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Cover

Nematophagous fungus, Vetricillium chlamydosporium infection on the egg of root-knot nematode Meloidogyne incognita

 ${\bf Inset:} \ {\it V. chlamy dosporium} \ {\bf proliferating \ inside \ the \ cyst} \\ {\bf nematode}$

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PREFACE

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

The ninth annual report of the Project Directorate embodies the endeavours of my scientist colleagues for the period April 2001 to March 2002. 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. Panjab Singh, Secretary, DARE & Director General, ICAR, New Delhi, for his encouragement and valuable guidance. The support extended by Dr. Mangala Rai, Deputy Director General (Crop Sciences), ICAR, New Delhi, is gratefully acknowledged. Dr. O. P. Dubey, Assistant Director General (Plant Protection), ICAR, New Delhi has always encouraged and inspired us to perform better. Sincere thanks are due to all project workers at Project Directorate of Biological Control and in different co-ordinating centres for completing the allotted research programmes. Thanks are also due to the Vice-Chancellors, Directors of Research of SAU based centres and Directors of ICAR-Institute-based centres for providing the facilities.

(R. J. Rabindra)

2. EXECUTIVE SUMMARY

2.1. Basic research

2.1.1. Introduction of natural enemies

Proposals for the import of twelve natural enemies have been submitted for the issue of import permits.

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

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

Cultures of host insects and natural enemies were sent to coordinating centers and other research organizations as nucleus cultures to facilitate their multiplication for field trials. Twenty-five multicellular trays were supplied to different centres for the multiplication of host cultures.

2.1.3. Biosystematic studies on Indian predatory Coccinellidae

Five apparently new species belonging to the genera *Protoplotina* Miyatake, *Microserangium* Miyatake, *Synonychimorpha* Miyatake, *Ghanius* Ahmad and *Ortalia* Mulsant were recorded from different parts of India. Chettalli (Coorg, Karnataka) and nearby areas were surveyed for coccinellids. Compilation of an identification guide for common coccinellids of the Indian region is in progress.

2.1.4. Survey for natural enemies

Larvae of *H. armigera* and *S. litura* were collected from different crops and ichneumonid parasitism ranged between 0 and 18% and was maximum on *Dolichos* sp.

Orius tantillus and O. maxidentex were collected from different crop ecosystems, with the former being more common.

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

A novel method of mass multiplying *E. argenteopilosus* was evaluated in the laboratory. Different parasitoid - host ratios - 1:5, 1:10, 1:15, 1:20, 1:25 - were tried. 1:5 was observed to be the optimum ratio for obtaining higher per cent parasitism.

Eriborus argenteopilosus was evaluated in cage studies on chickpea and cotton plants. On cotton plants, parasitism ranged from 18 to 45% and 1:5 was found to be the ideal ratio. On chickpea plants, the parasitism ranged from 9 to 40%.

Cage studies were conducted to study the interaction between *C. chlorideae* and *E. argenteopilosus*. *C. chlorideae* alone provided higher per cent parasitism than when there was interference by *E. argenteopilosus*. However, if exposure to *E. argenteopilosus* occurred 18 hours after parasitisation by *C. chlorideae*, the latter could parasitise the host normally. Similarly, if *E. argenteopilosus* was allowed to parasitise the host larva alone, it provided higher parasitism in comparison to interaction situations. If exposure to *E. argenteopilosus* occurred 24 or 48 hours after parasitism by *C. chlorideae*, the former could not develop from any parasitised larvae. Irrespective of the sequence of parasitisation, *C. chlorideae* appeared to be superior. In group exposures also, similar results were observed. The performance of *C. chlorideae* was not affected in the presence of *E. argenteopilosus*, but the performance of *E. argenteopilosus* was adversely affected by the presence of *C. chlorideae*.

A method has been standardized to mass rear the anthocorid, *Blaptostethus pallescens* (from the maize ecosystem) on *C. cephalonica*. Bean pods were used as oviposition substrates. The total developmental period was about 20 days and mean longevity of male and female was 64.4 and 53.2 days, respectively. Fecundity was 143 nymphs per female and about 58% of the progeny were females. One nymph could feed on a mean number of 87 eggs, adult male on 373 eggs and female on 408 eggs.

Studies are in progress to develop mass production protocols for predatory cecidomyiids and mites.

2.1.6. Behavioural studies on natural enemies

L-tryptophan (0.66%) treated plants attracted higher oviposition by *C. carnea* than untreated plants in the field and laboratory. *Corcyra* scale extracts fortified with tricosane and pentacosane at 0.1% and 0.2% and sprayed on the egg cards of *C. cephalonica* increased parasitization by *Trichogramma chilonis* in field conditions. Among the kairomonal compounds screened under multiple choice conditions for *T. chilonis*, nonocosane and hexacosane increased

parasitization. The adults of *C. carnea* showed positive response to kairomonal compounds from scales of *H. armigera*, such as dodecane and tricosane.

