were chosen for the study. From each location two 20 cent plots were identified for taking observations. Survey was made on natural enemies at weekly intervals. Common natural enemies collected were coccinellid beetles, carabids, mirid bugs, ichneumonids, chalcids, spiders, damsel flies, etc. High level of parasitism was observed on the stem borer egg masses collected from the field. Predominant parasitoids which emerged from the egg masses were *Tetrastichus schoenobii* and *Telenomus rowani*.

**Punjab Agricultural University, Ludhiana**

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

The experiment for the evaluation of *T. chilonis* and *T. japonicum* against rice stem borer and leaf folder was conducted at farmer's field at Khudi Kalan (Sangrur). Simultaneous releases of *T. chilonis* + *T. japonicum* were made at 20 DAT (days after transplanting) at three dosages, i.e. 50,000, 75,000 and 1,00,000 per ha at seven 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 the plot. The yield was recorded on whole plot basis.

The per cent leaves folded was significantly lower than control (23.2%) in all the treatments except at the lowest dose (50,000/ha) of the parasitoid (Table 63). The per cent dead hearts was lowest (1.5%) in the highest dose (1,00,000/ha) of the parasitoids and it was significantly lower than control (6.6%) and the lowest dose (50,000/ha) of the parasitoids. The per cent of white ears in control (19.0%) was significantly higher than all the treatments except

the lowest dose of the parasitoid. All the treatments gave significantly higher yield than control (39.94 q/ha). The highest yield (64.76 q/ha) was obtained from the plots where the parasitoids were released @ 1,00,000 per ha.

Table 63. Effectiveness of Trichogramma chilonis and T. japonicum for the control of leaf folder and stem borer at Barnala (Sangrur)

| *T. chilonis* + *T. japonicum* (Dosage/ha)* | Per cent leaves damaged | Per cent dead hearts | Per cent white ears | Yield (q/ha) |
|---|---|---|---|---|
| 1,00,000 | 6.2(14.38) | 1.5(7.60) | 3.3(10.49) | 64.76 |
| 75,000 | 12.8(20.96) | 4.0(11.54) | 9.0(17.49) | 50.69 |
| 50,000 | 18.4(25.44) | 6.6(14.82) | 15.0(22.82) | 44.62 |
| Insecticidal spray** | 7.0(15.30) | 2.8(9.63) | 3.7(11.08) | 62.41 |
| Control | 23.2(28.81) | 6.6(14.83) | 19.0(25.85) | 39.94 |
| CD(P=0.05) | (6.35) | (6.04) | (4.83) | 4.64 |

* Nine releases were made at weekly interval, 20 days after transplanting

** One spray of Monocil 36 SL(Monocrotophos) @ 1.4 litre/ha(Aug.29,1997)

**Tamil Nadu Agricultural University, Coimbatore**

### 4.22.8 Studies on the effect of release of *Trichogramma japonicum* and *T. chilonis* against stem borer and leaf folder

A field trial was laid out with the following treatments for the control of stem borer and leaf folder.

i. *T. japonicum* releases @ 1,00,000 parasitoids/ha thrice at weekly interval commencing the first release on noticing yellow stem borer activity and spraying of *B.t.* @ 1.0 kg/ha

ii. *T. chilonis* releaed thrice at weekly interval @ 1,00,000 parasitoids/ha on noticing leaf folder moth activit and spraying of B.T. at 1.0 kg/ha

iii. *T. chilonis* and *T. japonicum* released thrice at weekly intervals @ 1,00,000 parasitoids/ha on noticing leaf folder and stem borer moth activitiy and spraying *Bt* at 1.0 kg/ha.

iv. Need based chemical protection

v. Control

**Table 64. Evaluation of *Trichogramma* spp. and *Bacillus thuringiensis* against rice* pests**

| Treatments | Stem borer (%) | | | Leaf folder (%) | | | Grain Yield Kg/ha |
|---|---|---|---|---|---|---|---|
| | 25 DAT | 40 | 90 | 40 DAT | 55 | 75 | |
| *Trichogramma japonicum* + *B.t.* | 4.23$^{c}$ | 3.80$^{c}$ | 5.35$^{b}$ | 1.73$^{b}$ | 3.05$^{b}$ | 4.28$^{a}$ | 2055$^{a}$ |
| *T. chilonis* + *B.t.* | 4.83$^{c}$ | 5.70$^{b}$ | 5.28$^{b}$ | 1.35$^{b}$ | 4.93$^{a}$ | 3.33$^{ab}$ | 2076$^{a}$ |
| *T. japonicum*, *T. chilonis* + *B.t.* | 4.70$^{c}$ | 5.68$^{b}$ | 3.60$^{c}$ | 1.38$^{b}$ | 5.73$^{a}$ | 2.18$^{b}$ | 1868$^{a}$ |
| Chemical protection (Need based) | 6.83$^{b}$ | 7.60$^{a}$ | 7.38$^{a}$ | 2.30$^{b}$ | 5.45$^{a}$ | 3.23$^{ab}$ | 1923$^{a}$ |
| Control | 9.70$^{a}$ | 9.38$^{a}$ | 8.48$^{a}$ | 4.20$^{a}$ | 6.03$^{a}$ | 3.93$^{a}$ | 1777$^{a}$ |

*variety used was ASD 18

### 4.22.9 Evaluation of biocontrol based IPM in Rice

A field trial was conducted with var. ADT 36 using the following treatments in Rabi 1997.

1. Biocontrol plot - Release of 50,000 *Trichogramma*/ha at weekly interval commencing with moth activity (6 releases).

2. Chemical control - spraying endosulfan (0.07%)

3. Control

*Trichogramma* released plot recorded significantly lower incidence of stemborer in terms of dead heart on 45th day and white ear on 90th and 110th day and was better than endosulfan treated plot. Leaf folder incidence on 75th day in endosulfan treated plot and *Trichogramma* released plot were less than control. These plots gave significantly higher yield (3918 and 3412 kg, respectively) than control plot (2812 kg).

### 4.22.10 Survey and quantification of natural enemy complex

A plot of 20 cent area of rice (var. ADT 36) was fixed and samples of insects were collected at weekly interval in four subplots with 5 double sweeps in each sub plot using sweep net. Egg masses of rice yellow stem borer were also collected and parasitisation was recorded.

Phytophagous insects (46.28% ± 7.88), predators (35.37% ± 7.56), parasitoids (7.79% + 4.24) and scavengers and tourists (10.56%) were collected from these plots. The phytophages included earhead bugs, leafhoppers, stemborer and leaf folders as major pests; the predators included spiders and coccinellids as major fauna; parasitoids comprised *Tetrastichus, Telenomus, Xanthopimpla, Temelucha, Amauromorpha, Itoplectis, Cotesia, Opius, Phanerotoma, Stenobracon* and *Argyrophylax*.

## 4.23 BIOLOGICAL SUPPRESSION OF COCONUT PESTS

**Central Plantation Crops Research Institute, Kayangulam**

### 4.23.1 Field evaluation of *Apanteles taragamae* against *Opisina arenosella*

Culture of the early larval parasitoid *A. taragamae* was maintained in the laboratory. One hundred leaflet samples were collected every month from *Opisina* infested palms and the seasonal occurrence of the early larvae, the parasitoid and hyperparasitoids were recorded. The pest occurred almost throughout the year and early larvae were present in the field during April, June, August, November and December. Maximum field parasitism recorded was 53.3%.

### 4.23.2 Seasonal incidence of baculovirus, green muscardine fungus and bacteria on grubs of *Oryctes rhinoceros*

*Oryctes* grubs were collected from five locations, viz., Alappuzha, Ayiramthengu, Krishnapuram, Purakkadu and Thodiyur at regular intervals for assessing the natural incidence of the pathogens. Ten per cent of the grub population showed infection by baculovirus, 21% by green muscardine fungus and 28% by bacteria.

## 4.24 BIOLOGICAL SUPPRESSION OF FRUIT CROP PESTS

**Indian Institute of Horticultural Research, Bangalore**

### 4.24.1 Survey for the natural enemics of spiralling whitefly

Surveys were conducted in Bangalore (Karnataka), Coimbatore and Dharmapuri (Tamil Nadu) districts during 1997 for the natural enemies. The collection yielded only predators which included *Axinoscymnus puttarudriahi, Cryptolaemus montrouzieri, Mallada astur, Chilocorus nigrita* and *Cheilomenes sexmaculata* in all these locations. An entomo-pathogenic fungus *Paecilomyces farinosus* was isolated. The pathogenicity tests conducted against the nymphs and adults proved positive.

### 4.24.2 Predatory potential and development of *Mallada astur* on spiralling whitefly

Larvae of *M. astur* were collected on guava plants infested with spiralling whitefly. They were cultured on rice moth in the laboratory for further studies. The freshly laid eggs of *M. astur* were collected and kept in plastic jars. On hatching the larvae were transferred individually to small vials. One batch of ten larvae was fed individually with rice moth eggs. Another batch of 10 larvae was offered fresh nymphs of spiralling whitefly until pupation.

Larval development of *M. astur* was calculated instarwise and prey (nymph) consumption by *M. astur* was also computed instar wise. The number of nymphs of spiralling whitefly consumed during first, second and third instars of the predator averaged 60.20, 36.40 and 138.30, respectively. Third instar larvae of *M. astur* were more voracious and very active. A total of 234.90 whitefly nymphs were consumed by a single predator larva during its development (Table 65). A total of 13.5 days was required to complete the larval development on rice moth whereas it took longer (16.1 days) on spiralling whitefly.

### 4.23.3 Population dynamics of spiralling whitefly and its natural enemies on guava

Observations were recorded at fortnightly interval on guava trees located at Hebbal. Sampling was done on four shoots of 30 cm length each. The leaves (6th to 10th terminal leaves) were collected and the samples brought to the laboratory. The number of nymphs and adults present on the leaves were counted. Incidence of predators (larvae, pupae, adults) were recorded directly in the field on four shoots of 30 cm length on each tree. The samples (4 shoots/tree) were also collected and kept in cloth walled wooden cages (30 x 30 x 30 cm) to record the emergence of natural enemies.

Table 65. Comparative development and predatory potential of *Mallada astur* on *Corcyra* eggs and spiralling whitefly

| Larval instar | Duration of development (days) | | Number of whiteflies consumed |
|---|---|---|---|
| | Rice moth | Spiralling whitefly | |
| I | 5.09 ± 0.39 | 5.40 ± 9.42 | 60.20 ± 10.24 |
| II | 3.40 ± 0.26 | 2.80 ± 0.24 | 36.40 ± 3.40 |
| III | 6.80 ± 0.72 | 5.30 ± 0.62 | 138.30 ± 11.34 |
| Total | 16.10 ± 0.80 | 13.50 ± 0.71 | 234.90 ± 12.54 |

Whiteflies were found to be abundant during April-June'97 and declined subsequently. The population of whitefly was found to be very low during October-December. Six predators were encountered during April-December, out of which only *Crypiolaemus montrouzeri* and *Mallada astur* were associated with the spiralling whitefly for a longer time.

### 4.23.4 Studies on the egg parasitoids of pomegranate butterfly, *Deudorix isocrates*

At IIHR farm, pomegranate orchards were monitored for the incidence of *D. isocrates* and its natural enemies. A total of 647 eggs of *D. isocrates* was collected from June to November. The collection of eggs yielded *Telenomus* sp. (Hymenoptera : Scelionidae) and *Ooencyrtus papilionis* (Hymenoptera : Encyrtidae). The laboratory hosts like *Corcyra cephalonica, Helicoverpa armigera, Spodoptera litura, Phthorimaea operculella* and *Chilo partellus* were exposed to both the parasitoids, which failed to parasitise these. *O. papilionis* and *Telenomus* sp. were found to complete the development in 12-14 days on the eggs of *D. isocrates*. On one occasion, *Telenomus* sp. collected from *D. isocrates* also completed development on the eggs of citrus butterfly *Papilio demoleus* in the laboratory. In another preliminary study, the eggs of *D. isocrates* were exposed to *Trichogramma chilonis*. The parasitoid successfully completed the development on *D. isocrates* in 10 days. The studies indicated that *T. chilonis* could be utilised for trials against pomegranate butterfly.

**Dr. Y. S. Parmar University of Horticulture and Forestry, Solan**

### 4.23.5 Seasonal abundance of woolly apple aphid in relation to natural enemies

Seasonal abundance of the woolly apple aphid was monitored throughout the year at weekly intervals along with natural enemy activity and meteorological data at Solan. From

January to first week of May, mean colony count (0.1 - 1.2) and coverage of the aphid (0.05 - 0.42 cm) remained low. The activity of predators began by the last week of March, but was negligible up to third week of May due to low population of the host insect. The activity of *Aphelinus mali* became evident in first week of May. During this period, maximum and minimum temperature, relative humidity and rainfall were 14.5 - 27.7°C, 1.5 - 15.2°C, 42.7 - 69.9% and 343.3mm (30% of the rain-fall), respectively. Increase in colony count was noticed in May-June and it varied from 1.1 - 7.8 colonies with a coverage of 0.7 - 2.6 cm/ replicate during May - August-end. *A. mali* activity, though low, persisted consistently (0.1 - 1.4 mummies / replicate) from May to December. Low activity of predators (mainly chrysopids) also was seen in June-July. May-August segment of the year received high rainfall (587.6 mm out of 1143 mm recorded up to December 25, 1997; 51.4%) but even then there was increase in aphid population. Maximum and minimum temperature and relative humidity were 27.7 - 31.6°C, 15.2 - 21.4°C and 35.3 - 86.4%, respectively. In September-October, population remained subdued (usually <1 colony/replicate and coverage <0.4cm). Again in November, there was slight increase in aphid population (1.1 - 2.1 colonies, 0.3 - 0.5 cm coverage) when maximum and minimum temperature declined (21.1 - 16.0° and 7.9 - 1.4°C) and RH was 57.6 - 74%. Mummified aphid count was also low (<0.4 mummies/replicate).

Survey carried out in June 1997 in Kinnaur revealed low *A. mali* activity at a few sites in Rekong Peo (2250 m altitude) and at Koopa (2400 m) in Sangla valley.

### 4.23.6 Seasonal incidence of San Jose scale in relation to natural enemies

The samples of twigs regularly collected from apple orchards at Nauni, Solan showed parasitization by *Aphytis* sp. *proclia* group from 0 to 17.1% with a mean of 4.5%. Parasitization by *Encarsia perniciosi* was low (0 - 11.4%, mean 1.5%). Predatory coccinellids, primarily *Chilocorus bijugus*, were quite active and removed 73.8 - 93.2% population of the scale on some trees in the orchard where last year *C. bijugus* was released. It comprised 81.8% of the beetle population while *Pharoscymnus flexibilis* and *Sticholotis marginalis* were 10.9 and 7.3%. Mean population of beetles per young plant (2-year-old) was 0.9 during July to December, 1997, the maximum being 6.7 in August. Larvae of *C. bijugus* were present on infested plants during mid-July to third week of August only. No adult could be intercepted on plants under observation after mid-December. Even on plants having high predator activity, parasitization of *Aphytis* existed.

The samples of scale infested twigs collected from apple orchards in Sirmaur district (Dhamla and Habban) had parasitization by *Aphytis* (0 - 2.9%) only while in samples brought from Shimla district (Kotkhai and Jubbal), it was 0 - 2.3% by *Aphytis* and 0 - 1.7% by *Encarsia*. In Shimla district, although no coccinellid was encountered on twigs, 15.9 - 84.7% scale insects appeared damaged by the predators. In Kulu, parasitization by *Aphytis* and *Encarsia* was 8.6 and 4.3%, respectively.

**Kerala Agricultural University, Vellanikkara**

**4.23.7 Survey for the natural enemies of spiralling whitefly**

Survey for the natural enemies of spiralling whitefly (*Aleurodicus dispersus*) on guava and vegetables yielded *Encarsia* sp. and predatory coccinellid beetles.

**S.K.University of Agricultural Sciences and Technology, Shalimar**

**4.23.8 Incidence of San Jose scale and its natural enemies**

Five orchards at Anantnag, Srinagar, Budgam and Pulwama districts were selected and observations taken on the incidence of the pest and its natural enemies. These twigs were brought to the laboratory and observed for population count/cm$^2$ and for per cent parasitization. Infestation of the trees by the San Jose scale was 14 - 27% at Pulwama, 26 - 33% at Budgam, 25 - 32% at Srinagar and 18 - 33.5% at Anantnag. The population count/cm$^2$ varied from place to place and was 110 during first flush and 120 maximum during second flush. Similarly the parasitization was in the range of 3% to 6.5% during first flush and 3.5% to 6.5% during second flush.

The natural enemies recorded from these areas were *Encarsia* sp., *Aphytis* sp. *Chilocorus bijugus* and *Coccinella* sp.

The parasitism in all the locations was in the range of 3.0 - 6.5 per cent. It may be added that the occurrence of *Encarsia* sp. was more in Khanda, Beerwah and Wadwan (Budgam), Shopian and Awantipur (Pulwama) whereas *Aphytis* sp. was rare.

Among the predators, *C. bijugus* was dominant. At Wadwan (Budgam) predator population of 15/branch was found during October.

**4.23.9 Incidence of *Eriosoma lanigerum* and its natural enemies**

A neglected orchard was taken to record the woolly apple aphid and its parasitoids around Srinagar. The aphid was recorded during March but with no natural enemy. Parasitism was observed from April onwards and ranged between 7.9 to 23.2% with a peak in September. During October the parasitism was low due to low temperature caused by rains and in the 1st week of November, the pest disappeared.

## 4.24 BIOLOGICAL SUPPRESSION OF VEGETABLE CROP PESTS

### Indian Institute of Horticultural Research, Bangalore

#### 4.24.1 Survey for natural enemies of vegetable crop pests

During a regular survey for collection of natural enemies from pests of vegetable crops, heavy incidence of sphingid *Acherontia styx* was observed on brinjal at IIHR Farm. Eggs of *A. styx* were collected at weekly intervals to record egg parasitism if any. A maximum of 64% parasitism was obtained due to three unidentified species of egg parasitoids. However, no larval parasitoids could be recorded.

#### 4.24.2 Management of tomato fruit borer, *Helicoverpa armigera*

Tomato (var. Pusa Ruby) was planted in about 500 $m^2$ area during November. Twenty plots of 25 $m^2$ area each were prepared. The following treatments, *viz.*, 1) *Trichogramma pretiosum* @ 50,000 adults/ha/release for five times at weekly interval from flower initiation; 2) *Ha*NPV @ 250 LE/ha 5 sprays at weekly interval from flower initiation or incidence of the pest ; 3) *T. pretiosum* + *Ha*NPV @ 250 LE/ha 3 sprays-first spray 5 days after parasitoid release and subsequently at weekly intervals; 4) Release of parasitoid as above + *Ha*NPV @ 250 LE/ha - 2 sprays/first spray 5 days after release of parasitoid and second after 10 days were given with five replications. A control field was maintained separately. Parasitized eggs held in cards (Tricho cards) were made into small bits of 100 to 200 eggs and tied 5 m apart one day before adult emergence. *Ha*NPV was sprayed during evening. Observation on the incidence of *Helicoverpa armigera* was commenced from flower initiation.