Among the different genotypes of cotton, parasitization of *H. armigera* eggs by *T. chilonis* varied from 22.22 to 48.88 per cent. Highest parasitization was recorded on G-Cot-10 (48.88%), followed by CPD 428 (39.99). Lowest egg parasitization was recorded on variety Sahana (22.22%). Olfactometer responses of cotton leaves revealed highest attraction to variety CPD 428(50%), followed by CPD423 (43.33%) and CPD 447(43.33%).

Relative response of *T. chilonis* to seven chemical cues in multiple choice olfactometer indicated highest response to Pentacosane, followed by Heneicosane and Tricosane (all 0.1%) within 25 minutes of release. These three compounds at 0.05% concentration also enhanced the parasitization efficiency of *T. chilonis* on *C. cephalonica* eggs. Further, EAG responses of *H. armigera* females to leaves and bolls of different cotton varieties/hybrids revealed highest attraction to G-Cotton-10 (-1.176mv), followed by DHB 105(-1.005mv) and CPD 447 (-0.824mv). In case of cotton bolls, maximum mean EAG response was exhibited towards DHH 11(-0.990mv), followed by G-Cotton-10 (-0.856mv).

Forty-two compounds were trapped and identified from leaves and 27 from bolls of cotton varieties/ hybrids.

2.1.7. Artificial diets for host insects and natural enemies

Toddy palm leaf powder based diet was found promising for rearing *Opisina arenosella*, providing high percentage pupation and female adult emergence.

Chrysoperla carnea larvae (1-day old) were successfully reared on artificial diet for 15 generations. The mean adult emergence (%) of *C. carnea* reared on artificial diet and *Corcyra* was 85.7 % and 86.0 %, respectively. The artificial diet could be stored for 200 days in refrigerator (5 ° C). Artificial diet reared *Chrysoperla carnea* was effective against *Myzus persicae* on tobacco and was comparable with other predators.

2.1.8. Improved strains of trichogrammatids

After 55 generations of constant rearing at $36\pm1.5^{\circ}$ C, *T. chilonis* has adapted to this high temperature. The parasitism obtained in the first generation at this temperature was 41 per cent and survival <1 day in comparison to less than 5.0 per cent parasitism by other susceptible strains. After 55 generations, parasitism was 90.0 per cent and survival >4 days.

Telenomus remus, after 30 generations of constant rearing, gave 72.2 per cent parasitisation and its longcvity was 7.8 days. However, sex ratio, which was female biased up

to 32°C became male biased when shifted to 34°C. This strain could be useful for release in high temperature conditions against *S. litura*.

The 'Endogram' strain of Trichogramma chilonis was used to develop a multiple insecticide tolerant strain. This strain has now become tolerant to 0.09% endosulfan, 0.05% monocrotophos and 0.002% fenvalerate. The parasitism in all insecticides is 90 - 95 per cent and survival 15-40 per cent after 6 hours of constant exposure.

A strain of *T. chilonis* with high host searching ability was selected after 30 generations of rearing in insect rearing cage (30 cm³). This strain has significantly higher host searching ability and could parasitise 50.6 - 77.0 per cent eggs.

Amongst 6 different species tested against *H. armigera* in various climatic conditions, *T. chilonis* and *T. brasiliense* performed better at 25° - 35°C and *T. pretiosum* at 18° - 25°C. *Trichogramma achaeae* also parasitised significantly more eggs in higher temperature though not as effective as *T. chilonis* and *T. brasiliense*. *Trichogramma evanescens* was more effective at lower temperature than higher temperature. Results indicated that *T. chilonis* and *T. brasiliense* can be considered in temperatures between 25° and 35°C, and *T. pretiosum* between 18° and 25°C for evaluation against *H. armigera*. The developmental period of these species was 7.0 to 9.0 days at 30° and 35°C, 11.0 to 12.2 days at 25°C, 15.4 to 21.0 days at 20°C and 17.0 to 30.0 days at 18°C. At 18° and 35°C, many species failed to emerge, though some parasitisation was observed.

Functional response studies indicated that parasitoid: host eggs ratio of 1: 50-60 eggs is sufficient for effective host utilisation, parasitism and also avoidance of superparasitism.

2.1.9. Studies on entomopathogenic viruses and fungi

Nucleopolyhedrosis viruses from the coconut skipper, Gangara thyrsis and mottled emigrant white butterfly, Catopsilia pyranthae, a granulosis virus from the castor semilooper, Achaea janata and a poxvirus from maize stem borer, Chilo partellus have been isolated for the first time from India and their pathogenicity has been tested. A suspected nuclear polyhedrosis virus has been isolated from the paddy leaf roller, Cnaphalocrocis medinalis and coconut black headed caterpillar, Opisina arenosella.

Mass multiplication of nuclear polyhedrosis virus of *G. thyrsis* using female larvae resulted in 4-5 times more yield of POBs than when male larvae were used.

SMAY medium incorporated with chloramphenicol (50 ppm) and rose bengal (100 ppm) can be used successfully for isolation of *Nomuraea rileyi* without contamination from

field infected larvae of *H. armigera* and *S.litura*. Isolates of *N. rileyi* (33), *Metarrhizium anisopliae* (3) and *Verticillium lecanii* (14) from various hosts and an isolate of *Fusarium* sp. from rose aphid, *M. rosaeiformis* were isolated. The isolates Nr-26 and Nr-17 of *N. rileyi* (against *H. armigera*) and Nr-17, Nr-26, Nr-3, Nr-7 and Nr-12 (against *S. litura*) showed 100% mortality of the 3rd instar larvae when sprayed with spore suspension of 8.5X10⁸ conidia/ml. *Fusarium* sp. caused adult mortality of 73.6% and nymphal mortality of 63.8% of rose aphid (*M. rosaeiformis*) when sprayed @ 7.9X10⁶ spores/ml. Maximum sporulation of *Beauveria bassiana*, *M. anisopliae* and *V. lecanii* was observed with pongamia (3X10⁹, 2X10⁹ and 1.1X10⁹ spores/g, respectively) and castor oil cakes (2X10⁹, 2X10⁹ and 1X10⁹ spores/g, respectively). Dried silkworm pupal powder also served as a good substrate for *B. bassiana* (1.3X10⁹ spores/g) and *M. anisopliae* (3.6X10⁹ spores/g) apart from sorghum. Spent malt, and brewe's yeast (10:1) gave good sporulation of *M. anisopliae* (1.7X10⁹ spores/g). Mass production of *V. lecanii* using soy flour-molasses medium in laboratory grade fermentor was standardized. A talc-based formulation of *V. lecanii* was developed using fungal biomass from fermentor.

2.1.10. Entomopathogenic nematodes

PDBC isolates of *Heterorhabditis bacteriophora*, *H. indica*, *Steinernema carpocapsae* and *S. bicornutum* were found effective against five test insects.

Progeny production of all isolates was maximum in Galleria mellonella. H. bacteriophora recorded highest yield in Galleria, followed by S. litura and H. armigera. Among Steinernema isolates, S. bicornutum gave maximum yield in all insects.

For mass production in solid media, Wouts medium was suitable for all isolates. Highest yield of 78.9 lakhs IJs/250 ml flask was obtained for *S. carpocapsae* 1.4 and 7.2 IJs in dog biscuit +beef extract medium.

2.1.11. Biological control of plant parasitic nematodes

Two strains of *Paecilomyces lilacinus*, one each of *Verticillium chlamydosporium*, and *Pasteuria penetrans* were isolated and their bioefficacy tested against root-knot and reniform nematodes.

An easy and rapid laboratory method to screen antagonistic fungi for bioassay against nematodes has been developed. Addition of CaCO³ and chitin (0.01%) in liquid culture (PD broth) promoted the growth and sporulation of *P. lilacinus* and *V. chlamydosporium*. The fungi grew readily in media containing commercially available, low-cost ingredients such as cotton seed meal, groundnut seed meal, gingelly meal, glucose and corn cob powder.

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Comparative efficacy of different isolates of *P. lilacinus* and *V. chlamydosporium* against root-knot and reniform nematodes was evaluated under glasshouse conditions on tomato and cowpea, respectively. *P. lilacinus* can be recommended for the control of *M. incognita* and *R. reniformis* in red laterite soils, *V. chlamydosporium* for sandy loam soil in tomato and cowpea.

Integration of *P. lilacinus* and *V. chlamydosporium* with air-dried FYM/oil cake application, followed by light irrigation favoured the fungal establishment and parasitation on the egg masses of *Meloidogyne incognita* compared to their specific application. Aerial spores of *Paecilomyces lilacinus* (multiplied on sorghum grain) were more robust and viable compared to submerged spores (in potato broth). *Paecilomyces lilacinus* grown on sorghum grain and formulated in talc effectively reduced root-knot nematode populations in chrysanthemum @ 4-6 kg/acre along with neem cake @ 150-200 kg and enhanced the flower yield by 18-24%.

2.1.12. Weed pathogens

Through regular surveys, more isolates of different pathogens of water hyacinth namely Alternaria eichhorniae, A. alternata and Cercospora spp., were obtained. The period immediately after the south-west monsoon (August onwards) was found to be conducive to epiphytotics of these pathogens. Natural incidence of the two Alternaria spp., Cercospora spp., Lasiodiplodia theobromae, several Fusarium spp., Drechslera, Phoma and Nigrospora species was observed on water hyacinth from August 2001 to February 2002 in the water bodies in and around Bangalore.