A total of 4 observations were made from 20-12-97 onwards. The experiment is being continued. However, the data so far obtained reveal no natural parasitism in the field. This was confirmed by pre-treatment observation. The level of parasitism rose to 50% in the observation that followed first release. The study indicated that the incidence of pest was not at all uniform. About 30 to 50% larval mortality was observed in *Ha*NPV treated plots. *Campoletis chlorideae* was observed in control field.

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#### 4.24.3 Incidence of *Helicoverpa armigera* at Solan and its natural parasitization

Pheromone trap installed at the farm of University Campus revealed first appearance of the moth in XII standard week starting on March, 14 and continued till June-end. First egg

laying was noticed on April 1 on chickpea but from egg-samples periodically collected from different hosts, first parasitization was observed on May 3 on tomato. From April to first week of July, eggs collected from carnation, geranium, sonchus and tomato had average 4.1, 1.0, 3.0 and 29.1% parasitization by *T. chilonis* while those collected from pansy were free from parasitization. The larval parasitization by *Campoletis chlorideae* was low (up to 12.5%).

### 4.24.4 Field release of *Trichogramma pretiosum* in tomato field having marigold as trap crop

In two fields, after every 16 rows of hybrid tomato cultivar Naveen a row of tall African marigold (Golden Age) was planted as per recommendations. Egg density and larval count were recorded at weekly interval from May 3rd week to end of June. The control plot was about one km away from the experimental plot. Two releases of the egg parasitoid *T. pretiosum* were made @ 50,000 parasitized *Corcyra* eggs/ha in the second fortnight of May at 12-day interval and per cent parasitization was found to have increased from 4.5 to 35%. However, in the control plot, parasitization by the local parasitoid, *T. chilonis* also increased from 4.5 to 31.3% during the same period. As compared with tomato, egg density per plant on marigold was quite low (0.02-0.18 in May end-early June, as against 0.4-1.15 on tomato). However, most of the eggs laid on marigold were parasitized (44.4-70%). Marigold as trap crop did not have any added advantage to attract *H. armigera* for egg laying, but served as a good refuge for *T. pretiosum* as the eggs were parasitized.

Fruit harvest data revealed that on weight by weight basis, 4.1% of harvested fruits were damaged by the tomato fruit borer and damage per plant was 0.2% bored fruit in the treated plot as against 0.7% bored fruit per plant in the control field. In comparison to egg density, larval density per plant was quite low, thereby signifying the role of natural enemies which need to be conserved in such an ecosystem.

### 4.24.5 Incidence of pea leaf miner and its parasitoids

Pea leaf miner, *Chromatomyia horticola*, a major pest of peas in mid hills of Himachal Pradesh badly damages the foliage during March-April. Compound leaves damaged by it had as many as 26 larvae and pupae in third week of March (population being 0.2-25.9 in different dates of sampling) and out of these 21.1 - 58% larvae were parasitized by the external larval parasitoid, *Diglyphus* sp. (Eulophidae). From pupae of the host collected from mined leaves eulophid endoparasitoids emerged and the average parasitization was 13.9%. Broccoli was another preferred host (0.6-23 larvae and pupae/leaf) but per cent parasitization was only up to 15.4% by *Diglyphus*. Sweet pea, though less preferred (0.2 - 1.6 larvae and pupae/

compound leaf), had high parasitization by *Diglyphus* (0-100%) and the larval-pupal/pupal eulophid parasitoid (53.3%). Parasitization by the endoparasitoid was also observed on *Solanum nigrum* (15.4%), though the pest population was low (average 6/leaf).

## 4.25 BIOLOGICAL SUPPRESSION OF POTATO PESTS

**Mahatma Phule Krishi Vidyapeeth, College of Agriculture, Pune**

### 4.25.1 Mass production and maintenance of stock cultures of laboratory hosts and natural enemies

Mass cultures of three laboratory hosts (*Phthorimaea operculella*, *Corcyra cephalonica*, and *Maconellicoccus hirsutus*), six parasitoids (*Copidosoma koehleri, Chelonus blackburni, Trichogramma chilonis, T. japonicum, T. pretiosum* and *Trichogrammatoidea bactrae),* two predators (*Cryptolaemus montrouzieri, Chrysoperla carnea*), two species of weed insect (*Neochetina* spp.) and granulosis virus (GV) of potato tuber moth are being maintained.

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

A field experiment was conducted in farmers' field at village Peth (Pune) on var. Kufri Jyoti. The plot size was 50 sq.m. with a spacing of 45 x 30 cm. The experiment was laid out in randomized block design (RBD) with eight treatments replicating thrice. Four releases of *Copidosoma koehleri* at four dosages, *viz.*, @ 50,000, 37,500, 25,000, 25,000, 10,000 and 5,000/ha 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 miner/m row at 5 places in each treatment 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 and retrieved after 2 days. These eggs were further reared in the laboratory on punctured potato tubers 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.

All the treatments significantly reduced PTM infestation during 2nd, 3rd and 4th week

after initiation of treatments (Table 66). Releases of *Chelonus blackburni* @ 15,000 adults/ha/release showed the least infestation (0.40 mines/m row) during two weeks after commencement of treatment schedule. During third week, *Copidosoma koehleri* @ 50,000 adults/ha/release was the most effective (0.26 mines/m row) and was on par with *C. blackburni* @ 15,000 adults/ha/release, *C. koehleri* @ 37,500 adults/ha/release and endosulfan 0.05%. Moreover, four releases of *C. koehleri* @ 50,000 adults/ha/release and *C. blackburni* @ 15,000 adults/ha/release proved to be most effective after 4th week showing 0.13 leaf mines/m row and they were on par with the rest of the treatments except control.

Table 66. Efficacy of parasitoids against potato tuber moth leaf mines

| Treatment | Leaf mines (%) (Mines/m row) | No. of leaf mines/m row, after week | | | | Parasitism (recovery) (%) |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | |
| *C. koehleri* @ 50,000 adult/ha/rel. | 1.13 (1.27) | 1.27 (1.32) | 0.53 (1.07) | 0.26 (0.86) | 0.13 (0.78) | 66.22 |
| *C. koehleri* @ 37,500 adults/ha/rel. | 1.13 (1.32) | 1.43 (1.38) | 0.53 (1.10) | 0.46 (0.97) | 0.26 (0.87) | 45.89 |
| *C. koehleri* @ 25,000 adults/ha/rel. | 1.33 (1.35) | 1.43 (1.37) | 0.56 (1.13) | 0.73 (1.10) | 0.30 (0.89) | 35.66 |
| *C. blackburni* @ 15,000 adults/ha/rel. | 1.13 (1.27) | 1.20 (1.30) | 0.40 (0.93) | 0.40 (0.93) | 0.13 (0.78) | 56.66 |
| *C. blackburni* @ 10,000 adults/ha/rel. | 1.33 (1.35) | 1.40 (1.35) | 0.46 (0.97) | 0.60 (1.04) | 0.20 (0.83) | 41.89 |
| *C. blackburni* @ 5,000 adults/ha/rel. | 1.06 (1.24) | 1.50 (1.41) | 0.62 (1.07) | 0.93 (1.19) | 0.26 (0.87) | 34.66 |
| Endosulfan 0.05% | 1.13 (1.27) | 1.37 (1.36) | 0.60 (1.04) | 0.46 (0.97) | 0.30 (0.89) | -- |
| Untreated control | 1.33 (1.35) | 1.43 (1.38) | 2.26 (1.66) | 1.26 (1.32) | 1.06 (1.24) | -- |
| CD (P=0.05) | (NS) | (NS) | (0.13) | (0.14) | (0.12) | |

Figures in parentheses are n+0.5 transformations

The parasitoids were recovered only after second release and parasitism was noticed to be dose dependent. Maximum recovery (66.22%) was recorded from *C. koehleri* released

plot @ 50,000 adults/ha, followed by *C. blackburni* @ 15,000 adults/ha (56.66%), *C. koehleri* @ 37,500 adults/ha (45.89%) and *C. blackburni* @ 10,000 adults/ha (41.89%).

All the treatments were significantly superior to control in reducing the tuber infestation (Table 67). Amongst the treatments, four releases of *C. koehleri* @ 50,000 adults/ha/release proved to be the most superior in reducing tuber infestation (11.29%) and was on par with *C. blackburni* @ 15,000 adults/ha/release. *C. koehleri* @ 37,500 adults/ha/release and *C. blackburni* @ 10,000 adults/ha/release were the next best treatments showing 14.00 and 15.49% tuber infestation, respectively.

Table 67. Efficacy of parasitoids on tuber infestation by potato tuber moth and yield of potato

| Treatment | Average tuber infestation (%) | Control(%) | Yield (q/ha) |
|---|---|---|---|
| *C. koehleri* @ 50,000 adults/ha/rel. | 11.29 (19.4) | 67.59 | 192.7 |
| *C. koehleri* @ 37,500 adults/ha/rel. | 14.00 (21.97) | 59.44 | 172.3 |
| *C. koehleri* @ 25,000 adults/ha/rel. | 21.56 (27.64) | 37.54 | 140.7 |
| *C. blackburni* @ 15,000 adults/ha/rel. | 11.38 (19.69) | 67.03 | 185.7 |
| *C. blackburni* @ 10,000 adults/ha/rel. | 15.49 (23.14) | 55.13 | 175.0 |
| *C. blackburni* @ 5,000 adults/ha/rel. | 20.45 (26.86) | 40.76 | 138.3 |
| Endosulfan 0.05% | 16.78 (24.14) | 51.39 | 155.7 |
| Untreated control | 35.52 (35.96) | -- | 124.3 |
| CD(P=0.05) | (2.03) | -- | 26.25 |

Figures in parentheses are arc sin transformed values

The yield data show that all the treatments, except the lowest dosages of parasitoids were significantly effective over control. Maximum yield of marketable tubers (192.7 qt/ha.) was recorded with 4 releases of *C. koehleri* @ 50,000 adults/ha/release followed by *C. blackburni* @ 15,000 adult/ha/release, *C. blackburni* @ 10,000 adults/ha/release and *C. koehleri* @ 37,500 adults/ha/release.

### 4.25.3 Evaluation of parasitoids and microbial agents against PTM in country stores ('Arnies')

An experiment was conducted by preparing miniatures of country stores (Arnies) of 10 kg capacity. The potato tubers were collected from farmers' fields (Peth : Pune) and only healthy tubers were sorted out to arrange arnies. Five arnies were arranged 10m apart and covered with grass in two layers. Twenty pairs of newly emerged PTM adults were released in the vicinity of arnies for creating artificial infestation. Thereafter, the parasitoids were released in the respective arnies. GV and *B. thuringiensis* powders were smeared to the tubers in the separate arnies. Control was also maintained to compare PTM infestation. Observations on per cent tuber infestation were recorded by drawing 1 kg samples in 4 replications from each of the treatment twice, first after one month of storage and at termination, i.e. 2 months.

PTM infestation ranged from 8.92 to 34.24% one month after storage and increased to 18.03 to 40.53% at termination (Table 68). All the treatments were significantly superior to control in reducing PTM infestation. *B. thuringiensis* was the most effective (8.92% tuber infestation) and was on par with *C. koehleri* and *C. blackburni* after one month. At the time of termination, *C. blackburni* showed the least infestation (18.03%), followed by *B. thuringiensis*, *C. koehleri* and GV being on par with each other.

Table 68. Efficacy of parasitoids and microbial agents against potato tuber moth in country stores

| Treatments | Per cent tuber infestation after | |
|---|---|---|
| | 1 month | 2 months |
| *Copidosoma koehleri* @ 5 pairs/kg tubers | 12.28 (20.22) | 19.78 (26.23) |
| *Chelonus blackburni* @ 2 adults/kg tubers | 14.46 (22.09) | 18.03 (24.92) |
| Granulosis virus @ 1gm/kg tubers | 14.52 (23.30) | 22.56 (27.97) |
| *B. thuringiensis* @ 1 gm/kg tubers | 8.92 (17.23) | 19.04 (25.85 |
| Untreated control | 34.24 (35.73) | 40.53 (39.54) |
| C.D. (P=0.05) | (5.64) | (6.86) |

Figures in parantheses are arcsine transformed values

**4.25.4 Field evaluation of *Spodoptera litura* nuclear polyhedrosis virus and *Bacillus thuringiensis* in comparison with endosulfan against *Spodoptera litura* on potato**

The field experiment was conducted when the pest population was noticed with an average of 2 larvae/m row. Spraying was undertaken (10.10.1997) during evening hours. After one hour 10 larvae/treatment plot were collected along with treated foliage from respective treatment plots and reared under laboratory conditions at room temperature. These larvae were reared for one week by providing them with treated foliage of the respective treatments. Observations on larval mortality and yield per plot were recorded.

All the treatments were significantly superior to control in respect of larval mortality. *Sl*NPV @ 750 LE/ha ($4.5x10^{12}$ POBs/ha) showed highest larval mortality (87.50%), followed by *Sl*NPV @ 500 LE/ha ($3.0x10^{12}$ POBs/ha) and *B. thuringiensis* @ 0.5kg/ha, being on par with each other. The yield data were non significant. However, maximum yield (184.45 q/ha) was recorded from *Sl*NPV treated plot @ 750 LE/ha (Table 69).

Table 69. Efficacy of *Spodoptera litura* nuclear polyhedrosis virus and *Bacillus thuringiensis* against *Spodoptera litura* on potato

| Treatment | Larval mortality (%) | Tuber yield (Qt./ha.) |
|---|---|---|
| *Sl*NPV @ 500 LE/ha ($3x10^{12}$ POBs/ha) | 80.00 (64.34) | 168.2 |
| *Sl*NPV @ 750 LE/ha ($4.5x10^{12}$ POBs/ha) | 87.50 (69.54) | 184.5 |
| *B. thuringiensis* @ 0.5 kg/ha | 75.00 (60.64) | 169.6 |
| Endosulfan 0.05% | 67.50 (55.44) | 139.3 |
| Untreated control | 12.50 (20.47) | 123.7 |
| CD (P=0.05) | (11.67) | NS |

Figures in parentheses are arcsine transformed values

## 4.26 BIOLOGICAL SUPPRESSION OF WEEDS

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**4.26.1 Biological control of water hyacinth by *Neochetina eichhorniae* and *N. bruchi***

Successful control of water hyacinth has been achieved in Assam by the exotic weevils

*Neochetina eichhorniae* and *N. bruchi*. It was already reported in Disangmukh area of Sibsagar district where more than 5000 bighas of water hyacinth has been cleared off by these exotic insect species. These areas are presently utilized by the farmers for paddy cultivation and the control achieved is about 90%. Similarly in Jaysagar area of Sibsagar district water hyacinth has been cleared. The weevils have dispersed through rivers or by aerial migration to six districts of Assam, *viz.*,Sibsagar, Dibrugarh, Golaghat, Nowgaon, Kamrup and Sonitpur. In Lakhaibill, Panbera, Balmapathar, Maridisang and Dikhowmukh of Sibsagar district, stunted growth of water hyacinth accompanied by less flowering was observed. The population build up and intensity of damage was recorded in all these migrated areas (Table 70).

Table 70. Establishment of *Neochetina eichhorniae* and *N. bruchi* in Assam

| Location | No. of adults/leaf | | Mean intensity of leaf damage | | No. of scars/leaf | |
|---|---|---|---|---|---|---|
| | July 1997 | December 1997 | July 1997 | December 1997 | July 1997 | December 1997 |
| Sibsagar | 2.68 | 2.76 | 2.92 | 3.50 | 186.56 | 192.50 |
| Kakajan | 23.40 | 3.90 | 2.44 | 3.04 | 271.60 | 194.20 |
| Alengmara | 3.58 | 4.36 | 2.87 | 3.16 | 351.85 | 178.25 |
| Disangmukh | 1.60 | 2.76 | 2.40 | 2.24 | 225.00 | 154.32 |
| Guwahati | 1.50 | - | 1.22 | - | 114.04 | - |
| Bokakhat | 2.60 | - | 1.60 | - | 162.52 | - |

Intensity of leaf damage on 0-4 scale; 0-Nil, 1=25% leaf area damaged; 2=50% leaf area damaged; 3=75% leaf area damaged; 4=above 75% leaf area damaged

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**4.26.2 Activity of *Zygogramma bicolorata* on *Parthenium* in mid hills**

As reported last year, natural population of *Zygogramma bicolorata* was observed for the first time feeding on parthenium weed at Solan in June-July 1996 and adults formed in mid-October entered reproductive diapause. After a preoviposition period of 144-215 (182.2 $\pm$ 9.2 SE) days, these beetles commenced egg laying in second half of April 1997 when temperature range was 17-30°C. They laid 265-1413 (736.7 $\pm$ 173.3 SE) eggs in 16-47 (32 $\pm$ 5.4 SE) days of oviposition. Survival of overwintering males was longer (221-301, 281 $\pm$ 12.2 SE) than that

of the female (208-233 days, 221.8 ± 11.5 SE). From the first laid eggs, development up to adult stage was completed after mid-May (i.e. within a month). During May - August when temperature fluctuated (20-32°C), development period lasted 20-30 days. But from eggs laid in II half of September, adults emerged in November and development period lasted 49-65 days (temperature range 12-28°C) while for eggs laid in October, development period was 59-70 days (temperature range 7-23°C) till October end, 1997. From April to December, it completed at least five generations. Adults formed in first week of September commenced egg laying in mid-September after a preoviposition period of 6-26 (12±2.6 SE) days and laid 159-722 (359.9±87.3 SE) eggs in 17-35 (27.3±2.3 SE) days. However, adults formed in November and December underwent reproductive diapause without laying eggs.

The periodic observations on population of the beetle on 10-20 parthenium plants were recorded from June, 1997 to October, 1997. The number of adult beetles per plant varied from 0.4 to 4.3. The adult population was maximum in June end, 1st week of September and mid - October. Larval population was 0.1-1.8 per plant. The egg count varied from 0.1 to 10.5. After November, no adult could be traced on parthenium foliage.

**Kerala Agricultural University, Vellanikkara**

**4.26.3 Monitoring and evaluation of *Pareuchaetes pseudoinsulata***

Due to frequent incidence of NPV during the rainy season and very high temperature during the summer, culture of *P. pseudoinsulata* was lost and hence field release was not attempted during the period under report. There is no sign of the presence of the insect in Vellanikkara or other centres of release.

**4.26.4 Monitoring and evaluation of *Neochetina eichhorniae***

Sampling of water hyacinth plants from Alleppey, Kottayam, Ernakulam and Calicut was done and it reveals the establishment and spread of the beetle (Table 71).

**4.26.5 Monitoring and evaluation of *Orthogalumna terebrantis***

Field release of *Orthogalumna* commenced during 1990 and during the last six years, the mite has established all over the release sites and some of the neighbouring locations.

Almost all the plants showed mite infestation in all the released locations (Table 72). However, the brownish or yellowish streaks, typical symptoms of the mite infestation, are confined to the older leaves and older plants except in some shady areas.

Table 71. Population of *Neochetina eichhorniae* and morphological parameters of water hyacinth at different locations in Kerala

| Location | Month(1997) | Average of 10 plants | | | | |
|---|---|---|---|---|---|---|
| | | No. of leaves | Length of leaf(cm)* | Breadth of leaf (cm)* | No. of weevils | No. of scras |
| Alleppey | June | 7.50 | 52.00 | 10.62 | 2.90 | 77.80 |
| Kottayam | June | 6.30 | 40.56 | 10.23 | 2.00 | 2.50 |
| | December | 6.70 | 51.00 | 12.50 | 0.20 | 49.00 |
| Ernakulam | June | 9.10 | 46.80 | 9.56 | 2.20 | 116.00 |
| Calicut | June | 7.90 | 41.90 | 12.20 | 2.00 | 17.60 |

* All leaf measurements relate to the fourth leaf

Table 72. Field population of *Orthogalumna* at Alleppey, Moncompu, Kumarakom and Trichur

| Month | Mite population (average of 20 leaves) in 1997) | | | | |
|---|---|---|---|---|---|
| | Alleppey | Kumarakom | RRS Moncompus | | Thrissur |
| | | | Inside | Outside | |
| January | 61.45 | 45.80 | 91.80 | 60.50 | 12.35 |
| February | 141.65 | 42.85 | 56.60 | 110.55 | 18.60 |
| March | 139.95 | 36.05 | 66.45 | 55.90 | |
| April | 101.45 | 28.30 | 53.00 | 65.35 | 14.85 |
| May | 96.25 | 20.30 | 32.45 | 32.95 | 88.90 |
| June | 88.90 | 16.25 | 15.50 | 63.50 | 42.65 |
| July | 103.50 | 20.55 | 31.75 | 44.40 | 64.10 |
| August | 54.90 | 52.15 | 53.35 | 89.65 | 30.40 |
| September | 51.80 | 24.55 | 91.75 | 81.80 | 64.95 |
| December | | 49.50 | | | 56.50 |

### 4.26.6 Monitoring and evaluation of *Cyrtobagous salviniae*

Field releases of *Cyrtobagous* weevils continued from the College of Horticulture, Vellanikkara, Rice Research Station, Moncompu and the Regional Agricultural Research Station, Kumarakom.

Samples of *Salvinia* were collected from Alleppey, Kottayam and Palghat to assess the field population of *Cyrtobagous* weevils. The details are given in the Table 73.

Table 73. Field population of *Cyrtobagous salviniae*

| Month (1997) | Alleppey | | Kottayam | | Palghat | | Malappuram | |
|---|---|---|---|---|---|---|---|---|
| | Buds | Adults | Buds | Adults | Buds | Adults | Buds | Adults |
| January | 56.0 | 1.6 | 52.2 | 4.0 | 72.6 | 1.6 | - | - |
| March | 76.0 | 1.5 | 71.5 | 2.5 | 90.8 | 1.4 | 75.2 | 2.0 |
| June | 78.4 | 1.2 | 81.4 | 5.4 | 79.0 | 1.8 | 81.0 | 1.6 |
| September | 85.0 | 2.0 | 79.0 | 3.0 | 78.0 | 2.0 | 81.0 | 1.8 |
| December | - | - | 72.0 | 2.6 | - | - | - | - |

### 4.26.7 Assessment of impact of *Cyrtobagous salviniae* in suppressing *Salvinia molesta*

Extensive surveys were conducted in Thrissur and other districts of Kerala for the identification of isolated ponds with *Salvinia* where the insect *Cyrtobagous* has not dispersed (Table 74). In Thrissur district, *Salvinia* infestation is serious in kole lands which are the extensive paddy growing areas. *Cyrtobagous* weevils released here earlier have established well and the weed growth is under control.

In almost all the *Salvinia* infested ponds *Cyrtobagous* weevils were not observed and hence fresh release of *Cyrtobagous* was undertaken. The population build up and the extent of damage on *Salvinia* in the newly selected localities during December 1997 are given in Table 75.

### 4.26.8 Assessment of impact of *Neochetina eichhorniae* and *Orthogalumna terebrantis* in suppressing water hyacinth

A survey was conducted in Thrissur and other neighbouring districts for the identification of insect free *Eichhornia* infested isolated ponds and the details are given in Table

76. Both *N. eichhorniae* and *O. terebrantis* were observed in most locations at different intensities. Monitoring the spread and damage intensity was done from four selected ponds.

Table 74. Details of the survey conducted for the identification of isolated ponds with *Salvinia*

| Month | District | Location | Remarks |
|---|---|---|---|
| August 1997 | Ernakulam | Karummallur | Mild attack of *Cyrtobagous* |
| | Thrissur | Kumbidi | |
| | | Muplium | |
| | | Chavakkad | |
| | | Pudukkad | Severe attack of *Cyrtobagous* |
| September 1997 | | Ashtamichira | Severe attack of *Cyrtobagous* |
| | | Kattur | -do- |
| | | Chalakudy | -do- |
| | | Manakodi | -do- |
| October 1997 | Ernakulam | Panamad | Mild attack of *Cyrtobagous* |
| | Idukki | Thodupuzha | No salvinia problem |
| | Kasargod | Kasargod | Mild attack of *Cyrtobagous* |
| | Kozhikode | Perumana | -do- |
| | Kannur | Thalasseri | -do- |

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**4.26.9 Assessment of impact of *Neochetina* spp. and *Orthogalumna terebrantis* in suppressing water hyacinth**

Two fresh water ponds with water hyacinth were selected in the July 1997 and 2000 adult weevils of *Neochetina* spp. and 40 leaves containing *Orthogalumna terebrantis* were

introduced in each pond. Observations were recorded by monitoring visual damage, i.e. feeding scars on 25 leaves from each pond at 3 months interval. Simultaneously weevil and mite population were also recorded by randomly sampling 25 plants and 25 leaves per pond, respectively, and the data revealed that the weevil and the mite got established and their numbers were increasing steadily (Table 77).

Table 75. *Cyrtobagous salviniae* infestation in isolated ponds

| Locations | Healthy buds | Adults | Total plants | Affected plants |
|---|---|---|---|---|
| Vellanchira Kulam | 88.6 | - | 28.0 | 0.3 |
| Palkulam | 31.3 | 9.6 | 47.3 | 32.6 |
| Maraparattikulam | 31.0 | 7.0 | 37.3 | 31.6 |
| Manakodi | 79.0 | - | 37.0 | - |
| Irinjalakuda | 30.3 | 6.0 | 48.0 | 48.0 |
| Puthukad | 52.0 | 4.3 | 23.6 | 23.6 |

**Gujarat Agricultural University, Anand**

**4.26.10 Biological control of water hyacinth by release of *Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis***

The weevils have adapted to the new environment very well as evidenced by the presence of the larvae and adults in the bulbs as well as fresh damage observed on the leaves. The adult count varied from 1.45 to 3.10 per plant and damage holes from 70.35 to 120.25 per leaf.

**Punjab Agricultural University, Ludhiana**

**4.26.11 Assessment of impact of *Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis* in suppressing water hyacinth**

Releases of *N. eichhorniae, N. bruchi* and *Orthogalumna terebrantis*, were made near Ludhiana during 1992 in a pond where it got established on water hyacinth. The weevils have multiplied in the pond but so far not given any control. The weevils were collected from this pond and released at two more locations viz., Phillaur in one ha and at Goraya in 3 ha (Distt. Jalandhar). The weed population in these ponds has dried due to the severe cold and so the impact of the weevils could not be ascertained.

Table 76. Details of the survey conducted for the identification of isolated ponds with *Eichhornia*

| Month | Disctrict | Location | Remarks |
|---|---|---|---|
| August 1997 | Ernakulam | Karummallur | Mild attack of *Neochetina* & Mite |
| | | Kodungallur | -do- |
| | | Panayikulam | -do- |
| | | Cherpu | -do- |
| | | Chavakkad | -do- |
| September 1997 | Thrissur | Manakodi | Severe attack of *Neochetina* & mite |
| | | Ashtamichira | No attack of *Neochetina* & mite |
| | | Karuvannur | Mild attack of *Neochetina* & mite |
| | | Chalakudy | Mild attack of *Neochetina* & mite |
| October 1997 | Ernakulam | Panamad | Severe attack of *Neochetina* & mite |
| | Kannur | Thalasseri | -do- |

Table 77. Efficacy of *Neochetina* spp. and mites in suppressing water hyacinth

| Month | Leaf feeding due to Neochetina sp. | | Average No. of weevils/plant | Average No. mites/plant |
|---|---|---|---|---|
| | Score | Damage | | |
| Sep.1997 | | | | |
| Pond I | 1.00 | 14.28 (5-20%) | 1.68 | 15.00 |
| Pond II | 1.20 | 21.75 (0-40%) | 1.48 | 17.80 |
| Nov.1997 | | | | |
| Pond I | 1.60 | 27.80 (0-40) | 2.40 | 21.60 |
| Pond II | 1.44 | 30.40 (20-45) | 2.55 | 29.40 |

Figures in parentheses are ranges of leaf area damaged

### 4.26.12 Monitoring of *Zygogramma bicolorata*

Regular surveys were carried out in different parts of the state. At each location the population of the *Z. bicolorata* was counted from 10 plants at random.

*Z. bicolorata* was wide spread throughout the state except in the districts of Bathinda, Ferozepur, Patiala, Sangrur, Mansa and Moga. It was observed in Ropar (55.5 beetles / 10 plants), Hoshiarpur (14.4 beetles / 10 plants), Ludhiana (11.4 beetles / 10 plants), Kapurthala ((7.5 beetles / 10 plants) and Jalandhar (6.5 beetles / 10 plants).

**Indian Institute of Horticultural Research, Bangalore**

### 4.26.13 Evaluation of *Bactra venosana* in suppressing *Cyperus rotundus*

Healthy pre-flowering stage *Cyperus rotundus* plants were collected from the field along with their tubers. Soaked tubers were planted at the rate of 10 in 45 x 45 cm cement pots of 60 cm height in 20 pots and 16 of them enclosed in nylon wire mesh cages to prevent natural infestation by *Bactra venosana*. The pots were used for the experiment one month after planting. The adults from the stock culture of *Bactra venosana* were released at the rate of 1, 2 and 4 pairs into the cages set up over the cement pots. Four replications were maintained. Adults were not released into 4 cages and another set of 4 pots with *C. rotundus* was left open.

Observations were recorded one month later, on the total number of plants damaged, the average weight of the tubers as well as the aerial parts of the plant and the number of plants that produced sprouts. Observations were recorded at regular intervals for dead heart symptom. One month after release, counts were taken on the number of plants surviving in each cage. Five plants from each cage were randomly removed for observations. After one more month observations were recorded on sprouting of the remaining tubers. In the case of undamaged tubers the aerial parts were cut off at the time of the first observation for determining sprouting ability.

Releases of *B. venosana* adults brought about death of the aerial parts of all plants in all the treatments within one month, irrespective of the number of pairs of adults released. Dead heart symptom was visible two weeks after release of adults. The insect was observed to cause complete death of aerial parts of *C. rotundus* plants. Observations carried out after one month revealed that *B. venosana* attacked tubers weighed only about 0.23g as compared to 0.94g for control. Only 19% of the tubers sprouted one month after insect damage (Table 78). However, significant differences in tuber weights and sprouting ability were not noticed among

treatments where 1, 2 or 4 pairs of adults were released, indicating that releases of even one pair of adults can bring about suppression of *C. rotundus*. Natural infestation of *B. venosana* could be noticed in treatments where the plants were not caged.

Table 78. Effect of release of *Bactra venosana* on potted *Cyperus rotundus*

| Parameter | 1 Pair | 2 pairs | 4 pairs | No release enclosed | No release not enclosed |
|---|---|---|---|---|---|
| Damage (%) | 100 | 100 | 100 | 0 | 30.0 |
| Wet weight of tuber (g) | 0.27 0.15 (0.10-0.48) | 0.23 0.06 (0.15-0.32) | 0.17 0.04 (0.12-0.23) | 1.71 0.71 (0.46-2.20) | 1.18 0.51 (0.38-1.80) |
| Sprouting (%) | 20 | 20 | 10 | 100 | 80 |

### 4.26.13. Effect of host switching on development of reproductive organs in *Zygogramma bicolorata*

Studies carried out during the previous years indicated that newly emerged adults of *Z. bicolorata* are capable of feeding on sunflower plants. It was also observed that continuous feeding on sunflower leaves resulted in degeneration of reproductive organs. Therefore, detailed studies were carried out under laboratory conditions to determine the effect of host switching on the development of reproductive organs in the beetle. For this newly emerged adults were released on parthenium leaves for 5, 10, 15 and 20 days and then transferred to sunflower leaves. Studies were also carried out by releasing freshly emerged adults on sunflower leaves and transferring them to parthenium leaves after 15 days.

The top four leaves of young sunflower plants of the variety Morden, grown in large cement pots under field conditions, were used for the tests. Parthenium and sunflower leaves were provided to the adults in the form of bouquets, with their cut ends dipped in small plastic containers, through holes in their lids. The studies were carried out in 600 ml rectangular clear plastic containers with wire mesh windows on their lids for aeration. At least 20 adults were used per treatment. Observations were recorded daily on the number of eggs laid and adult mortality.

To determine the effect of feeding on reproductive organelles (ovarian follicles and testes), adults that remained alive in the above treatments were dissected after specified time intervals,

preserved in 70% isopropyl alcohol for a minimum of 24 h before dissection. The preserved adults were later fixed in paraffin wax and dissected using a binocular microscope.

Freshly emerged adult females of *Z. bicolorata* that were released on parthenium were observed to start laying eggs by 8th day. An average of 14.2 eggs/female was obtained by 10th day which increased to 21.5 and 84.7 by the 15th and 20th day, respectively (Table 79). However, adults released on sunflower were observed to lay only 1.02 and 1.04 eggs/ female by 10th and 15th day, respectively. However, females that fed continuously on sunflower for more than 15 days were not observed to lay eggs.

Table 79. Fecundity and mortality of *Zygogramma bicolorata* on parthenium and sunflower

| Treatment | Eggs/ female | Mortality (%) |
|---|---|---|
| Parthenium - 5 days and Sunflower - 5 days | 0 / 0 | 0 / 50 |
| Parthenium -10 days and Sunflower- 10 days | 14.20 / 1.02 | 0 / 50 |
| Parthenium-15 days and Sunflower- 15 days | 21.5 / 1.04 | 0 / 40 |
| Parthenium- 20 days and Sunflower - 20 days | 89.7 / 0.00 | 0 / 90 |
| Sunflower- 15 days and Parthenium- 10 days | 2.06 / 30.00 | 55 / 10 |
| Sunflower- 15 days and Parthenium- 15 days | 0 / 53.4 | 40 / 30 |
| Sunflower- 15 days and Parthenium- 10 days and Sunflower- 5 days | 0 / 87/ 0 | 65 / 0 / 0 |
| Sunflower- 15 days and Parthenium- 5 days and Sunflower- 5 days | 0 / 10.5 / 0 | 80 / 0 / 20 |

When females that had fed on sunflower for 15 days were shifted to parthenium, oviposition rate increased gradually. Thus, females exposed to parthenium for 10 and 15 days after feeding on sunflower laid an average of 30 and 52.4 eggs. However, no eggs were laid by females when they were shifted back to sunflower after exposure to parthenium. Feeding on sunflower caused high mortality ranging from 50 - 90% within a period of 7 - 14 days.

Feeding on sunflower caused structural changes in the follicles, which could explain the low egg laying. All the females which had fed on sunflower for 5 days had follicles of pre-vitellogenesis phase I. With an increase in the duration of feeding, there was a gradual increase in the maturation of the ova and by the 10th day about 84% of the females had follicles in the pre-vitellogenesis phase II. However, sustained feeding on sunflower caused follicular degeneration. Thus, 88% of the females that had fed on sunflower for 15 days had follicles of pre-vitellogenesis phases I and II. By the 20th day further inhibition in follicular development was noticed. None of the females had mature ova 15 days after feeding.

Shifting of these females to their natural host was found to induce normal development of the follicular cells. Thus, when adults were exposed to parthenium for 10 or 15 days after feeding on sunflower for 5 days, about 33 and 41% of the females were in vitellogenesis phases II and III indicating that they had well developed ova. However, shifting these females back to sunflower was found to inhibit oogenesis.

Studies on the structural differences of testes also indicated similar results. Parthenium fed males had well developed bilobed testes, whereas males fed with sunflower had small.

**Research achievements made in the lateral funded projects**

**Studies on the pest potential of mexican beetle *zygogramma bicolorata* introduced for biocontrol of parthenium (ICAR Adhoc Scheme, Principal Investigator : Dr.S.Ramani)**

Survival of adults of the end of 15 weeks feeding on sunflower was about 18-20% while on parthenium, it was 92-100%. Mortality of first instar larvae was very high when reared on sunflower as compared to parthenium. Sunflower leaves (Hyb. Arun) smeared with different concentrations of parthenin increased the consumption and growth of the beetles. The total fecundity increased with the increase in concentration of parthenium.

**Biological control of *Agrotis* spp. with entomophilic nematodes (DBT funded project, Principal Investigator : Dr.S.S.Hussaini)**

Out of ninety four samples collected from potato growing areas and other host crops of *Agrotis* spp, nine samples yielded entomophilic nematodes. Out of different artificial media tested for the mass production of entomophilic nematodes, Wout's medium without soyflour and vegetable oil was found to be ideal.

Morphometric study of IJs and males of different populations using a compound microscope revealed that out of the nine entomophilic nematodes isolated seven were *Steinernema* sp. and two were *Heterorhabditis* sp. The two populations from Bangalore and Delhi resembled *Steinernema carpocapsae* based on male characteristics and morphometrics. However the characteristics of IJs differed widely and require further confirmation.

Bio-efficacy tests on the effect of different isolates of entomophilic nematodes against different larval populations of *Agrotis* spp. showed that all the isolates (PDBC EN 6.11, PDBC EN 3.1, PDBC EN 13.21, PDBC EN 13.22) are effective at the dosages of 50 IJ and 75 IJ/larva.

**Biocontrol of Maize Tissue Borers using entomophilic nematodes (ICAR adhoc scheme, Principal Investigator : Dr.S.S.Hussaini)**

Two samples from Sugarcane Breeding Institute, Coimbatore yielded entomophilic nematodes belonging to *Steinernema* sp. and *Heterorhabditis* sp. Nematodes were mass produced *in vivo* on larvae of *Corcyra cephalonica, Helicoverpa armigera* and *Galleria mellonella.* A single larva inoculated with 400-500 infective juveniles yielded about 30,000 nematodes. In preliminary bioefficacy tests in the laboratory on larvae and pupae of *Chilo partellus,* isolate PDBC EN 6.11 (*Steinernema* sp.) was more virulent than PDBC EN 13.21 (*Heterorhabditis* sp.)