Cotton, okra, chickpea, pigeonpea, rice, castor, rose, coconut, citrus, coffee, mango and guava belonging to 10 different families, *viz.* Malvaceae, Papilionaceae, Poaceae, Euphorbiaceae, Rosaceae, Palmae, Rutaceae, Rubiaceae, Anacardiaceae and Myrtaceae, did not show susceptibility to *Alternaria* spp. However, okra showed symptoms of phytotoxicity.

2.1.13. Software development

CD version of the software "PDBC INFOBASE" was created and made auto-run.

"Helico-Info", a software on *Helicoverpa armigera* developed in MS-Access 97, gives details on the taxonomy of the pest, its host plants, distribution, natural enemies and detailed biocontrol measures to be undertaken in a particular crop.

The software "Safer Pesticides in Biocontrol", developed in Visual Basic 6.0 helps the user to identify safer pesticides for use based on the crop, pest and natural enemy.

2.2. Biological suppression of sugarcane pests

At PAU, Ludhiana, eight releases of *Trichogramma chilonis* at 10 days interval during April-June @ 50,000 per ha reduced the incidence of early shoot borer by 51.7 per cent over control. Biocontrol was equally effective as chemical control. The egg parasitism was very high (56.0%) in the parasitoid released fields.

Four releases of *Trichogramma japonicum*, coinciding with availability of egg masses of top borer @ 50,000 per ha during May-July reduced the incidence of top borer by 50.7 per cent.

In large scale demonstration of the effectiveness of *T. chilonis* over 40 ha, eleven releases of the parasitoids at weekly interval during July-September, reduced the incidence of stalk borer by 60.82 per cent. The parasitisation in the released field was 79.50 per cent as compared to 6.27 per cent in the control.

In large scale demonstration in collaboration with two sugar mills of Punjab over 1400 ha, twelve releases of *T. chilonis* @ 50,000 per ha at 10 days interval during July-October reduced the incidence of stalk borer by 60 per cent.

At SBI, Coimbatore, *T. chilonis* showed higher parasitisation on shoot borer eggs, followed by internode borer and *C. cephalonica* eggs in host preference studies. In a two-choice test in a Y-tube olfactometer, adults of *T. chilonis* reared on *C. cephalonica* showed greater movement towards shoot borer than internode borer. Previous host history did not influence parasitisation rates of *T. chilonis* in the present generation.

In different field trials against internode borer, *T. chilonis* releases generally reduced internode borer incidence.

In seven field trials with *Sturmiopsis inferens* against shoot borer at dosages of 10-38 females/acre, there was a decrease in shoot borer incidence and increase in parasitism rates in some trials. *S. inferens* adults emerging in the laboratory showed male biased ratios in seven months whereas in the rest it was female biased. The mating rates of females were generally high. Parasitisation rates on shoot borer were moderate with occasional complete failure. Top borer served as a better host.

Press-mud formulated *Beauveria brongniartii* evaluated in the field against white grubs, either alone or in combination with insecticides, reduced grub numbers and increased infection. Grubs collected from previous seasons' experimental plots showed considerable infection rates indicating field persistence of the applied fungus. The fungus formulated with press mud or lignite caused considerable mortality of grubs in laboratory bioassay.

Media pH did not show distinct influence on the growth parameters of *B. brongniartii*, *B. bassiana* and *Metarhizium anisopliae*. The three species of fungi did not affect the emergence rates of *T. chilonis*, but caused considerable mortality in the spider *Hippasa greenalliae* and the braconid *Cotesia flavipes*. *Beauveria brongniartii* was safe to *Bombyx mori*, but the other two fungi caused some mortality of the larvae. All the three species were toxic to *Apis florea*.

2.3. Biological suppression of cotton pests

At College of Agriculture, Pune (MPKV), the IPM module was found effective in the suppression of sucking pests as well as bollworm complex of cotton and recorded maximum good quality kapas.

At ANGRAU, Hyderabad, the performance of BioIntensive Insect Pest Management (BIPM), consisting of biocontrol based practices, was evaluated on cotton in comparison with farmers' practice and untreated control. The square and boll damage and the population of sucking pests was lower in BIPM plots than in farmers' practice and control. Since BIPM received less spray of chemical insecticides, more natural enemies were conserved. Although the yields were higher in farmers' practice, BIPM module fared well in terms of monetary returns by recording higher cost-benefit ratio.

At PAU, Ludhiana, twelve releases of *T. chilonis* @ 1,50,000/ha/week during July-September was less effective for the control of cotton bollworms. However, when *T. chilonis* (12 releases @ 1,50,000/ha/week) and insecticides (9 sprays at weekly interval) were integrated, it proved effective against bollworms.

At GAU, Anand, studies on cotton pest management revealed that sucking pests and bollworms can be more effectively managed by IPM module than insecticide treatments. The IPM module gave significantly better protection to buds and bolls. In the field, inundative releases of *T. chilonis* in combination with *Chrysoperla carnea* kept the sucking pests and bollworms at a significantly lower level than insecticide treatments.