Pot culture experiment indicated that infestation of *Chilo partellus* on maize plants sprayed with 1000 IJ/plant was lower than that on plants sprayed with 500 IJ/plant. Morphometric analysis of infective juveniles and males confirmed that PDBC EN 13.21 belonged to Steinernematidae and PDBC EN 13.22 belonged to Heterorhabditidae. PDBC EN 13.21 fits in the range of *Steinernema carpocapsae* and needs further confirmation.

**Use of Semiochemicals to increase the biocontrol potential of some important predators and parasitoids (DBT funded project, Principal Investigator : Dr.N.Bakthavatsalam)**

Adults of C. carnea responded to acid hydrolysed solution of L-tryptophan at 0.33mg/ 100ml and even at higher doses. In the field cage studies 3-day-old acid hydrolysed L-tryptophan recorded better oviposition. Substitution of hydrolysis with oxidation of L-tryptophan using hydrogen peroxide and aminoacid oxidiser was attempted. Aminoacid oxidiser was on par with acid hydrolysis at particular concentration in wind tunnel methods. Attempts were made to formulate a kairomone using the scale extracts mixed with tricosane and other commercially available kairomones for field studies to increase the efficiency of the larvae of *C. carnea.* The experiment is in progress. The predation potential of *C. carnea* was more when kairomone was sprayed. Buds and flowers of cotton infested by *Helicoverpa armigera* larva were also found to evoke behavioural response in adult *C. carnea.* Electroantennogram studies confirmed the behavioural responses of adult chrysopids to kairomones. In insect activity meter studies, the adults moved less and slowly in the kairomone treated zones while the larvae moved faster in kairomone treated zones.

**Developing strategies for the management of parthenium weed in India using fungal pathogens (CABI project, Principal Investigator : Dr.P.Sreerama Kumar)**

This project, planned for 1996-99, is sponsored by the Department for International Development (DFID); previously the Overseas Development Authority, (ODA) of the United

Kingdom (UK) under the Natural Resources Institute's (NRI) Renewable Natural Resources Research Strategy (RNRSS). CABI Bioscience, Ascot (UK Centre) (formerly the International Institute of Biological Control, IIBC), is the UK collaborator and four institutes viz., PDBC (Bangalore), National Research Centre for Weed Science (Jabalpur), Tamil Nadu Agricultural University (Coimbatore) and Kurukshetra University (Kurukshetra) are the Indian counterparts. The project commenced in India only in the second half of 1997 after the formalities for approval were complete.

One of the chief objectives of this project is the identification of suitable indigenous fungal candidates for the management of *Parthenium hysterophorus* L., commonly called parthenium or congress grass. Karnataka State has been assigned to PDBC for exploration of fungal pathogens of parthenium. Extensive and critical surveys were made in ten districts of the State starting from the later part of 1997. Plant samples exhibiting fungal infection were collected at various localities; the associated fungi isolated and pathogenicity assessed employing standard phytopathological methods. The fungi satisfying the Koch's postulates and found to be damaging to the weed were identified locally or referred to the Project Leader in UK for confirmation of identity. All the proven pathogens were initially evaluated for virulence and other characters in the laboratory and in pot culture experiments.

The Project Co-ordinator under a Training Course entitled "Biological Control and Management of Parthenium Weed" at CABI Bioscience, UK from 17th March to 5th April 1998. The two rust pathogens, namely, *Puccinia abrupta* (Jackson) var. *partheniicola* Diet. & Holw. and *P. melampodii* Diet. & Holw. were handled during the programme. Indian strains of parthenium were tested for their susceptibility to the pathogens. A range of Indian crop plants were assessed for their reaction to two different strains (W1496 and W1500) of *P. melampodii*. All the species investigated were found immune to the rust. Many studies, including the specificity testing of rust species using a wind tunnel to simulate natural dispersal conditions, environmental requirements of the rust species, Bruzesse and Hasan clearing and staining technique for host-range testing, and several other related experiments were performed using the Indian parthenium strains and our own crop species.

**National repository of natural enemies of crop pests and weed (DBT funded project, Principal Investigator : Dr. S.P.Singh)**

Strains of *Trichogramma chilonis* and *T. japonicum* were collected from sugarcane, rice, maize, tur and cotton ecosystems in Punjab and sorghum ecosystem from Dharwad district and Sriganganagar (Rajasthan). Nucleus cultures of five coccinellid predators, viz., *Cheilomenes sexmaculata*, *Chilocorus nigrita*, *Cryptolaemus montrouzieri*, *Coccinella*

*septempunctata* and *Scymnus coccivora* were continuously maintained in the laboratory. Nucleus cultures of *Neochetina eichhorniae, N. bruchi, Orthogalumna terebrantis, Cyrtobagous salviniae* and *Zygogramma bicolorata* collected from in and around Bangalore are maintained. Braconids viz., *Cotesia plutellae, Cotesia flavipes* and *Myosoma chinensis* were collected from Hoskote, Adugodi, Rajankunte, Jakkur and Doddajala in and around Bangalore and also from New Delhi. Species and strains of chrysopids were collected from different crop ecosystems. Species of chrysopids maintained are *Mallada astur, Mallada boninensis, Apertochrysa* sp., *Ankylopteryx* sp.-1 and *Ankylopteryx* sp.-2. Cultures of *Telenomus remus ,Telenomus* sp. and *Tetrastichus ? sokolowskii* were maintained on *Spodoptera litura* eggs. Work has been initiated on the multiplication of two anthocorid species - *Orius tantillus* and *Cardiastethus exiguus*. *Goniozus nephantidis, Brachymeria nosatoi, B. nephantidis, Elasmus nephantidis, Apanteles taragamae* and *Bracon hebetor* were collected from *Opisina arenosella* in different locations. *Campoletis chlorideae* and *Eriborus argenteopilosus* were the two potential ichneumonids multiplied on *Spodoptera litura*. Attempts are being made to produce a multicellular tray for the mass rearing of lepidopterous host insects which would in turn help in the production of ichneumonids in large numbers. An encyrtid parasitoid *Leptomastix dactylopii* was recovered from field collected mealybugs.

More than hundred isolates of fungi showing antagonistic potential against pathogenic fungi were isolated from rhizosphere and rhizoplane soil samples of cereals, pulses, oil seeds, vegetables, fruits, spices and plantation crops from different parts of the country. Extensive surveys were undertaken in Bangalore Urban, Bangalore Rural, Mandya, Mysore, Dharwad, Bidar, Gulbarga, Raichur, Bellary and Chitradurga districts of Karnataka State for collecting various fungal pathogens of parthenium weed (*Parthenium hysterophorus*). *Nomuraea rileyi* and *Beauveria bassiana* were found to infect *Helicoverpa armigera* and *Spodoptera litura* in Khammam District of Andhra Pradesh during December. The entomopathogenic fungi, *Hirsutella nodulosa* and *Verticillium lecani* were obtained from SBI, Coimbatore and CPCRI, Kayangulam, respectively. The isolated fungi are being identified for further studies and maintenance. Nematode pathogens were isolated from adult nematodes and egg masses, purified, identified and maintained in axenic form. The fungi obtained from other institutes were also maintained for further studies.

## 5. TECHNOLOGY ASSESSED AND TRANSFERRED

### 5.1 Technology assessed

5.1.1 Production of trichogrammatid egg parasitoids

Trichogrammatid egg parasitoids are an important group of bioagents which have been used successfully for the biological suppression of various caterpillar pests damaging crops like sugarcane, paddy and cotton. In India, *Trichogramma* spp. are in great demand today. The Project Directorate of Biological Control, Bangalore has standardized mass production technology for trichogrammatid egg parasitoids. The egg parasitoids are now used for the biological suppression of lepidopterous pests on sugarcane, cotton, maize, sorghum, castor, citrus, apple, cole crops, tomato and other crops.

5.1.2 Multiplication of chrysopid predators

Chrysopids have great potential for use as biocontrol agents of aphids, whiteflies, and early stages of caterpillar pests. Mass multiplication technology has been perfected at the Project Directorate for the production of chrysopids. The chrysopids are now in use on cotton and sunflower for suppression of sucking and lepidopterous pests.

5.1.3 Multiplication of *Cryptolaemus montrouzieri*

Mass production technology of *Cryptolaemus* has been developed on a large scale on mealybugs in the laboratory and field release techniques for different crop ecosystems have been standardized. The production and release technology of *C. montrouzieri* has been successfully transferred for the first time to 125 small and marginal farmers under ICAR Lab to Land Phase I Programme. Further improvised technology is being assessed.

5.1.4 Multiplication of *Leptomastix dactylopii*

An exotic parasitoid, *Leptomastix dactylopii* was introduced from West Indies in 1983 for the biological control of mealybug pests. This parasitoid is specific to citrus mealybug, *Planococcus citri*. It possesses excellent host searching ability and has already established in orchards where releases have been made. The mass production and field release technology has been developed for this exotic parasitoid.

5.1.5 Multiplication of *Cyrtobagous salviniae* for the biological control of water fern

Water fern, *Salvinia molesta* introduced into India, perhaps, through botanical gardens has become a serious problem, it choked rivers, canals and lagoons in Kerala. In 1982, the weevil *Cyrtobagous salviniae* of Brazilian origin was introduced from Australia for the suppression of *Salvinia molesta* in India. Mass multiplication procedures developed include cultivation of *S. molesta* in small water tanks and then rearing *C. salviniae* on these. Releases of *C. salviniae* have proved successful in the biological suppression of salvinia in Karnataka and Kerala. Annual savings ( in terms of labour for removing weed) of Rs.68 lakhs is being realised since 1984-85.

5.1.6 Multiplication of *Neochetina bruchi, N. eichhorniae* and *Orthogalumna terebrantis* for the control of water hyacinth

Water hyacinth appeared in India early in the century and spread throughout the country in all types of water bodies causing hindrance to irrigation, fishing, water sports, navigation and paddy cultivation. In 1982, three exotic natural enemies i.e. *Neochetina bruchi*, *N. eichhorniae* and *Orthogalumna terebrantis* were introduced into India. Production and release procedure was developed and transferred to the concerned end users.

5.1.7 Production of baculoviruses, nuclear polyhedrosis viruses (NPV) and granulosis viruses (GV)

Technology has been developed for mass production of NPV of various pests. Host specific NPVs are now being utilized for the suppression of *Spodoptera litura, Helicoverpa armigera* and several other Lepidoptera. GVs are successfully used for the suppression of *Chilo infuscatellus* and *Phthorimaea operculella*. Baculovirus of *Oryctes rhinoceros* has been successfully utilized in Kerala, Andhra Pradesh and other coconut and oil palm growing areas of the country.

**5.2 Technology transferred**

Transferred the endosulfan tolerant strain of *Trichogramma chilonis* to M/S Excel Industries Limited, 184/87, Swami Vivekananda Road, Jogeshwari, Mumbai 400 012 for Rs.5,00,000/-. The strain is tolerant (physiologically) to endosulfan at 0.07% concentration.

The product meets / conforms to the following specifications / parameters etc. (to be specified on case to case basis).

i. *Trichogramma chilonis* is tolerant to 0.07% endosulfan concentration.

ii. Adults survive for about 6 hours (and successfully parasitize the host eggs) on freshly sprayed/treated area, whereas susceptible strain dies within 15-30

iii. Parasitism obtained is >90% compared to <5% by susceptible strain

iv. Tolerance level maintained for 3-4 generations without any breakdown. However, a small culture should always be exposed to endosulfan to maintain desired quality in the laboratory.

v. Capable of parasitising *Helicoverpa armigera* on cotton immediately after plants are sprayed and is able to emerge successfully.

## 6. EDUCATION AND TRAINING

### 6.1. Education

The Project Directorate is recognised as a Post Graduate Centre for conducting research for Ph.D degree by the Mysore University, Mysore; Bangalore University, Bangalore and University of Agricultural Sciences, Dharwad.

Three students have registered for Ph.D in Mysore University, Mysore under the guidance of Dr.S.P.Singh, Project Director during the year 1994 and the following two students from Project Directorate of Biological Control, Bangalore have completed and joined the service in 1997.

| | |
|---|---|
| Ms. Chandish R. Ballal | Studies on the feasibility of using biocontrol measures for developing a BIPM programme for the management of *Helicoverpa armigera* |
| Mr. S.K. Jalali | Studies on the management of borer pests of fodder maize with special reference to *Chilo partellus* |

One person from Central Plantation Crops Research Institute, Kasargod has registered for Ph.D programme during 1995 and the following research work is in progress.

| | |
|---|---|
| Ms. A. Sujatha | Investigations on the natural enemy complex of the coconut leaf caterpillar, *Opisina arenosella* with special reference to egg and early larval parasitoids and predators |

### 6.2. Training

Dr.S.S.Hussaini, Senior Scientist (Nematology) attended a training programme on "Statistical softwares for data analysis" from July 1st to 11th 1997 at National Academy of Agricultural Research Management, Rajendranagar, Hyderabad.

Mr.S.R.Biswas, Senior Scientist (Agri. Statistics) attended a training programme on "Advanced course on Management Information System for Agricultural Research" from July 15th to 26th 1997 at National Academy of Agricultural Research Management, Rajendranagar, Hyderabad.

Dr.P.L.Tandon, Principal Scientist (Agri. Entomology) attended a training programme on "Management of Agricultural Research Stations / Institutes (MARS)" from August 18th to 23rd 1997 at National Academy of Agricultural Research Management, Rajendranagar, Hyderabad.

Dr.N.S.Rao, Senior Scientist (Agri. Entomology) attended a training programme on "Management of Agricultural Research Stations / Institutes (MARS)" from August 18th to 23rd 1997 at National Academy of Agricultural Research Management, Rajendranagar, Hyderabad.

Mr.S.R.Biswas, Senior Scientist (Agri. Statistics) attended a training programme related to "Novell Netware 4.1, Windows, MS Office and VisC$^{++}$" from August 25th to September 2nd 1997 at University of Agricultural Sciences, GKVK Campus, Bangalore 560 065.

Dr.N.S.Rao, Senior Scientist (Agri. Entomology) attended a training programme related to "Novell Netware 4.1, Windows, MS Office and VisC$^{++}$" from August 25th to September 2nd 1997 at University of Agricultural Sciences, GKVK Campus, Bangalore 560 065.

Ms.I.M.Dautie, Assistant Administrative Officer, attended a training programme on "Establishment Rules" from 10th to 14th November 1997 at Institute of Secretariat and Training Management, New Delhi 110 007.

Dr.C.Sankaranarayanan, Scientist (Nematology) attended a training programme on "Advanced Training course in nematode taxonomy" from December 15th to 28th 1997 at Aligarh Muslim University, Aligarh 202 002.

## 7. AWARDS AND RECOGNITIONS

Dr.S.P.Singh, Project Director has been nominated as Member of the editorial board of International Journal "Biocontrol News and Information" brought out by CAB International, London (UK).

Dr.P.L.Tandon, Principal Scientist was presented with a medal and a citation by Indian Potato Association, Shimla for the best research paper in the Journal of Potato Association.

Dr.P.Sreeramakumar, Scientist (Plant Pathology) has been nominated as a Link Scientist for the International Mycological Institute (IMI), United Kingdom, since 1997.

Dr.S.S.Hussaini, Senior Scientist (Nematology) was honoured by the Plant Protection Association of India for his contribution to the growth of Plant Protection Association during the past 25 years (1972 - 1997).

## 8. LINKAGES AND COLLABORATION IN INDIA AND ABROAD INCLUDING EXTERNAL PROJECTS

Collaborative projects with Ministry of Science and Technology, Department of Biotechnology, Government of India, New Delhi during the year 1997-989 are

| | | |
|---|---|---|
| Biological control of *Agrotis* spp. with entomophilic nematodes | : | 32,75,000/- |
| Use of semiochemicals to increase biocontrol potential of some important predators and parasitoids | : | 45,90,000/- |
| National repository of natural enemies of crop pests and weeds | : | 98,15,000/- |

AP Cess fund project during the year 1997-98

| | | |
|---|---|---|
| Biocontrol of maize tissue borers using entomophilic nematodes | : | 18,51,000/- |

**EXTERNAL PROJECTS**

The following collaborative project between IIBC, UK (now incorporated into CABI Bioscience) and Project Directorate of Biological Control (ICAR), Bangalore is in operation.

| | | |
|---|---|---|
| Developing strategies for the management of parthenium weed in India using fungal pathogens | : | 04,95,000/- |

## 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 (SAU) based co-ordinating centres. The following crops/works on biological control are allotted.

**Head quarters**

| | | |
|---|---|---|
| Project Directorate of Biological Control, Bangalore (Karnataka) | - | Basic Research |

**ICAR Institute based centres**

| | | |
|---|---|---|
| Central Plantation Crops Research Institute, Regional Station, Kayangulam (Kerala) | - | Coconut |
| Central Tobacco Research Institute, Rajahmundry, (Andhra Pradesh) | - | Tobacco |
| Indian Agricultural Research Institute, New Delhi | - | Basic Research |
| Indian Institute of Horticultural Research, Bangalore (Karnataka) | - | Fruits& 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 Science & 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 (Maharastra) | - | 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) | - | Fruits & Vegetables |
| Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu) | - | Rice, Cotton & & Pulses |
| Dr.Y.S.Parmar University of Horticulture & Forestry, Solan (Himachal Pradesh) | - | Fruits & Vegetables |

## GENERAL / MISCELLANEOUS

### 10. LIST OF PUBLICATIONS

**Project Directorate of Biological Control, Bangalore**

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Prasad, R.D., Rangeshwaran, R. and Sreerama Kumar, P. (1997). Mass production of *Trichoderma harzianum* and its shelf-life in different formulations. Poster presented in "International Conference on Integrated Plant Disease Management for Sustainable Agriculture", 10-15 November 1997, New Delhi, India; abstract.

Sankaranarayanan, C., Hussaini, S.S., Sreerama Kumar, P. and Prasad, R.D. 1997. Nematicidal effect of some fungal filtrates against root knot nematode. *Journal of Biological Control* (Accepted for publication).

Singh, S.P. 1997. Biological Control in India, In - *National Seminar on Plant Protection towards Sustainability*, Plant Protection Association of India. December 22-24, 1997, NPPTI, Hyderabad, 78 pp.

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Singh, S.P. 1997. Biological Control - Problems and Prospects published in a journal volume on Challenges in Plant Science and Agriculture by 2000 AD. Maharashtra Academy of Engineering and Educational Research, Pune.

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Sitaramaiah, S., Ramaprasad, G., Sridhar, U., Nageswara Rao, S. 1997. Pagathotalo Nelapenki purugulu Bedada. *Eenadu*, November 1997.

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**Sugarcane Breeding Institute, Coimbatore**

Easwaramoorthy, S., Srikanth, J. and Santhalakshmi, G. 1996. Seasonal occurrence of the fungus *Hirsutella nodulosa* Petch and granulosis virus of sugarcane internode borer *Chilo sacchariphagus indicus* (Kapur). *Entomon* **21** (3&4):205-209.