The entomophilic nematodes *Heterorhabditis indica* and *Steinernema carpocapsae* were found effective against *H. armigera* in cotton.

2.4. Biological suppression of tobacco pests

At CTRI, Rajhamundry, talc based formulation of *Steinernema carpocapsae* was found effective @ 1x 10 5 IJ/sq.cm in succession with NPV @ 1.5 x 10 12 PIB/ha in containing per cent seedlings damage caused by *S. litura* (3.40 %). EPN individually was also effective @ 4x10 5 IJ/sq cm with less percent seedlings damaged (4.88%) compared to control (26.88%).

2.5. Biological suppression of pulse crop pests

At ANGRAU, Hyderabad, different biocontrol based sequences of treatments consisting of HaNPV, Bt and NSKE were evaluated for their efficacy against pod borer complex in pigeonpea. Sequential application of HaNPV-NSKE-HaNPV-NSKE starting from flower initiation stage at 10 days interval between each spray proved better than other treatments, giving minimum larval population of H. armigera and damage by pod wasp and podfly. It also resulted in good yield.

At GAU, Anand, Bt-HaNPV-Bt-HaNPV gave higher yield as well as decrease in H. armigera larval population, % pod and grain damage as compared to control. Entomopathogenic nematode, Heterorhabditis sp. was found effective against Helicoverpa in pigeonpea.

2.6. Biological suppression of rice pests

At College of Agriculture, Pune (MPKV), releases of egg parasitoids, T. japonicum and T. chilonis each @ 1,00,000 adults/ha/release/week three times were found to be most effective in reducing the infestation of leaf folder and stem borer and recorded the maximum yield.

At AAU, Jorhat, inundative releases of *Trichogramma japonicum* and *T. chilonis* @ 50,000/ha/week and 1,00,000/ha/week, starting from 30 days after transplanting in farmers' fields of Borholla during *rabi*, 2001 gave significantly good control of stem borer (2.39%) in the 3rd week after release. In a similar experiment conducted during *kharif* 2001 in farmers' fields at Rongamati, Dergaon the per cent dead heart was 4.46% in the 3rd week after parasitoid release.

Biocontrol based IPM in rice was evaluated at Borholla during *rabi* 2001 and the results revealed that significantly good control of stem borer was achieved in the *Trichogramma* released plot (2.58%) in the 3rd week after release against 7.51% in the unreleased plot. In a similar experiment conducted at Rongamati (Dergaon) during *kharif* 2001, with parasitoid release, significantly good control of stem borer was achieved (2.84%) compared to unreleased plot (7.59%).

At PAU, Ludhiana, seven releases of *T. chilonis* and *T. japonicum* @ 1,00,000 per ha at weekly interval, starting at 30 DAT proved very effective for the control of leaf folder and stem borer, on par with chemical control. However, lower dose of parasitoid was ineffective. Large scale demonstration of IPM (7 releases of *T. chilonis* and *T. japonicum* @ 1,00,000 per ha per week) proved very effective for the control of leaf folder and stem borer.

2.7. Biological suppression of oilseed pests

At PAU, Ludhiana, for the control of mustard aphid, chemical control proved to be the best. However, among the bioagents, *Ischiodon scutellaris* (15,000 first instar larvae/ha) proved better than *Verticillium lecanii* (10⁸ conidia/ml).

2.8. Biological suppression of coconut pests

At ANGRAU, Hyderabad, Mycohit, a *Hirsutella thompsonii* based formulation, was tested for its efficacy against coconut mite (three sprays of Mycohit (1%), at 15 days interval). Mycohit application did not give any mycelial fragments in mite colonies and resulted in no significant reduction in mite population.

2.9. Biological suppression of fruit crop pests

At SKUAS & T, Srinagar, the parasitoids of San Jose scale, *Encarsia perniciosi* and *Aphytis proclia* have established at the released sites, causing parasitism between 28.37 and 48.00 %.

At YSPUH & F. Solan, it was formed that *Chrysoperla carnea* larvae can be safely released on malathion (0.05%), endosulfan (0.05%) and profenophos (0.05%) treated apple trees, after 10, 15 and 30 days of the spray. None of these insecticides had any adverse effect on overwintering population of *Aphelinus mali* when sprayed in mid-November.

The release of *Chrysoperla carnea* at the rate of 4 larvae/aphid colony on the apple tree in October end did not effectively suppress the woolly apple aphid apparently due to visitation of predatory ants to the colonies.

2.10. Biological suppression of vegetable crop pests

At College of Agriculture, Pune (MPKV), five sprays of HaNPV @ 250 LE/ha (1.5x10¹² POBs/ha) at weekly interval, and 5 weekly releases of *T. pretiosum* @ 50,000 adults/ha/release + 3 sprays of HaNPV @ 250 LE/ha, first spray starting from 5 days after first release of the parasitoid starting from 50% flowering were the most effective against tomato fruit borer, giving minimum larval population and fruit infestation and maximum yield.