Srikanth, J., Easwaramoorthy, S., Kurup, N.K. and Santhalakshmi, G. 1997. Spider abundance in sugarcane : impact of cultural practices, irrigation and post-harvest trash burning. *Biological Agriculture and Horticulture* **14**:343-356.

**Gujarat Agricultural University, Anand**

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**Kerala Agricultural University, Thrissur**

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**Punjab Agricultural University, Ludhiana**

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**Dr. Y.S. Parmar University of Horticulture & Forestry, Solan**

Gupta, P.R. and Raja Ram Mohan 1997. Management of *Helicoverpa armigera* with *Trichogramma pretiosum* and *Bacillus thuringiensis* var. *kurstaki* on tomato. Paper presented in *First National Symposium on Pest Management in Horticultural Crops* held on 15-17 October, 1997 at Bangalore. Abstract and Souvenir, pp. 103.

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## 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 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 entomophathogenic nematodes against some important lepidopterous and coleopterous insect pests

xvi. Biological control of soil borne and other pathogens by anatagonistic 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 centres**

i. Biological suppression of sugarcane pests

a. Survey and seasonal fluctuation studies on 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, SBI)

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. Evaluation of BIPM for cotton pests (GAU, TNAU and ANGRAU)

c. Identification of host plants which harbour arthropod natural enemies (PAU, GAU, TNAU, ANGRAU)

d. Standardisation of release technology for *Trichogramma chilonis* (PAU, GAU, TNAU, ANGRAU)

iii. Biological suppression of tobacco pests

a. Evaluation of *Bt kurstaki*, *Bt aizawai* and *Sl* NPV against *Spodoptera litura* in tobacco nursery (CTRI)
b. Evaluation of BARC *B* strain (dust formulation) against *Helicoverpa armigera* in transplanted crop (CTRI)
c. Biointensive IPM of *Helicoverpa armigera* in transplanted crop (CTRI)
d. Preliminary evaluation of bird perches in tobacco nurseries against *Spodoptera litura* (CTRI)
e. Evaluation of *Bacillus thuringiensis* against *H. armigera* (GAU)

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 chick pea (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 *Bt* 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. Evaluation of baculovirus of *Oryctes rhinoceros* (CPCRI, TNAU, ANGRAU)
e. Pathogenicity trials with bacterium and NPV against *Rhynchophorus ferrugineus* (CPCRI)
f. 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 (IIHR)
c. Evaluation of *Cryptolaemus montrouzieri* against spiralling whitefly on guava (IIHR)
d. Seasonality of natural enemies of spiralling whitefly in guava (IIHR)
e. Development of dimethoate resistant strain of *Leptomastix dactylopii* (IIHR)

ix. Biological suppression of temperate fruit crop pests

a. Seasonal incidence of San Jose scale and its natural enemies at different altitudes (SKUAST , Dr.YSPUH&F)
b. Seasonal incidence of apple woolly 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. parasitizing 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, SKUAT, GAU, Dr.YSPUHF)
b. Evaluation of *Trichogrammatoidea bactrae* against *Plutella xylostella* on cabbage (IIHR, ANGRAU, MPKV, GAU, Dr.YSPUHF)
c. Evaluation of different formulations of *Bacillus thuringiensis* against *Plutella xylostella* on cabbage (IIHR, ANGRAU, MPKV, GAU, Dr.YSPUHF)

d. Control of *Leucinodes orbonalis* using *Bacillus thuringiensis* on brinjal (IIHR, ANGRAU)
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 the 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 *S* NPV and *Bacillus thuringiensis* in comparison with endosulfan as standard check against *Spodoptera litura* on potato (MPKV)
d. Occurrence of natural enemies of potato tuber moth including pathogens in different seasons (MPKV).

xii. Biological suppression of weeds

a. Evaluation of *Bactra venosana* in suppressing *Cyperus rotundus* (IIHR)
b. Assessment of impact of *Cyrtobogus salviniae* in suppressing *Salvinia molesta* (KAU).
c. Assessment of impact of *Neochetina eichhorniae*, *N. bruchi* and *Orthogalumna terebrantis* in suppressing water hyacinth (AAU, KAU, PAU, MPKV, GAU)

## 12. CONSULTANCY, PATENTS, COMMERCIALISATION OF TECHNOLOGY

Consultancy service was provided on the release technique of *Trichogramma chilonis* on cotton crop against *Helicoverpa armigera* to six persons from M/S Excel Industries, Mumbai, at Dharwad (Karnataka) for one day in September, 1997. Consultancy service is being provided to Government of Pondicherry in the establishment of a Biological control laboratory for the mass production of natural enemies and for this an amount of Rs.15,000/- has been realised.

The knowhow on production techniques of strain of *Trichogramma chilonis* tolerant (physiologically) to endosulfan at 0.07% concentration was sold to M/S Excel Industries, Mumbai for Rs.5,00,000/- on highest tender basis and the staff of M/s Excel Industries Limited, Mumbai trained on maintenance and testing of endosulfan tolerant strain *Trichogramma chilonis* at PDBC, Bangalore (from 17.2.1998 to 19.2.1998). Trainees were also given hands on training on production of *Corcyra cephalonica* and *Trichogramma* in mass production laboratory.

## 13. RAC, MANAGEMENT COMMITTEE, SRC, QRT MEETINGS WITH SIGNIFICANT DECISIONS

### 13.1 Significant decisions made in Second Research Advisory Committee Meeting held on 23rd and 24th September 1997

i. In addition to the core budget of the PDBC, the funding of the projects should be project based (as projected by the scientist) and funds should be delineated project-wise right from the beginning.

ii. The Biosystematics unit was asked to concentrate on Braconidae, Tachinidae, Coccinellidae and Syrphidae. In some of these groups like Coccinellidae and Syrphidae the emphasis on larval taxonomy was to be given. It was also requested that field identification guides be developed for identification of important groups of natural enemies in different crop ecosystems.

iii. The Project Directorate of Biological Control has been acting as a nodal agency for import of natural enemies. A number of agencies are importing bioagents/ biopesticides without any quarantine procedure. As a result, there is a danger of introducing unwanted organisms into the country. Therefore PDBC should be officially recognised as the nodal agency for the import of bioagents / biopesticides on the lines of NBPGR, New Delhi. PDBC should also be the nodal point for export of natural enemies. This is necessary to conserve biodiversity and prevent exploitation of entomophagous biodiversity.

iv. The Project on mass multiplication of reduviids was asked to be deferred for the present till the importance of the reduviids is established in different ecosystems.

v. A quality control laboratory of international standard be established at PDBC to undertake quality testing of biocontrol agents / biopesticides ofinsect pests, diseases and weeds on top most priority.

vi. The Biotechnology laboratory needs to be strengthened, so that the gene responsible for resistance to insecticides can be identified and the strain further utilised for selection and hybridisation. The laboratory was asked to continue the work on artificial diets for host insects and natural enemies.

vii. Mass production of natural enemies requires separate funds and this has to be generated from other sources (revolving fund, from other agencies, NATP, DBT, etc.).

viii. The members of the RAC also felt that the norm of scientists:technician ratio of 1:1.5 may not be strictly adhered to for Project Directorate of Biological Control as there is a greater need for this centre to mass produce several biocontrol agents which call for greater technical manpower.

ix. The members of the RAC unanimously and whole heartedly appreciated the efforts of all the project workers and enforced their commitment to support the research efforts of the Project Directorate.

x. Based on the final allocation of funds by the ICAR to PDBC, the Project workers were requested to moderate their requirements for project funding and project realistic estimates for the same. The projects and the objectives to be achieved were to be prioritised.

**13.2. Significant decisions made in Third Management Committee Meeting held on 24th September 1997**

i. On the appointment of Technical Officer (T-6) (Estate/Farm Officer) and filling up of three technical assistants (T-II-3), the committee after a detailed discussion recommended the proposal with an observation that for the post of Technical Officer (T-6) (Estate/Farm Officer) specific qualification should be defined and the post advertised. While filling the vacant posts the mandatory instructions regarding the vacant posts may be followed.

ii. Approval for the proposal for which the consultancy service to be undertaken by the members of the Institute and the committee approved the proposal.

iii. Post facto approval was given for the parasitoid strain and production process developed at Project Directorate and the Committee approved the proposal of accepting the highest bid for the sale of *Trichogramma chilonis* developed at PDBC. However, a concern was voiced by the members that this had resulted in selling of all rights to the industry, thus excluding the possibility of further distribution of the product to other institutions or agencies. Therefore the following two points were suggested for future consideration.

   a. Exclusive rights of the product developed by the institute should not be sold to any company but the nucleus culture could be made available at a reasonable price to several organisations/ companies who have the capability of mass producing and distribution to the farmers.

   b. The exclusive right of a product may be sold only in the case of contractual research in which case a MOU would have been already signed.

   c. It is therefore necessary to develop further guidelines for such bioagents and their strains.

iv. Placing the recommendation of the Third QRT, and the same was appreciated by the Committee.

v. The Project Directorate has prepared IX Plan Proposals project-wise and the same was appreciated by the committee.

vi. Post facto approval for the appointment of two private doctors Dr.Vishwanath N. Patil, Ganganagar, Bangalore and Dr.P.V.Mahalakshmi, Sanjaynagar, Bangalore as Authorised Medical Attendants for the treatment of employees of Project Directorate of Biological Control, Bangalore w.e.f. 01-04-1997 (PDBC/5-6/Adm./97-98/25250-263 dated 24-4-97) for a period of one year due to urgency and expiry of the earlier appointment order was given.

vii. A proposal for recommendation of construction works for the additional laboratory space through vertical expansion of the existing ground floor was placed before the committee and the Management Committee while appreciating the space constraint requested PDBC to pursue the matter with the Council and to get the administrative approval / expenditure sanction at the earliest.

viii. For acquisition of land for PDBC to conduct field experiments, the Management Committee suggested to explore the possibilities of getting land from the UAS on lease basis. Government of Karnataka could also be approached for getting land for experimental purposes.

ix. Approval for the purchase of furniture and fixtures was given subject to availability of non-recurring grants.

x. In a proposal for additional allocation under loans and advances due to increased staff strength of PDBC, the Management Committee recommended that loans and advances are required to be increased to Rs.12.00 lakhs in view of the facts stated.

**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 were discussed and implemented.

**13.4. Significant recommendations made by the Third QRT**

i. At present PDBC is finding it difficult to conduct field experiments for large scale testing of biocontrol agents on crops. In view of intensification of research on biocontrol, more area will be required by the PDBC in future. Acquisition of cultivable area around Bangalore is costly. The QRT suggested that PDBC may have MOU with UAS, Bangalore, which is adjacent to PDBC, to get field facilities on cost basis. Further, if the PDBC requires any field facilities for the crops not

grown in UAS, Bangalore or existing co-ordinating centres, on similar arrangements PDBC may be allowed to have MOU with SAU and ICAR institutes on cost basis.

ii. As a consequence of liberalisation policy, many new pests, diseases and weeds like subabul psyllid, serpentine leafminer, spiralling whitefly, coffee berry borer, cotton leaf curl, etc. have entered the country. The natural enemies of these pests have to be imported from their native habitat. Therefore, the QRT recommended the establishment of quarantine station with insectary, screen houses, incinerator and other facilities at PDBC to facilitate the import of natural enemies and testing them for the management of pests, diseases and weeds. This may be given top priority. This was also the recommendation of the previous QRT.

iii. A beginning has been made in biological control of plant diseases by the use of antagonistic fungi and bacterium like *Trichoderma* spp., *Gliocladium* spp., *Pseudomonas florescence* and *Chaetomium* spp. for the suppression of soil borne diseases in pulses, oilseeds and plantation crops. There is a need to intensify the research in this area at PDBC. Exploration for new agents at the co-ordinating centres should also be initiated where Microbiologists/Plant Pathologists are located.

iv. There are periodical outbreaks of pests and diseases of crops, including non-mandate crops of ICAR, promoted by various boards like Spices Board, Coconut Board, Cashew Development Board, etc. Recent outbreak of *Helopeltis* on cashew in the West coast and slug caterpillar on coconut in coastal and peninsular India are some of the examples. No concerted efforts have been made to identify the cause for the outbreak of these pests. One of the reasons for outbreaks may be decline of natural enemies of these pests. Hence, it suggested that a closer research linkage should be established between commodity Boards and PDBC for collaborative research in the biological control.

v. In the recent past, a large number of commercial insectaries forproduction of biocontrol agents have come up. The users of biopesticides are finding it difficult to

get the products tested for quality.At present, there are no agencies to certify the quality of biocontrol agents. Therefore, PDBC should establish quality control laboratory and should be made a nodal agency for developing norms and parameters for quality control of bioagents in collaboration with Bureau of Indian Standards and Plant Protection Directorate, Govt. of India.

vi. There has been considerable advancement in technology development in several fields of biological control of pests, diseases and weeds. Acquaintance of know-how experience in these areas increases competency of scientists to undertake research. Therefore, it is suggested that scientists working PDBC should have advanced training in national / international institutes and obtain expertise from international scientists through their visits to PDBC in mechanisation of mass production technology, insect behaviour, biosystematics, insect cell line culturing and genetic engineering.

vii. The research centres of the PDBC should be equipped with mass production facilities based on the expertise available so as to impart training to rural youth and women to create confidence in entrepreneurship. Training for rural youth may be given for self employment or to get employment in areas like production of NPV, *Beauveria, Pseudomonas, Trichoderma, Gliocladium, Metarhizium, Telenomus, Trichogramma, Chrysoperla, Mallada, Cryptolaemus, Chilocorus,* etc. This would help in fulfilling the social obligation of the PDBC.

viii. The QRT recommended the establishment of centres for mass production of biocontrol agents with specific revolving fund. In addition to mass production and selling of bioagents, these centres may also be made responsible for creating awareness among the farmers about beneficial aspect of biocontrol agents. They may also impart training to the officials of the Development Departments, SAUs, NGOs, etc.

PDBC should establish a separate Technology Information Centre to create awareness on all aspects of biological control of insect pests,diseases & weeds by establishing a permanent exhibition depicting technologies transferred or ready for transfer; publish literature, video films, etc., on biocontrol, natural enemies for sale and information about areas where consultancy could be provided.

ix. During the course of interaction with scientists of co-ordinating centres working in ICAR institutions, it was observed that these scientists have been put to great inconvenience for want of needed funds, mobility and sufficient supporting staff in the implementation of programme. This observation was also made by the previous QRT which strongly recommended to remove anomalies. However, this has not been implemented. Therefore, it is once again recommended that funds for centres working in ICAR institutes particularly non-plan areas should be released in the same way as it is being done to SAUs.

x. The information generated on biological suppression of pests including insect, nematodes, diseases and weeds in SAUs, ICAR institutes and other research bodies may be compiled by the Project Directorate of Biological Control and useful information may be passed on to needy institutes and to development departments. This should be a continuous process and needs to be updated every year. The PDBC may take up consultancy services for establishment of biocontrol laboratories in SAUs, commodity bodies and other development departments by preparing project reports including the design of the laboratories, infrastructure requirements, financial outlay and suggestions for streamlining the working of such laboratories.

xi. The PDBC and co-ordinating centres have now grown in their manpower and operational areas with 53 scientists, 101 technicians and 4 supporting and administrative staff with 16 co-ordinating centres operating with approximately Rs.4.5 crores. As the ICAR decided to release the funds to co-ordinating centres through PDBC, there is a strong need for accounts branch with adequate staff at PDBC.

xii. The IARI centre was given the twin objective of working on predators, parasitoids and insect pathogens. Progress made during the period under review at this centre was not up to the mark. Therefore, QRT recommended that the insect pathology work may be deleted from the IARI programme as PDBC has a strong Insect Microbiology unit to do research on all aspects of Insect Pathology. Studies on insect parasitoids and predators may be retained at IARI and entrusted to the competent person in the division.

xiii. The centre at the Indian Institute of Sugarcane Research, Lucknow has has provided with 12 technical persons to assist scientists. The progress made in sugarcane biological control research and extension is not commensurate with supporting manpower. This is because of scattering of the staff at different locations. For effective functioning and implementation of the programmes given to the centre, the technical assistants be consolidated and given a mission mode programme to tackle a problem at a time to get meaningful results.

xiv. During the course of review of work in PDBC, it was made known that very useful biocontrol agents have been recorded from Sikkim on maize. There are no projects on biocontrol of maize pests. Sikkim is one of the leading maize producing states in the country. A centre for exploration and utilisation of natural enemies of maize and vegetable pests may be established in Sikkim.

The previous QRT recommended starting a co-operative centre for biocontrol of locusts and grasshoppers. Since these pests are major production constraints and no work is being undertaken at PDBC currently, it was recommended to establish a centre in Rajasthan.

xv. At present the PDBC has no offshore quarantine centre. Establishment of offshore quarantine stations is requisite for introduction of insect weed killers and fungal pathogens of weeds to overcome the danger of spread of introduced agent. Hence, for all initial evaluation studies of these agents, such a station is most necessary. Therefore, it was recommended to establish a research centre of PDBC in Andaman & Nicobar Islands to make a comprehensive survey of natural enemies and to serve as an offshore quarantine station.

xvi. The previous QRT recommended establishment of eight field stations of PDBC to facilitate the collection of indigenous natural enemies to identify promising ones for evaluation. However, this has not been implemented yet. Therefore, it was once again recommended that these centres should be established in different agro-climatic zones. The establishment of PDBC centres will enhance its capability to favourably negotiate international natural enemy exchange projects.

xvii. There is immediate need for mechanisation of the production of biocontrol agents to meet the increasing demand and to lower cost of production. Therefore, it was recommended to establish an engineering section at PDBC, Bangalore with a scientist qualified in production mechanisation.

xviii. There has been considerable awakening among farmers, extension functionaries of development departments, agro-based industries, entrepreneurs and voluntary organisations on the importance and utilisation of biocontrol agents in pest management. The PDBC has enough trained resource persons to impart training. The QRT recommends establishment of a full fledged training unit at PDBC with necessary infrastructure and staff to organise and conduct training programmes.

## 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 deliberations of Directors' meeting chaired by the Director General, ICAR, New Delhi from 5th to 6th May, 1997.

Participated in the workshop organised by ICAR to fine tune the research programmes pursued under NATP in different thematic areas and presented a full proposal on biological control for discussion during the time of workshop held from 29th May to 3rd June, 1997 at Directorate of Water Management, Patna.

Participated in the Assessment Committee Meeting as an expert member for assessment of scientists for grade promotion by 5-yearly assessment of their performance in Entomology held at Kerala Forest Research Institute, Peechi on 13th August 1997.

Participated in the Institutional Monitoring Committee Meeting of the project entitled 'Development, Production and Demonstration of Biocontrol Agents under IPM' sponsored by the Department of Biotechnology on 30th July, 1997 at UAS, Dharwad.

Participated in the meeting at ICAR on 26th August, 1997 under the Chairmanship of Deputy Director General (CS) and discussed the issues pertaining to Project Co-ordinators of Crop Science Division and participated in the Third Annual Project Co-ordinators Meeting at ICAR, New Delhi chaired by Director General, ICAR, New Delhi on 27th August.

Visited Tunisia from 26th September to 5th October, 1997 as a consultant on biological control of citrus pests under the Indo-Tunis Work plan for co-operation in the field of agricultural research as per the letter received form the Under Secretary to the Govt. of India, New Delhi vide letter No.11-76/96-IC. III dated 18th September, 97 and submitted a consultancy report.

Participated in the First International Conference on Parthenium Management held at University of Agricultural Sciences, Dharwad during October 6-8, 1997 and presented an invited paper entitled 'Perspectives in biological control of *Parthenium* in India' and chaired the session on Management of Parthenium Through Pathogens.

Participated in the First National Symposium on Pest Management in Horticultural Crops: Environmental Implications and Thrusts (October 15-17, 1997), Bangalore and chaired a Session on Biological Control and its Ecological and Economic Implications.

Participated in the Project Screening Committee Meeting for Entomology Projects chaired by DDG (CS) on 5th and 6th November 1997 at NCIPM, IARI Campus, New Delhi.

Participated in a meeting with Director General, ICAR on 13th November 1997 at ICAR and made a brief presentation of the Biological Control Programmes in the Country to the visiting team from Kenya lead by Dr.Hans R. Herren, Director General, International Centre for Insect Physiology and Ecology, Nairobi.

Participated in the International Conference on Ecological Agriculture : Towards Sustainable Development held from 15th to 17th November 1997 at Chandigarh and presented a lead paper entitled 'Bioagents-pesticides interaction'.

Participated in the Institutional Management Committee Meeting of the DBT project entitled "Development, Production and Demonstration of Biological Control Agents under IPM" on 21st November 1997, University of Agricultural Sciences, Dharwad.

Participated and chaired the Session-V (Insect Pests) on 29th November 1997 in the Group discussion of the Scientists of AICRP on Tropical Fruits held at University of Agricultural Sciences, Dharwad from 27th to 30th November, 1997.

Participated in the 3rd IFOAM-ASIA Scientific Conference and General Assembly 'Food Security in Harmony with Nature' during 1st - 4th December, 1997 at UAS, Bangalore, India, Chaired session No.5 on 'Biological Methods'.

Participated in the Management Committee Meeting of the National Centre for Integrated Pest Management (NCIPM), IARI Campus, New Delhi on 10th December 1997.

Participated in the National Seminar on Plant Protection towards Sustainability on 22nd December 1997 at National Plant Protection Training Institute, Rajendranagar, Hyderabad and presented a lead paper entitled "Biological control in India".

Participated in the meeting called by DDG (CS) for discussing the IX Plan and NATP at the Central Research Institute for Jute and Allied Fibres (CRIJAF), Barrackpore, Calcutta from 26th to 29th December 1997.

Participated in the meeting called by the DDG (CS) for discussing an effective work plan for speedy implementation of various provisions as per the stipulations of the Memoranda of Understanding signed between ICGEB and ICAR on 8th January, 98 at ICGEB, New Delhi. As a result of participation PDBC has been identified as a centre for testing cry 5 proteinof *Bt* against 5 key pests of crops. The issue of protoplasm fusion was also raised which has opened up several possibilities of collaboration between ICGEB and PDBC scientists.

Participated in the Cane Development Seminar organised by Harinagar Sugar Mills Limited, West Champaran District, Bihar on 11th February, 98. During the seminar suggestions on integrated pest management were given to the farmers.

Participated in the meeting called by ADG(CC) on 24th February 1998 to formulate strategies for management of *Helicoverpa armigera* on cotton, pulses, oilseeds and other crops.

Participated in the Directors' meeting chaired by Director General, ICAR, New Delhi on 4th and 5th March 1998, held at NBPGR Auditorium, New Delhi.

Participated in the brainstorming session on IPM (NATP) at NCIPM, IARI, New Delhi which was chaired by Dr.M.D.Pathak on 16th March, 98.

Delivered a key note address entitled 'Current Scenario of Integrated Insect Pest Management in Cotton for Sustaining Productivity' at the Annual Meet of Alumni Association of College of Agriculture, Punjab Agricultural University, Ludhiana on 17th March 1998.

Participated in the Departmental Promotion Committee as an Expert Member duly constituted by the Council vide letter dated 8.9.97 and assessed the scientists in the discipline of Agricultural Entomology for promotion to higher grades under the career advancement scheme at NRC for Cashew, Puttur on 17th October, 1997.

Acted as paper setter-cum-examiner for the Ph.D qualifying examination held from 20th June 1997 conducted by Mysore University, Mysore.

Conducted qualifying examination of Mr.V.N.Patel, Ph.D. Student of the Department of Entomology, UAS, Bangalore.

Participated in the training programme on Managing Higher Sugarcane Productivity, June 14-17, 1997 held at Gateway Hotel, Residency Road, Bangalore for the Senior Managerial Personnel of Sugarcane factories.

Mr.P.Sreerama Kumar participated in

First International Conference on Parthenium Management held at University of Agricultural Sciences, Dharwad during October 6-8, 1997.

Dr.P.L.Tandon participated in

A Seminar on World Food Summit, Rome Declaration on World Food Security and World Food Summit Plan of action with particular reference to food security in India and Karnataka on 17.2.1997

First National symposium on Pest Management in Horticultural Crops; Environmental implications and thrusts held during 15-17th October 1997.

Workshop on Karnataka's Agricultural Policy and Food Security, organised by ACTION AID, India at Bangalore on 27th October 1997 and took part in discussions.

Dr.N.Bakthavatsalam attended

First National symposium on Pest Management in Horticultural Crops; Environmental implications and thrusts held during 15-17th October 1997.

Ms.Chandish.R.Ballal attended

First National symposium on Pest Management in Horticultural Crops; Environmental implications and thrusts held during 15-17th October 1997.

**Central Plantation Crops Research Institute, Kayangulam**

Dr.B.Sathiamma, Senior Scientist (Ent.) attended

The Sixth Biocontrol Workers' Group Meeting at PDBC, Bangalore on 19.6.97 and 20.6.97.

The Doctoral Committee meeting at the Department of Zoology, University of Kerala, Kariavattom, Kerala on 3.6.97.

Mrs.Chandrika Mohan, Scientist - Senior Scale (Entomology) attended

The Karshaka Seminar held at Allapuzha under the auspices of Department of Agriculture, Kerala on 24.3.97.

The Ernakulam District Agricultural Seminar held on 19.7.97 at North Parur.

Dr.Murali Gopal, Scientist (Microbiology) attended

The International Conference on Frontiers in Biotechnology on November 26-29, 1997 held at Regional Research Laboratory, Thiruvananthapuram.

**Central Tobacco Research Institute, Rajahmundry**

Shri.S.Sitaramaiah, Senior Scientist (Biocontrol) and Shri.S.Gunneswara Rao, Scientist (Biocontrol) attended II QRT Meeting of AICRP on Biological Control of Crop Pests and Weeds at Bangalore on 5.3.1997.

Shri S.Sitaramaiah, Senior Scientist and Shri S.Gunneswara Rao, Scientist participated in the Sixth Biocontrol Workers' Group meeting held at PDBC, Bangalore from 19th to 20th June 1997.

Shri S.Sitaramaiah, Senior Scientist and Shri S.Gunneswara Rao, Scientist attended a National Seminar on Present Scenario on Insecticide Resistance in *Helicoverpa* and Pesticidal Application Technology at Secunderabad on 20th December 1997.

Shri S.Gunneswara Rao, Scientist attended a National Seminar on Plant Protection towards sustainability at NPPTI, Hyderabad from 22nd to 24th December 1997.

**Indian Institute of Horticultural Research, Bangalore**

Dr.M.Mani, Dr.K.P.Jayanth, Dr.C.Gopalakrishnan and Dr.A.Krishnamoorthy attended and presented papers at the First National Symposium on Pest Management in Horticultural Crops: Environmental Implications and Thrusts held at the Institution of Agricultural Technologists, Bangalore during October 15-17, 1997.

Dr.K.P.Jayanth attended and presented a paper at the First International Conference on Parthenium Management held at the University of Agricultural Sciences, Dharwad during October 6-8, 1997.

Dr.A.Krishnamoorthy and Dr.M.Mani attended and presented a paper at the National Symposium on Citriculture, 17-19 November,1997, Nagpur.

Dr. M. Mani acted as External Examiner for a Ph.D. student in Zoology at Shivaji University, Sholapur and Bharathiar University, Coimbatore in 1997.

Dr. M. Mani acted as External Examiner for PG students in Agricultural Entomology at UAS, Dharwad and TNAU, Coimbatore in 1997.

Dr.M. Mani participated in 'Brain Storming Session on Research Requirement of Grape Production, Export and Processing for 21st Century' on 16th September, 1997 at IIHR, Bangalore.

Dr.M. Mani, Dr.K.P. Jayanth, Dr. A. Krishnamoorthy and Mr. C. Gopalakrishnan attended the Sixth Group Meeting of the Biocontrol Workers held at PDBC, Bangalore on 19th and 20th June, 1997.

**Acharya N.G.Ranga Agricultural University, Hyderabad**

Smt.Ramila Saxena, Asst. Entomologist participated in

Bimonthly T & V meetings organised by APAU for the Officers of the State Department of Agriculture

Krishi Vigyana Sadassu held at Medchal (Ranga Reddy) on 13-6-97.

Sixth Biocontrol Workers' Group Meeting held at Bangalore on 19-6-1997 and 20-06-1997.

At Regional Agricultural Research Station at Lam (Guntur) on 4-10-97.

At Agricultural Research Station (Warangal) on 7-10-97.

Krishi Vigyan Sadassu held at Agricultural Research Institute, Rajendranagar from 24-11-97 to 25-11-97.

Dr.P.Swarna Sree, Asst. Entomologist participated in

Kisan Mela conducted at Tandur on 22-1-97.

Kisan Mela conducted at Maize Research Station, Amberpet on 26-2-97.

Pre-ZREAC meeting at RARS, Palem on 20-3-97

ZREAC meeting at ARS Sangareddy from 10-4-1997 to 11-4-1997

The discussion regarding cotton experiments with Entomologist at Regional Agricultural Research Station, Lam (Guntur) on 3.5.1997.

Implementation of cotton experiment of 1997-98 at Agricultural Research Station (Warangal) on 14-10-1997.

Kisan Mela conducted at Maize Research Station, Amberpet from 20-11-1997 to 21-11-1997.

Krishi Vigyana Sadassu held at Agricultural Research Institute, Rajendranagar from 24-11-1997 to 25-11-1997.

Bimonthly T & V meetings organised by APAU for the Officers of the State Department of Agriculture.

**Gujarat Agricultural University, Anand**

Dr. D.N.Yadav attended

Farmers' mela organised jointly by Directorate of Extension, and Biocontrol Laboratory at Anand.

Dholka on 2.5.97 for sugar cane pest management.

Kothamba on 21.8.97, Panchmahal (Backward District of Gujarat) on paddy pests

Bodeli(Vadodara dist.) on cotton pests management on 3.9.97

Ukardi na muvada(Kapadvanj taluka)for cotton growers on 13.9.97

Bethali(Vadodara dist.) for cotton growers on 5.12.97

Veena village of Nadiad taluka on tobacco pest management on 18.12.97

**Kerala Agricultural University, Vellanikkara**

Dr.(Ms.)S.Pathummal Beevi, and Ms.K.R.Lyla participated in the 6th Biocontrol Workers' Group meeting held at PDBC, Bangalore from 19th to 20th June 1997.

**Punjab Agricultural University, Ludhiana**

Dr.D.R.C.Bakhetia attended

The meeting of Staff Research Council, NRCRM (ICAR), Bharatpur, April 30,1997.

The meeting of Staff Research Council, NRCG (ICAR),Junagarh, May 8-9,1997.

Sixth Biocontrol Workers' Group Meeting of All India Coordinated Research Project on Biological Control of Crop Pests and Weeds at PDBC, Bangalore, June 19-20,1997.

One day seminar on Cotton leaf curl at CIPHET, Abohar arranged by CICR, Nagpur; August 25,1997.

The fourth Annual "Rapeseed Mustard Group Meeting", Anand (Gujarat); August 29-31,1997. Chaired session IV (Planning and Technical Programme formulation).

The National Seminar on "Insect and Environment" at Punjab University Chandigarh, September 18-20, 1997 and presented two research papers.

A seminar on "Fibre and food requirement of Pakistan in the first decade of 21st Century", University of Faisalabad (Pakistan), November 25-26,1997.

A workshop on "Status and scope of using Biopesticides / Bioagents in Agriculture in the Punjab", PAU, Ludhiana on December, 17,1997.

Dr.Maninder

Attended "International Conference on Ecological Agriculture: Towards Sustainable Development', at Chandigarh; November 15-17,1997.

**Dr.Y.S.Parmar University of Horticulture and Forestry, Solan**

Dr.P.R.Gupta participated in

Sixth Biocontrol Workers' Group meeting at PDBC, Bangalore on June 19-20, 1997

First National symposium on pest Management in Horticultural Crops : Environmental Implication and Thrusts organised by Association for Advancement of Pest Management in Horticultural Ecosystems, in Bangalore during October 15-17, 1997 and presented a paper.

## 15. WORKSHOPS, SEMINARS, SUMMER INSTITUTES, FARMERS' DAY, etc., ORGANIZED BY THE PROJECT DIRECTORATE

Sixth Biocontrol Workers' Meeting was organised on 19-20, June 1997 at Project Directorate of Biological Control, Bangalore.

A Farmers' mela and exhibition were arranged on 16th July and the first consignment of the exotic parasitoid *Diglyphus begini* was released. This parasitoid has been imported from California, USA, for the biological suppression of the leaf-miner, *Liriomyza trifolii* on castor, vegetable and ornamental crops. A leaflet containing all the relevant information on *Diglyphus begini* was also released during this occasion. The proceedings of the day were chaired by Prof.G.K.Veeresh. Vice Chancellor, UAS, Bangalore.

**Celebration of golden jubilee of India's Independence at PDBC**

Monthly celebration programmes will be continued till 15th August 1998. The following programmes were conducted till 31-03-1998.

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| 15.08.1997 | Mass pledge to serve the Nation, Video films were shown pertaining to the theme |
| 16.08.1997 | Organised Hindi Seminar on the topic entitled "*Jaivik Niyantran Ki Saphaltayen*" |
| 16.09.1997 | Seminar on Management of Agriculture Institutes/ Stations and Research Project Planning, Appraisal, Resource, Smoothing, Monitoring and Evaluation and Management of Information System for Agriculture Research. |
| 16.10.1997 | Seminar on "Special Statistical Techniques in Biological Sciences and "An overview of Developing and Writing a Research Proposal for NATP". |

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| 16.11.1997 | Quami Ekta Week celebrations. All staff members and their families participated. |
| 16.12.1997 | Seminar on "Pest Management in Horticultural Crops: Environmental Implications and Thrusts" and MSTATC in Statistical Analysis. |
| 16.01.1998 | Organised a quiz programme on insects for XI and XII class students. Fiveteams participated and the winning teams were given prizes. |
| 16.02.1998 | Seminars on "Taxonomy of entomopathogenic nematodes with special reference to Steinernematidae and Heterorhabditidae" and "Biological Control of *Agrotis* spp. with entomophilic nematodes". |
| 16.03.1998 | Seminar on Methods of culturing entomopathogenic nematodes (*in vivo/in vitro*), Methods of work with Entomophilic Nematodes and Biological control of *Chilo partellus* using entomopathogenic nematodes. |

## 16. DISTINGUISHED VISITORS

**Project Directorate of Biological Control, Bangalore**

Dr.Mangala Rai, Deputy Director General (CS), ICAR, New Delhi visited on 17th April 1997.
Dr.Chermiti Brahim, Ecole Superieure d'Horticulture de Chott Merium-4042, Tunisia visited on 13th - 15th May 1997.
Dr.R.S.Kanwar, Former Additional Director of Research, Punjab Agricultural University, Ludhiana on 17th June 1997.
Dr.Amita Biswas, Department of Biotechnology. Ministry of Science and Technology, Government of India, New Delhi visited on 26th June 1997.
Ms.Natalie Daalder, Country Manager, ACIAR from the Australian High Commissioner's Office in New Delhi visited on 27th June 1997.
Dr.Robert D.Lumsden and Dr.K.P. Hebbar, Biocontrol of Plant Diseases Laboratory, USDA, Beltsville, Maryland, US visited on 28th June 1997.
Dr.S.T.Murphy, International Institute of Biological Control, Silwood Park, Ascot, Berkshire, UK visited on 7th July 1997.
Dr.S.W.Adkins, Dr.K.Dhileepan and Dr.S.W.Dearden, Scientists from University of Queensland, Australia and Dr.H.C.Evans, Dr. (Ms.) M.K.Seir and Dr. (Ms.) Jo L.Harvey from International Institute of Biological Control, London, United Kingdom visited on 10th October 1997.

Dr.Balakrishna.R.Rao, Professor of Biology and Entomology, East Strassberg, USA visited on 24th October 1997.

**Central Plantation Crops Research Institute, Kayangulam**

Justice Sukhdev Singh Kang (Retd.), His Excellency Governor of Kerala.
Shri.V.J. Kurien, IAS., Managing Director, Cochin International Airport Limited
Justice V.P.Singh, Hon'ble Chief Justice of Kerala
Justice J.S.Verma, Hon'ble Chief Justice of India
Dr.Phil Jones, Rothamsted Experimental Station, Harpenden, U.K.
Mr.M.N.Manjunath, IAS, ADC to Her Excellency Governor of Tamil Nadu
Dr.S.Venugopalachari, Hon'ble Minister of State for Agriculture, Government of India
Dr.H.P.Singh, Director, NRC for Banana, Thiruchirappalli, Tamil Nadu
Shri Mallikarjunappa, Member of Parliament
Dr.D.R.Prafulla Chandra Shimoga, Member, Coconut Development Board.