For the suppression of DBM on cabbage, release of *T. bactrae* @ 50,000 adults/ha/ release five times at weekly interval commencing from 25 days after planting was found significantly superior to untreated control. Spraying of Delfin WG @ 1 kg/ha five times at 10 days interval starting from initiation of flowering was also found most effective.

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Spraying of Delfin WG @ 1kg/ha five times at 10 days interval starting from initiation of flowering was found most effective against *L. orbonalis* on brinjal.

At ANGRAU, Hyderabad, two Bt formulations, viz. Dipel and Delfin, were tested along with the release of T. chilonis for their efficacy against L. orbonalis. Even though significant differences between treatments and control were noticed in terms of extent of damage, there was not much variation among treatments.

At YSPUH & F, Solan, incidence of the greenhouse whitefly, *Trialeurodes vaporariorum* on ornamentals and vegetable crops is on an increase. On French bean, severe attack of the whitefly occurred from June to September and its developing stages were preyed by the larvae of the coccinellid *Serangium montazerii*. During August, 58.8% pupae were parasitized by *Encarsia transvena*.

AT PAU, Ludhiana, for the management of tomato fruit borer, releases of *T. pretiosum* (5 releases at weekly interval @ 50,000 per ha) + 3 sprays of *Ha*NPV (1.5x10¹² POB per ha) + 3 sprays of endosulfan (@ 2.5 l/ha, at 15 days interval) proved most effective. However, *Ha*NPV alone and *T. pretiosum* alone were less effective.

At GAU, Anand, among different formulations of *B. thuringiensis* evaluated against *P. xylostella* on cabbage, *Btk*I was found most effective in reducing the pest population. *Trichogramma pretiosum* + *Ha*NPV (3 sprays) and IPM module were found superior to insecticide as well as control in tomato.

2.11. Biological suppression of potato pests

At College of Agriculture, Pune (MPKV), field releases of *C. koehleri* @ 1,250 mummies/ha/release and *C. blackburni* @ 15,000 pupae/ha/release four times at weekly interval commencing from 45 days after planting of potato crop by placing them in perforated plastic vials hung 5m apart were found effective for the suppression of PTM in potato field. Large scale releases of *C. koehleri* @ 50,000 adults/ha/release and *C. blackburni* @ 15,000 adults/ha/release four times at weekly interval starting from 45 days after planting of potato crop were significantly more effective than untreated control in reducing PTM infestation. The parasitoids were carried over from fields to storage to the extent of 6-9%.

Release of *C. koehleri* @ 1 mummy/4 kg tubers and *C. blackburni* @ 2 adults/kg tubers at fortnightly interval was found to be the most effective method in country stores, resulting in 10.83 and 19.20% tuber infestation by PTM, respectively. Application of *Bt* @ 1 g/kg of tubers at monthly interval was also effective and on par with these.

2.12. Biological suppression of weeds

At AAU, Jorhat, successful control of water hyacinth has been achieved by the field release of the exotic weevils *Neochetina eichhorniae* and *N. bruchi*. In Disangmukh of Sibsagar district, more than 700 hectares of water body has been cleared.

3. INTRODUCTION

3.1. Brief History

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

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

3.2. Past achievements

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

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

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

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

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

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

Suitable low temperatures for short term storage of trichogrammatids, Eucelatoria bryani, Carcelia illota, Allorhogas pyralophagus, Copidosoma koehleri, Hyposoter didymator, Cotesia marginiventris, Leptomastix dactylopii, Sturmiopsis inferens and Pareuchaetes pseudoinsulata have been determined. Superior strains of Trichogramma chilonis have been determined for cotton, sugarcane and tomato crops. Endosulfan tolerant strain of Trichogramma chilonis was developed for the first time and the technology transferred to a private company for large scale production. High temperature and multiple insecticide tolerant strains of T. chilonis are being developed. Different pesticides have been screened against 37 natural enemies for identifying relatively safer ones to be used in BIPM. Primary cell culture from the embryos of Spodoptera litura was established to facilitate the multiplication of obligate

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microorganisms. Baculoviruses from several lepidopterous hosts were identified and cross infectivity studied. Physico-chemical characters of NPVs of *Spodoptera exigua* and *Galleria mellonella* were analysed.

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

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

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

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

Bt and SINPV formed important components of BIPM in tobacco. Bt and HaNPV were important components of BIPM of pod borer complex in pigeonpea and pod borer of chickpea.

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

Apanteles taragamae, Bracon hebetor, Goniozus nephantidis, and Brachymeria nosatoi are the key biocontrol agents on Opisina arenosella. Their inundative release coinciding

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the first release with the first appearance of the pest has proved effective. *Oryctes* baculovirus has been highly successful in reducing the *Oryctes rhinoceros* population in Kerala, at Minicoy, Androth (Lakshadweep) and Andaman Islands.

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

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

Significant impact of *Neochetina eichhorniae*, *N. bruchi* and *Orthogalumna terebrantis* against water hyacinth was seen in Assam, Maharashtra, Gujarat, Kerala and Punjab. *Fusarium pallidoroseum* was found suitable as a candidate for parthenium control.

Training programmes on mass production and demonstration of the impact of *Trichogramma, Cryptolaemus, Chrysoperla, Ha* NPV and *Sl* NPV have been conducted in many states.

Software on biological control namely, PDBC INFOBASE, giving information about bioagent producers, and BIOCOT, giving information about biocontrol measures for cotton pests have been developed.

3.3. Mandate

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

3.4. Organisational set-up

With a view to fulfil the mandate effectively and efficiently, the Project Directorate is functioning with Biosystematics, Introduction and Quarantine Laboratory, Mass Production Laboratory, Pathology Laboratory, Entomophagous Insect Behaviour Laboratory, Biotechnology Laboratory and a Technical and Documentation Cell.

3.5. Financial statement

| Head | Plan * | Non-plan | Total |
|-----------------------------------|--------|----------|--------|
| Pay & allowances | 13.31 | 88.51 | 101.82 |
| TA | 3.00 | 1.75 | 4.75 |
| Other charges including equipment | 34.29 | 18.00 | 52.29 |
| Works/petty works | 33.30 | .50 | 33.80 |
| Total | 83.90 | 108.76 | 192.66 |

^{*} Excluding co-ordinating centres

Centre wise budget (ICAR share)

| Name of the centre | Amount sanctioned (Rs. in lakhs) | Total expenditure (Rs. in lakhs) |
|-----------------------|-------------------------------------|----------------------------------|
| CPCRI, Kayangulam | * | |
| CTRI, Rajahmundry | * | |
| IARI, New Delhi | * | |
| IIHR, Bangalore | * | |
| IISR, Lucknow | * | |
| SBI, Coimbatore | * | |
| AAU, Jorhat | 4.45 | 11.41 |
| ANGRAU, Hyderabad | 4.75 | ** |
| GAU, Anand | 8.60 | 13.69 |
| KAU, Thrissur | 5.05 | 8.23 |
| MPKV, Pune | 3.75 | 7.29 |
| PAU, Ludhiana | 8.55 | 11.86 |
| SKUAS&T, Srinagar | 3.55 | ** |
| TNAU, Coimbatore | 3,65 | 4.93 |
| YSPUH&F, Nauni, Şolan | 4.35 | ** |
| GBPUA&T, Pantnagar | 2.40 | ** |

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

^{**} Expenditure details not furnished

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3.6. Staff Position

| Category | Posts sanctioned up to 31.03.2001* | Posts filled up to 31.03.2001 | Vacant positions |
|---------------------------------|------------------------------------|----------------------------------|---------------------|
| PDBC, Bangalore | | | |
| Scientific | 25 | 22 | 3 |
| Technical | 21 | 18 | 3 |
| Administrative | 8 | 7 | 1 |
| Supporting | 6 | 6 | |
| SAU-based Centres | 4 | | |
| Scientific | 21 | 17 | 2 |
| Technical | 31 | 31 | - |
| Administrative | 1 | 1 | - |
| ICAR Institute-based Centres | | | |
| Scientific | 12 | 10 | 2 |
| Technical | 38 | 38 | |

^{*} including X Plan sanctioned posts

PDBC Annual Report 2001-2002 PROJECT DIRECTORATE OF BIOLOGICAL CONTROL BANGALORE Organisational Chart BIOSYSTEMATICS AND INTRODUCTION LABORATORY CFCRI KAYANGULAM SAU CENTRES POST GRADUATE EDUCATION AAU.IORIIAT AFAU. HYDERABAD CTRI, RAJAHMUNDRY MASS PRODUCTION LABORATORY GAU, ANAND IARI, NEW DELHI GBFUA&T. PANTNAGAR HHR. BANGALORE KAU. THRISSUR PATHOLOGY LABORATORY HSR, LUCKNOW MPAU, PUNE PAU, LUDHIANA SKUASAT, SRINAGAR RESEARCH AND TRAINING COORDINATING CELL TNAU. COIMBATORE BIOTECHNOLOGY LABORATORY DR.YSPUHAF, SOLAN TECHNICAL CELL COMMITTEES SERVICES AND ADMINISTRATION DOCUMENTATION MANAGEMENT COMMITTEE PUBLICATION COMMITTEE ESTABLISHMENT LIBRARY ADMINISTRATION AND ACCOUNTS RESEARCH ADVISORY COMMITTEE ARIS AND NISBS STORES AND PURCHASE GRIEVANCE CELL FARM SECTION ESTATE JOINT STAFF DESIGN SECTION SECURITY

4. RESEARCH ACHIEVEMENTS

4.1 Importation of natural enemies

Proposals have been submitted to Plant Protection Advisor to Govt. of India for obtaining import permits for Smicronyx lutulentus, Procecidochares connexa, Nephaspis bicolor, Ganaspidium utilis, Chrysocharis parksi, Delphastus pusillus, Telenomus triptus, Telenomus ullyetti, Glabromicroplitis croceipes, Meteorus pulchricornis and Trichogramma mwanzai. The import permits are still awaited.