**Assam Agricultural University, Jorhat**

Dr.R.S.Paroda, Director General, ICAR, New Delhi visited the biocontrol laboratory on 29th December 1997

**Acharya N.G.Ranga Agricultural University, Hyderabad**

Dr.T.Bapi Reddy, Associate Director of Research, Regional Agricultural Research Station, Palem visited on 8.1.97
Visitors from Sri Lanka and ICRISAT visited during January 1997
Dr.C.Raja Reddy, Director of Research, ANGRAU visisted on 14.2.97 and 8.7.1997

**Gujarat Agricultural University, Anand**

Dr.K.Nagarajan, Director, CTRI, Rajahmundry visited on 3-3-97
DR.R.N.Chowdhary, IGFRI, Jhansi visited on 5-5-97
Dr.C.P. Enth, ICAR, New Delhi visited on 22-5-97
Dr.D.N. Moga, Director of Campus, Sardar Krishi Nagar, GAU, Gujarat visited on 11-7-97
Dr. Mangala Rai, DDG, ICAR, New Delhi visited on 30-8-97
Dr.D.R.C.Bakhetia, Professor and Head, Department of Entomology, PAU, Ludhiana visited on 31-8- 97
Dr.J.S. Yadav, PC (R&M), New Delhi visited on 31-8-97

Dr.G.S. Sachan, Professor of Entomology, G.B.Pant University of Agriculture and Technology, Pantnagar visited on 31-8-97
Dr.R.P.S.Alhawat, Director of Research, GAU, Ahmedabad visited on 2-9-97
Dr.G.S.Sandhu, Res. Scientist (Oilseeds), PAU, Ludhiana visited on 31-9-97
Dr.H.N.Saiyed, Director, NIUH, Ahmedabad visited on 24-9-97
Sh.L.K.Menn, Prof. Agronomy, KARI, Kenya visited on 30-11-97
Sh.C.M.Mtery, Professor, Plant Breeding, KARI, Kenya visited on 30-11-97

**Kerala Agricultural University, Thrissur**

QRT-PDBC team consisting of Dr. G.K.Veeresh, Vice-Chancellor, UAS, Bangalore; Dr. S. Lingappa, Head, Department of Entomology, UAS, Dharwad and Dr. O.P. Bhalla, Retired Head, Department of Entomology, YSPUH & F, Solan visited on 21st January 1997.
Dr.S.P.Singh, Project Director, PDBC, Bangalore visited on 19th July 1997.

**Mahatma Phule Krishi Vidyapeeth, Pune**

Dr.R.S.Deshmukh, Director of Research, Mahatma Phule Krishi Vidyapeeth, Rahuri and Prof.V.S.Dhamal, Associate Director of Research, NARP (PZ), Pune visited on 28th July 1997
His Excellency Dr.P.C.Alexander, Governor of Maharastra visited the biocontrol laboratory on 5th September 1997

**Punjab Agricultural University, Ludhiana**

Dr A.K. Raheja, Assistant Director General (PP), ICAR,New Delhi.
Dr S.P. Singh, Project Director, Project Directorate of Biological Control,Bangalore.
Dr G.C.Tewari, Principal Scientist (Agri. Entomology), ICAR, New Delhi.
Dr O.P. Lal, Head, Division of Entomology, IARI, New Delhi.
A Delegation from Federal Government of Nigeria comprising Dr.E.O.Guang, Vice-Chancellor,UAM, Nigeria, Dr T.O. Okolo, Head of unit, NSS, Nigeria, Dr B.A.Kalu, Dean, College of Agronomy, UAM, Nigeria, Dr A.A.Ohjo, Plant Breeder, UAM, Nigeria, Dr. J.C.Umeh, Economist, UAM Nigeria, Dr L.L.Belo, Plant Breeder,UAM, Nigeria, Dr. M.O.Obsali, Agronomist,UAM, Nigeria, Dr S.U. Irtwange,Engineer,UAM,Nigeria.
A High level Delegation from Iraq comprising Dr. Abdullah Najam Abdallah Al-Ani,Under Secretary of the ministry, Dr Naqid Abdul Ridha, Director General of the State Commission for checking and arresting seeds, Dr Hussain Fawzi, Director General of the "Mabaiyna Al Nahrain" company for producing and improving seeds, Dr Bassim Abdul Hameed Al-

Samarrai, Director General of State Commission for organizing Agricultural Investments, Mr Jabbar Hassan Hashim, Director of Agriculture in Babylon Government.
Dr Hugh D. Loxdale, Principal Research Scientist, Entomology and Nematology, ICAR, Rothamsted, U.K.

## 17. PERSONNEL

**Project Directorate of Biological Control, Bangalore**

| | |
|---|---|
| Dr.S.P.Singh | Project Director |

**Biosystematics, Introduction and Quarantine laboratory**

| | |
|---|---|
| Mr.B.S.Bhumannavar | Senior Scientist (Agri. Entomology) & laboratory Chief (on study leave w.e.f.17-09-1997) |
| Mr.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 Behaviour 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) |

**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 (Agri. Entomology) |
| Ms.Chandrika Mohan | Scientist SS (Agri. Entomology) |
| Dr.Murali Gopal | Scientist (Agri. Microbiology) |

**Central Tobacco Research Institute, Rajahmundry**

| | |
|---|---|
| Mr.S.Sitaramaiah | Senior Scientist (Agri. Entomology) |
| Mr.S.Gunneswara Rao | Scientist (Agri. Entomology) |

**Indian Agricultural Research Institute, New Delhi**

| | |
|---|---|
| Dr.K.L.Srivastava | Senior Scientist (Agri. Entomology) |

**Indian Institute of Horticultural Research, Bangalore**

| | |
|---|---|
| Dr.M.Mani | Senior Scientist (Agri. Entomology) |
| Dr.A.Krishnamoorthy | Senior Scientist (Agri. Entomology) |
| Dr.K.P.Jayanth | Senior Scientist (Agri. Entomology) |
| Mr.C.Gopalakrishnan | Scientist SS (Plant Pathology) |

**Indian Institute of Sugarcane Research, Lucknow**

| | |
|---|---|
| Dr.N.K.Tewari | Senior Scientist (Agri. Entomology) |
| Dr.R.K.Tanwar | Scientist (Agri. Entomology) |

**Sugarcane Breeding Institute, Coimbatore**

| | |
|---|---|
| Dr.S.Easwaramoorthy | Senior Scientist (Agri. Entomology) |
| Mr.J.Srikanth | Scientist (Agri. Entomology) |

**Assam Agricultural University, Jorhat**

| | |
|---|---|
| Dr.A.Basit | Professor (Agri. Entomology) |
| Mr.B.Bhattacharya | Asst. Professor (Agri. Entomology) |

**Acharya N.G.Ranga Agricultural University, Hyderabad**

| | |
|---|---|
| Ms.Ramila Saxena | Assistant Entomologist (Agri. Entomology) |
| Dr.P.Swarna Sree | Assistant Entomologist (Agri. Entomology) |

**Gujarat Agricultural University, Anand**

| | |
|---|---|
| Dr.D.N.Yadav | Principal Research Scientist (Agri. Entomology) |
| Dr.D.M.Mehta | Associate Research Scientist (Agri. Entomology) |
| Mr.J.J.Jani | Associate Research Scientist (Agri. Entomology) |

**Kerala Agricultural University, Vellanikkara, Thrissur**

| | |
|---|---|
| Dr.P.J.Joy | Professor (Agri. Entomology) |
| Dr.(Ms.)S.Pathummal Beevi | Associate Professor (Agri. Entomology) |
| Dr.K.R.Lyla | Asst. Professor (Agri. Entomology) |

**Mahatma Phule Krishi Vidhyapeeth, College of Agriculture, Pune**

| | |
|---|---|
| Prof.B.G.Awate | Entomologist |
| Dr.Dhoble Shivaji Yashavant | Entomologist |
| Dr.D.S.Pokharkar | Asst. Entomologist |

**Punjab Agricultural University, Ludhiana**

| | |
|---|---|
| Dr.Maninder Shenhmar | Entomologist |
| Mr.Jagmohan Singh | Assistant Entomologist |

**Sher-e-Kashmir University of Agricultural Science & Technology, Srinagar**

| | |
|---|---|
| Dr.G.M.Zaz | Associate Professor (Agri. Entomology) |
| Mr.Abdul Majid Bhat | Assistant Professor (Agri. Entomology) |

**Tamil Nadu Agricultural University, Coimbatore**

| | |
|---|---|
| Dr.M.Swamiappan | Professor (Agri. Entomology) |

**Dr. Y. S. Parmar University of Horticulture & Forestry, Nauni, Solan**

| | |
|---|---|
| Dr.Prem Raj Gupta | Entomologist |
| Dr.Anil Sood | Assistant Entomologist |

**Govind Ballabh Pant University of Agricultural Sciences & Technology, Pantnagar**

| | |
|---|---|
| Dr.U.S.Singh | Associate Professor (Plant Pathology) |

## 18. ANY OTHER RELEVANT INFORMATION SUCH AS SPECIAL INFRASTRUCTURAL DEVELOPMENT

### Equipments

The laboratories were further strengthened during 1997-98 with scientific instruments like Fermenter (30 l cap.), Basket centrifuge, Compound research microscope, Stereozoom binocular microscope, Freeze drier, Highly Sensitive Electronic Balance, Millepore water purifying system, GC/MS/DS, Climatic chamber, BOD Incubators (CFC Free), Image analysis system, Programmable autoclave, Vacuum concentrator, Spectrophotometer, Growth chamber etc. The centres have acquired need based equipments and other necessary facilities.

### Library

The library has a collection of 1,422 books, 906 volumes of journals, 22 bulletins and several miscellaneous publications including several reprints on various aspects of biological control. Nine foreign journals and several Indian Journals have been subscribed . For quick and efficient literature search CD-ROM (Compact Disc- Read Only Memory) is provided with CABPESTCD abstracts upgraded up to February, 1998.

### Technical Documentation

Colour laser printer, Replacement of old and defective Fax machine were added to the technical cell for documentation work as well as for quick communication.

**Aris Cell**

The local server of Aris for PDBC was established with 7 nodes and VSAT was procured.

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" was brought out.

**National Repository of Natural enemies**

Establishment of a National Repository of Natural Enemies is underway with the funds obtained from by Department of Biotechnology, Government of India, New Delhi.

**Buildings**

Ground floor of the main laboratory building was completed at a cost of Rs.52,12,500/- and the same was inaugurated on 9th May 1997 by Dr.R.S.Paroda, Secretary, DARE & Director General, ICAR. Administrative and financial approval has been given for the proposal of constructing first floor on the same building and 33% of the cost estimate has been deposited with CPWD for continuing the work.

A building with two floors has been completed opposite to the existing old laboratory at a cost of Rs.23,78,219/- and was inaugurated on 9th May 1997 by Dr.R.S.Paroda, Secretary, DARE & Director General, ICAR. ARIS Cell and the Committee room were established in the ground floor. First floor and second floor house pathology laboratory in which various units like insect pathology, fungal and bacterial antagonists, weed pathology and entomophilic nematodes are located.

A generator room at a cost of Rs.2,97,660/- was completed to house a 100 KVA Generator.

Erection of a 250 KVA transformer with HT installation and internal cable distribution costing Rs.33,76,000/- is under process - CPWD will soon complete this work .

# 19 निष्पादित सारांश

## 19.1 मौलिक अनुसंधान

### परियोजना निदेशालय जैविक नियंत्रण, बेंगलोर

तेरह परपोषी कीटों, बीस परजीवियों एवं सात कीटभक्षक कीटों का संवर्धन लगातार किया गया।

प्रतिवेदन काल के दौरान, अनेक परपोषी कीटों के 59 संवर्धनों और प्राकृतिक शत्रुओं के 80 संवर्धनों को समवर्गीय केन्द्रों एवं अन्य अनुसंधान संगठनों को भेजा गया। **ट्राइकोडर्मा हरजिएनम** के निरूपण को 6 समवर्गीय केन्द्रों को भेजा गया।

**लिरयोमाइजा ट्राइफोली** के परजीवी कीट **डिग्लीफस बेगिनि** को केलिफोर्निया से मंगाया गया। इस परजीवी कीट को संगरोध परिस्थिति में सफलतापूर्वक पाला गया तथा नेट हाउस परीक्षणों में इन परजीवी कीटों की सफलतापूर्वक पुनः प्राप्ति की गयी। इन परजीवी कीटों को क्षेत्रों में छोड़ा गया, किन्तु अभी तक पुनः प्राप्ति नही हो पायी।

जैवसैद्धान्तिक अध्ययन के अंतर्गत कीटभक्षक कीट **कोक्सिनेलिड्स** के ग्यारह वंशों एवं पांच समुदायों के अंतर्गत आने वाली तीस जातियों का जैवसैद्धांतिक अध्ययन किया गया। दो जातियों को निर्दिष्ट किया गया जो कि **स्युडोकिम्नस चेपिन** एवं **सीरेन्जियम ब्लैकबर्न** वंशों के अंतर्गत आती है। **कोक्सिनेलिड्स** की टिप्पणी युक्त जांच सूची एवं **कोक्सिनेलिड्स** जैव विभिन्नता के आंकड़ों का संकलन जातीय आधार पर किया जा रहा है।

**हेलिकोवर्पा आर्मिजेरा** को पालने के लिए एक एक्रेलिक बहुकोशिकीय इकाई निर्मित की गयी। यह इकाई पारदर्शी, स्वदेशी, सस्ती, सतह निर्जर्मिकरण के लिए आसान, टिकाऊ एवं उत्तरजीविता 80 से 90% तक प्रदान करती है।

**इस्किओडोन स्कुटेलेरिस** के जीवन चक्र प्राचल, प्रयोगशाला में **एफिडोफेगस सिरफिड्स** को दो विभिन्न पालने की इकाईयों पर निर्धारित किया गया है।

**केम्पोलेटिस क्लोरिडे** की मादाओं के पहचान लक्षणों के अध्ययन में पाया गया कि जिन कोकुनों की लम्बाई (ल.) 6.5 मिमी. से अधिक, वजन (व.) 10.5 मिग्रा. से अधिक, ल. x त्रिज्या (त्रि.) 16.5 से अधिक, ल. x व. 70 से अधिक, व. x त्रि. 30 से अधिक, ल. x व. x त्रि. 180 से अधिक तथा व./त्रि. 4.4 से अधिक हो तो निश्चित रूप से मादाओं की प्राप्ति पायी जायेगी।

**हेलिकोवर्पा आर्मिजेरा** के पंख शल्क, **क्रायसोपरला कारनीया** के लारवों की कीटभक्षक क्षमता को बढ़ाने के लिए उच्च कोटी का कारक पाया गया।

सूर्यमुखी की विभिन्न प्रजातियों की कलियों के जाति मार्डन के हेक्सेन घोल **ट्राइकोग्रामा किलोनिस** के प्रौढ़ों को आकर्षित करता है। निरीक्षण में पाया गया कि कली का घोल (सायनोमोन) के द्वारा सर्वाधिक (52%) अनुक्रिया होती है।

**ट्रा. किलोनिस** के ग्रहणशील विभेद् की अपेक्षा एण्डोसल्फान सहिष्णुता विभेद् परजीवी **हे. आर्मिजेरा** के अण्डों को एण्डोसल्फान के छिड़काव के तुरन्त बाद 3% की अपेक्षा 56% तक परजीवित करते हैं और छिड़काव के 5 दिनों के बाद सहिष्णुता विभेद् में परीजीविता तथा अविर्भाव अधिक पाया गया।

**क्रायसोपरला कारनिया** को **इनविट्रो** में पालने के लिए सोयाबीन जलअपघटित पाउडर आधारित आहार (0.2 ग्राम) अतिउत्तम पाया गया है।

उपभोग संभाव्यता **इनविट्रो** में तथा कोरसेरा पर पाले गये **क्रा. कारनिया** के लिए **हे. आर्मिजेरा** के अण्डें एवं **एफिस गोसीपी** आहार उत्तम पाये गये। **काइलोमीनस सेक्समेकुलेटा** पालने के लिए सूअर के यकृत पेस्ट आधार एक अर्द्धसंश्लेषित आहार उत्तम पाया गया है।

जननांगीय तंत्रों के मोमीय-काग लक्षणों की बाह्य अभिव्यक्ति आधार पर **हे. आर्मिजेरा** एवं **स्पोडोप्टेरा लिट्यूरा** से जनद् विशिष्ट विषाणुओं को एकत्र किया गया।

तीन सौ सूर्यमुखी राइजोस्फियरिक जीवाणुवीय पृथक्करणों को **स्क्लेरोशियम** एवं पी डी बी सी नं. 19 (**स्युडोमोनाज प्युटिडा** ?) के प्रतिरोधी प्रतिक्रिया के लिए परीक्षण किया तो पाया कि **स्के. रोल्फसाई** दोनों संवर्धनों में पूर्ण अवरोध वृद्धि करता है।

**ट्राइकोडर्मा** एवं **ग्लॉयक्लेडियम** स्पे. के 100 से अधिक वियुक्तों को, जो कि रोगाणुवीय कवकों के प्रति प्रतिकारक संभाव्यता दिखाते हैं, मृदा प्रतिदर्शों **राइजोस्फियर** एवं **राइजोप्लेन** से वियुक्त किये गये।

**ट्राइकोडर्मा** स्पे., **ट्रा. हरजिएनम** से पी डी बी सी टी एच 2 एवं **ग्लॉयक्लेडियम विरेन्स** पृथक्क किये गये, इनमें से पृथक किये गये **ग्लॉयक्लेडियम** द्वारा **स्के. रोल्फसाई** के माइसिलिअल विकास के सर्वाधिक अवरोधक परिणाम प्राप्त हुए।

**स्टेइनरनेमा** स्पे. 107 से 2200 मि. की उत्कर्ष प्रसर पर पृथक किये गये तथा बालू दोमट एवं क्ले दोमट मृदा में प्रयोग के लिए सर्वोत्तम पाये गये। एक वियुक्त पी डी बी सी ई एन 6.11 को निवेशित करने के एक दिन के अन्दर ही **एलूटेल्ला जाइलोस्टेल्ला** एवं **ओपिसिना एरेनोसेल्ला** के लारवे मर गये तथा **हे. आर्मिजेरा, स्पो. लिट्यूरा** एवं **कोरसेरा सीफेलोनिका** के लारवे निवेशित करने के दो दिन के अन्दर मर गये।

**मीलॉयडोगाइन इन्कोग्निटा** के प्रति **ट्रा. कोनिन्गी, ट्रा. हरजिएनम,** पी डी बी सी टी एच 2, **ग्ला. विरेन्स** एवं **ग्ला. डेलिक्वेसेन्स** 94.5% तक घातक सिद्ध हुए।

कर्नाटक में पार्थेनियम रोगों की व्यापकता एवं गहनता के क्षेत्रीय सर्वेक्षण में अनेक पर्ण धब्बे/चित्तीजनक

रोगाणु ग्रस्त थे जो कि **अल्टरनेरिया, कोलेटोट्रिकम, फ्युजेरियम, स्कलेरोशियम रोल्फसाई, स्कलेरोटिनिया स्कलेरोटिओरम** एवं अन्य रोगाणुओं से ग्रस्त पाये गये। अनेक स्थानों पर फाइलोडी के कारण पार्थेनियम पौधे प्रचंड रूप से क्षतिग्रस्त पाये गये। पत्ती मोडक विषाणु का प्रकोप बड़े क्षेत्रफल पर पाया गया।

पार्थेनियम के प्रति **ग्लॉयक्लेडियम विरेन्स** के निस्यंदक संवर्धन का प्रयोग, कवकजाल पहले निकलने एवं बाद में निकलने के अध्ययन में पाया गया कि विभिन्न सान्द्रताओं पर यह पार्थेनियम के बीजाकुंरण एवं नवोद्भिद् ऊर्जास्विता को काफी हद तक कम करता है।

## भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली

**बेसिलस थ्युरिन्जेन्सिस** की 7 प्रजातियाँ लगातार संधारित की गई । **बे. थ्युरिन्जेन्सिस** की दो प्रोटोक्सिन जातियों **कुर्सटेकी** एवं **इजरायलेन्सिस** तथा एक अन्य बी टी एस ४२ (पादप जैव प्रोद्यौगिक रा. अनु. के., भा कृ अनु सं, नई दिल्ली से प्राप्त) **हे. आर्मिजेरा** के उपांत्य निरूप लारवों पर एल डी 50 उपयोगिता **कुर्सटेकी, इजराइलेन्सिस** एवं बी टी एस 42 की मात्रा क्रमशः 33.01, 195.47 एवं 22.39 / लारवा निश्चित की गई।

## गोविन्द वल्लभ पन्त कृषि विज्ञान एवं प्रशिक्षण विश्वविद्यालय, पंतनगर

**इनविट्रो** परीक्षण में **ग्लॉयक्लेडियम विरेन्स** पृथक पी आई । (जी वी) को **फ्यूजेरियम आक्सीपोरम** एफ. स्पे. **ग्लॉडियोलि** जिससे ग्लॉडियोलस कॉर्म रॉट एवं पैलोज रोग होते हैं, के प्रति प्रमुख प्रतिरोधी के रूप में सफल पाई गई।

**ग्ला. विरेन्स** पी आई । (जी वी) को ज्वार के दानों पर संधारित किया गया और चने के म्लानि एवं जड़ सडन रोग के प्रति 7 निरूपणों का परीक्षण किया तथा चने में जब उसके अकेले या विटावेक्स के साथ प्रयोग किया गया तो यह नवोद्भिद् पौध निकलने, पादप के खड़े होने के शक्ति तथा अन्न उत्पादन के सुधार में सर्वश्रेष्ठ परिणाम प्राप्त हुए।

**स्कलेरोशियम रोल्फसाई, राइजोक्टोनिया सोलेनाई** एवं **फ्यूजेरियम सोलेनाई** के प्रति **ट्रा. हरजिएनम** वियुक्त ।(टी एच ।) तीव्र वृद्धि, अत्यन्त बीजाणुजनक वियुक्ति के रूप में अति प्रतिरोधक संभाव्य (**इनविट्रो** एवं इन विवो दशाओं में), किन्तु कार्बेनडाजिम के लिए अत्यन्त संवेदनशील पाया गया। अति प्रतिरोधक संभाव्य के संकर विभेद् विकास एवं प्रोटोप्लास्ट संयोजन द्वारा कार्बेन्डाजिम सहिष्णुता की प्रक्रिया के लिए अध्ययन हो रहा है, टी एच 1 एवं टी एच 3 से प्रोटोप्लास्ट के प्रथक्करण एवं शुद्धीकरण की तकनीक विकसित करने के प्रयास किये गये।

## 19.2 गन्ने के हानिकारक कीटों का जैविक दमन

**एसिगोना स्टेनिएलस** एवं **काइलो इनफ्सकेटेलस** का लारवा परजीवी **कोटेशिया फ्लेविपस** प्रायः पाया गया। **टोपोब्रेकोन** स्पे. (1.7 से 2.8%) को पहली बार **स्किरपोफागा एक्सर्पटेलिस** लारवे के परजीवी के रूप में अभिलेखित किया गया। **ट्रा. किलोनिस** की 50,000/ है. की दर से 10 दिनों के अन्तराल से, मई-जून में प्रयोग करने से पौध एवं पेड़ी फसल में **का. इनफसकेटेलस** तथा जूलाई से अक्टूबर में **का. आरीसिलियस** के नियंत्रण के लिए उत्तम पाया गया। जुलाई से अक्टूबर में **ट्रा. किलोनिस** (50,000/ है. की दर से 10 दिनों के अन्तराल से) + **को. फ्लेविपस** (10,000/है. की दर से 20 दिनों के अन्तराल से) एक साथ मिलाकर छोड़ने से **का. आरीसिलियस** के नियंत्रण के लिए अत्यन्त प्रभावी पाया गया। (प कृ वि वि)

कोयम्बतुर में **स्टरमियाप्सिस इन्फेरेन्स** की अधिक सक्रियता जनवरी माह में (5.6%) और नवम्बर माह में (6.1%) पाई गई। **कोटेशिया फ्लेविपस** की सक्रियता केवल अगस्त माह में (0.5%) देखी गई। तना बेधक के लिए कणिकामय विषाणु पुरे वर्ष सक्रिय विशेषत: अगस्त माह में अधिक सक्रिय पाया गया। प्रयोगशाला में **ब्यूवेरिया ब्रोन्गनियार्टि** कवक को शीरे पर उत्पादित किया गया तथा श्वेत ग्रब्ज के अण्डों पर इनकी सीमित ओविसिडल सक्रियता देखी गई। गमले में किये गये प्रयोग में, **ब्यू. ब्रोन्गनियार्टि** की $10^{13}$-$10^{17}$ बीजाणुओं / है. के समतुल्य मात्रा के प्रयोग से ग्रब्ज के पहले निरुप की अपेक्षा तीसरे निरुप के ग्रब्ज के प्रति अधिक घातक सिद्ध हुए। (ग प्र सं)

## 19.3 कपास के हानिकारक कीटों का जैविक दमन

कपास में जैव नियंत्रण आधारित आई पी एम विधि से गोलक शलभ कीटों द्वारा होने वाली क्षति को सफलतापूर्वक कम किया गया। जैव नियंत्रण आधारित आई पी एम के अन्तर्गत **हे. आर्मिजेरा** के अण्डों का **ट्राइकोग्रामा किलोनिस** द्वारा अत्यधिक परजीवीकरण पाया गया। यद्यपि आई पी एम (जैव कारक + नीम आधारित कीट नाशी) के प्रयोग तथा प कृ वि वि में योजित छिड़काव से उपज एकसमान अधिक प्राप्त हुई । (प कृ वि वि)

मूँगफली के साथ अन्तः फसले उगाने पर लाभदायक कीटो की महत्ता एवं भूमिका पाई गई जिससे कि आई पी एम उपयोगिता को विशिष्ट आयाम मिला। आई पी एम की युक्तियां अपनाने से कपास के बीज की उपज सर्वाधिक (18.27 क्विंटल / है.) प्राप्त हुई । आई पी एम प्रक्रियायें अपनाने से वृद्धि मूल्य लाभ अनुपात अधिक (10.07) प्राप्त हुआ जबीके इसकी तुलना में किसानों के द्वारा अपनाई गई प्रक्रियाओं से (1.55) तथा कीटनाशियों के प्रयोग करने से (1.59) वृद्धि मूल्य लाभ अनुपात प्राप्त हुआ। (आ एन जी रा कृ वि वि)

तुलनार्थ प्रयोग एवं कीटनाशी प्रयोग की तुलना से आई पी एम के अन्तर्गत कपास के साथ अन्तरफसल उगाने से **काइलोमीनस सेक्समेकुलेटा** की सक्रियता अधिक पाई गई। अध्ययन से ज्ञात हुआ कि मक्का,

**केशिया ऑकिडेन्टेलिस**, पार्थेनियम, अरण्डी, ढैंचा, गेंदा, तम्बाकू इत्यादि कपास के कीटों के अनेक परजीवियों/कीटभक्षक कीटों को आश्रय प्रदान करते हैं। (गु.कृ वि वि)

## 19.4 तम्बाकू के हानिकारक कीटों का जैविक दमन

मोरामपुडी में नर्सरी उगाने वालों ने पाया कि **स्पो. लिट्यूरा** के रासायनिक नियंत्रण से मूल्य लाभ अनुपात केवल 1:1.35 मिला जबकि **बे. थ्यूरिन्जेन्सिस (बी. टी.) कुर्सटेकी** 1.0 किग्रा./है. + **स्पो. लिट्यूरा** न्यूक्लीयर पोलीहेड्रोसिस विषाणु 250 एल ई/है. की दर से तम्बाकू नर्सरी में **स्पो. लिटयूरा** के प्रति एक साथ छिड़कने से मूल्य लाभ अनुपात 1:1.49 प्राप्त हुआ। **हेलिकोवर्पा आर्मिजेरा** के लिए जैव गहनता आई पी एम के अन्तर्गत **हे. आर्मिजेरा** एन पी वी 450 एल ई/है. तथा अन्य प्रबंधन प्रक्रियायें जो कि प्राकृतिक शत्रुओं की सक्रियता को बढ़ाये जैसे चिड़ियों का अड्डा खड़ा करना तथा तम्बाकू एफ सी वी क्षेत्रों में गेंदा वंश के पौधों को दो लाइनों में उगाने से **हे. आर्मिजेरा** द्वारा क्षति को 1.3% तक जबकि किसानों द्वारा अपनाई गई विधि से क्षति 20 से 30% तक पाई गई । (के त अनु सं)

## 19.5 दलहनी फसलों के हानिकारक कीटों का जैविक दमन

हे. एन पी वी की 125 एल ई/है. + एन्डोसल्फान 0.035% की दर से एक साथ छिड़कने से **हे. आर्मिजेरा** के लारवों की संख्या को कम करने में प्रभावी पाया गया तथा हे. एन पी वी को 250 एल ई/है. की दर से छिड़कने से उपज अधिक प्राप्त हुई। **बे. थ्यूरिन्जेन्सिस** निरूपण, डाईपेल एवं बी टी के ॥ 1.0 किग्रा./है. की दर से चने में प्रयोग करने से **हेलिकोवर्पा** के प्रति प्रभावी पाया गया। (आ एन जी रा कृ वि वि)

अरहर में **बे. थ्यूरिन्जेन्सिस** एवं हे. एन पी वी को क्रमांतर रूप से प्रयोग करने पर फली बेधकों के व्यवस्थापन हेतू प्रभावी पाया गया। (प कृ वि वि)

## 19.6 धान के हानिकारक कीटों का जैविक दमन

तना बेधकों के नियंत्रण के लिए रबी मौसम में प्रतिरोपण के 30 दिनों के बाद **ट्रा. जेपोनिकम** को 50,000/है./सप्ताह की दर से प्लावित रूप से छोड़ने पर प्रभावी पाया गया। (आ कृ वि वि)

धान के तना बेधकों एवं पत्ती मोड़कों के नियंत्रण के लिए प्रतिरोपण के 20 दिनों के बाद **ट्रा. [illegible]** एवं **ट्रा. जेपोनिकम** को 10 दिनों के अंतराल पर 1,00,000/है. की दर से एक साथ छोडने पर अत्यन्त प्रभावी पाया गया । (प कृ वि वि)

## 19.7 ऊष्णीय फलों वाली फसलों के हानिकारक कीटों का जैविक दमन

सर्पिल श्वेत मक्खी से कीटरोगाणु कवक **पायसिलोमाइकस फेरिनोसस** को पृथक किया गया। अनार

पर श्वेत मक्खी **साइफोनिनस फाइलिरिए** का प्रकोप देखा गया तथा **एफेलिनिड** परजीवी कीट **एनकार्सिया आजिमि** भी पाया गया। अनार के सफेद फूँगा **प्लेनोकोकस लिलेसिनस** को **एनसीर्टिड टेट्राक्नेमॉयडीया इन्डिका** द्वारा 60% तक परीजिवित पाया गया। अनार पर लगने वाली तितली **डीयूडोरिक्स आइसोक्रेटस** के अण्डें **ऊएनसीरटस पेपिलिओनिस** एवं **टेलीनोमस** स्पे. द्वारा परीजीवित पाया गया। अमरूद में **एलियूरोडिकस डिसपर्सस** के प्रति हरी जालीदार पंख वाले **मलाडा एस्टर** प्रमुखतः पाये गये तथा इसका एक लारवा 10 से 12 दिनों में सर्पिल श्वेत मक्खी के 230 निम्फों का उपभोग करता है। बंगलोर के समीप वेस्थूर गाँव में अमरूद के हरित कवकीय शल्क **क्लोरोपुलविनेरिया सिडाई** को **क्रिप्टोलिमस मोन्ट्रोजेरी** द्वारा नियंत्रण करने की सामर्थयता को प्रदर्शित किया गया। (भ बा अनु सं)

## 19.8 शीतोष्ण फलों वाली फसलों के हानिकारक कीटों का जैविक दमन

सोलन एवं कश्मीर में लोमश सेब माँहू की संख्या कम होने पर भी कीट परजीवी **एफीलिनस माली** मई से दिसम्बर माह तक सक्रिय पाया गया । (डा वाइ एस प ब व वि वि वि एवं शे क कृ वि वि)

सोलन, शिमला एवं कुल्लु में सेन जोज शल्क **एफीटिस** स्पे. (**प्रोक्लिया** समूह) एवं **एनकार्सिया पर्निसीओसी** द्वारा परजीवित पाये गये। जुलाई से अगस्त माह में **काइलोकोरस बिजुगस** के लारवों की संख्या अधिक पाई गयी। (डा वाइ एस प ब व वि वि वि)

## 19.9 सब्जियों वाली फसलों के हानिकारक कीटों का जैविक दमन

अण्डा परजीवियों की 3 जातियाँ बैगन **स्फिनजिड, एकेरोन्टिया स्टिक्स** से एकत्र की गई जिनसे कि 64% तक परजीवीकरण पाया गया। टमाटर के फल बेधक **हे. अर्मिजेरा** के 30% से 50% लारवें एन पी वी से संक्रमित पाये गये तथा 50% अण्डें **ट्रा. प्रेटिओसम** द्वारा परीजिवित पाये गये। (भा बा अनु सं)

टमाटर में, **ट्राइकोग्रामा किलोनिस** द्वारा **हे. आर्मिजेरा** के अण्डों का औसत परजीविकरण 29% जबकि **केम्पोलेटिस क्लोरिडीए** द्वारा लारवों का परजीवीकरण 12.5% पाया गया। (डा वाइ एस प ब व वि वि वि)

मटर की पर्णसुरंगी कीट **क्रोमेटोमिया होर्टिकोला, डिग्लीफस** स्पे. द्वारा मटर में ( 21.1 से 58%), **ब्रोकोलाई** में ( 0 से 15.4%) तथा मीठी मटर में ( 0 से 100%) परजीवीकरण पाया गया। (डा वाइ एस प ब व वि वि वि)

## 19.10 आलू के हानिकारक कीटों का जैविक दमन

आलू प्रकंद मौथ के लारवों से **एपेन्टेलस** स्पे. एवं **ब्रेकोन** स्पे. पाई गई। संग्रहित अलूओं से दो हायमेनोप्टेरस परजीवीयों एवं कोक्सिनेलिड्स कीटभक्षक कीट को प्राप्त किया गया। पर्णसुरंगी कीट को नियंत्रित करने के लिए चार सप्ताहों में **कोपिडोसोमा कोईहिल्लरी** को 50,000 प्रौढ/है. तथा **किलोनस ब्लैकबर्नी** को 15,000 प्रौढ़/है. की दर से छोड़ने पर एक समान प्रभाव दिखाते हैं। (म फु कृ वि वि)

प्रयोगशाला परीक्षण में लघु आरनीज (20 किग्रा. क्षमता) जिसमें केवल प्रारंभिक मात्रा में परजीवियों को छोड़ा गया, **बे. थ्युरिन्जेन्सिस** प्रयोग एवं कणिकामय विषाणु का प्रयोग किया इस अध्ययन से ज्ञात हुआ कि **बे. थ्युरिन्जेन्सिस** की । ग्राम/किग्रा. आलू प्रकन्दों की दर से प्रयोग करने के एक माह बाद प्रकंद संक्रमण को कम करने में प्रभावी पाया गया। **स्पो. लिट्यूरा** एन पी वी की 750 एल ई/है. (= 4.5 x $10^{12}$ पी ओ बी एस/है.) की दर से प्रयोग करने से लारवों के लिए 87.5% घातक सिद्ध हुआ तथा आलू कन्दों की उपज अधिक 184.5 क्विंटल/है. प्राप्त हुई । (म फु कृ वि वि)

## 19.11 खरपतवारों का जैविक दमन

बड़े सीमेन्ट के गमलों में उगाये गये **सिपेरस रोटन्डस** को एक माह के अन्दर **बेक्ट्रा वेनोसोना** के सिर्फ एक जोड़ी कीट ने 100% तक क्षतिग्रस्त किया। कीट द्वारा उपभोग करने के कारण पादप वृद्धि, कन्द भार में एवं क्षतिग्रस्त कन्दों के पुनर्जनन क्षमता में कमी आई। क्षेत्रीय दशाओं में **ट्राइकोग्रेमेटॉयडीए बेक्टरे** द्वारा अत्यधिक मात्रा में **बे. वेनोसोना** के अण्डें परजीवित पाये गये। सूर्यमुखी की पत्तियों का उपभोग करने पर **जाइगोग्रामा बाइकोलोरटा** के प्रजननीय अंगों को अपभ्रंश पाया गया, जबकि प्रौढ़ों द्वारा 15 दिनों तक सूर्यमुखी पर उपभोग करने के उपरान्त यदि पार्थेनियम का उपभोग कराते हैं तो उनके अण्डनाल पुटक एवं वृषण सामान्य विकसित पाये गये। (भा बा अनु सं)

साल में **जा. बाइकोलोराटा** की 5 पीढ़ीयाँ पूर्ण करती है। क्षेत्र में, प्रौढ़ों की अधिकतम संख्या (1.3 बीटल्स/पौधा) जून के अंत में, सितम्बर के पहले सप्ताह में, तथा अक्टूबर के मध्य में पायी गयी। (डा वाई एस प ब व वि वि वि)

जलकुंभी के सफलता पूर्वक नियंत्रण की उपलब्धि, आसाम में शिवसागर जिले के दिसांगमुख क्षेत्र में विदेशी कीट वीविल्स **निओकेटिना आईकोर्निए** एवं **नि. ब्रुकी** द्वारा पायी गई तथा शिवसागर जिले के शेष बचे जलकुंभी क्षेत्रों में पुष्पन कम पाया गया। (आ कृ वि वि)

**नि. आईकोर्निए** एवं **नि. ब्रुकी** जलकुंभी पर स्थापित पाये गये। **जाइगोग्रामा बाइकोलोराटा** को रोपड, नवांशहर एवं जालंधर में पार्थेनियम पर विस्तृत क्षेत्रों में फैला पाया। (प कृ वि वि)

**आर्थोगेलूम्मा टेरेब्रेन्टिस** निर्धारित स्थानों पर जलकुंभी का आंशिक नियंत्रण करने के पश्चात स्थापित हो गया। (के कृ वि वि)

## ACRONYMS

| | | |
|---|---|---|
| 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 |

International experts on *Parthenium* biological control at PDBC

ICAR Foundation day celebrations on 16th August 1997, where farmers are explained about *Diglyphus begini*, an introduced parasitoid for American serpentine leaf miner

Dr. R. S. Paroda, Director General, ICAR visiting Weed Biocontrol Laboratory during the inauguration. Pathology Laboratory

Social Audit Committee members showing interest in *in vitro* reared chrysopids