4.2 Taxonomic studies on Coccinellidae of the Indian region

Five apparently new species belonging to the genera *Synonychimorpha* Miyatake (predatory on *Lepidosaphes* sp. on citrus, from Chettalli), *Ortalia* Mulsant (from Tamil Nadu), *Microserangium* Miyatake and *Ghanius* Ahmad (from Thiruvannamalai, Tamil Nadu) and *Protoplotina* Miyatake (predatory on *Aphis gossypii* infesting brinjal, from Uttar Pradesh) were recorded during this period. Of these, *Ghanius* is reported for the first time from India. Compilation of an identification guide for common coccinellids of the Indian region is in progress.

4.3. Survey for natural enemies

4.3.1 Survey in Lakshadweep for the spiralling whitefly and establishment of natural enemies

Encarsia spp., introduced in the islands of Kavaratti and Agatti during 2000-01 were found to have established well in June 2001, when a survey was made for checking establishment.

4.3.2. Survey for the predators of spiralling whitefly, Aleurodicus dispersus

During the surveys around Bangalore, Anegleis perrotteti (Mulsant), Horniolus sp., Jauravia dorsalis (Weise), J. pallidula Motschulsky, Nephus regularis (Sicard), Pseudoscymnus sp., Pseudaspidimerus flaviceps (Walker), Scymnus latemaculatus Motschulsky, S. coccivora Ayyar, S. posticalis Sicard and S. saciformis Motschulsky (Coleoptera: Coccinellidae) were recorded feeding on A. dispersus.

4.3.3. Monitoring the population of Aleurodicus dispersus and its parasitoids

The populations of A. dispersus and its parasitoids were monitored on papaya, guava, Cassia siamea and Michelia sp. at weekly interval. The incidence of Encarsia

guadeloupae was moderate to heavy during June-November and decreased during December-March (Table 1). Parasitisation was observed on all the four hosts on which the monitoring was done. The population of the host as well as the parasitoids was reduced to negligible levels during January-February 2002.

Table 1. Seasonal incidence of parasitoids of spiraling whitefly

| Months | | N | lean per cent i | ncidence | |
|----------------|--------|-------|-----------------|-----------|----------|
| | Papaya | Guava | Cassia | Michaelia | Bauhinia |
| June 2001 | 28.23 | 29.16 | 66.08 | 23.67 | - |
| July 2001 | 37.97 | 34.10 | 77.11 | 22.49 | - |
| August 2001 | 37.07 | 37.91 | 60.19 | 31.03 | = |
| September 2001 | 41.61 | 39.92 | 57.97 | 38.93 | - |
| October 2001 | 67.71 | 52,41 | 65.17 | 74.17 | - |
| November 2001 | 66.94 | 52.10 | 74.79 | 71.29 | 44.46 |
| December 2001 | 3.95 | 9.71 | 13.14 | 30.10 | 30.64 |
| January 2002 | 6.38 | 13.40 | 16.09 | 4.89 | 19.63 |
| February 2002 | 1.51 | 0.89 | 7.38 | 0 | 7.04 |
| March 2002 | 0 | 3.03 | 0 | 9.18 | 3.86 |

4.3.4. Survey for natural enemies of Helicoverpa armigera and Spodoptera litura

Larvae of *H. armigera* and *S. litura* were collected from different agro-ecosystems in Hessaraghatta, Shiddlughatta, Doddaballapur, Rajankunte, Hosakote, Davangere, GKVK Campus, Devanahalli, etc. near Bangalore and from Pavagada, Chintamani and Jalgaon from crops like cotton, tomato, rose, marigold, pigeonpea and dolichos and parasitism levels identified. Parasitism by ichneumonids was 0-18% and by tachinids 0-13%. Maximum parasitism by ichneumonids was observed during October – January on dolichos.

Orius spp., mainly O. tantillus and also O. maxidentex were collected from maize, sunflower, marigold and rose in and around Bangalore.

4.3.5. Collection of dipteran and mite predators from the field

Cecidomyiids and phytoseiids were collected from different crops like tomato, cowpea, pigeonpea, field beans, cucurbits, jasmine, *Bauhinia*, etc. in and around Bangalore.

4.4. Culturing techniques for host insects and natural enemies

4.4.1. Rearing of Eriborus argenteopilosus

An experiment was conducted to evaluate a novel method of mass multiplying E. argenteopilosus in the laboratory using 5 l jars and exposing the host larvae with diet and butter paper strips in the jars at different ratios (1:5, 1:10, 1:15, 1:20, 1:25)

The per cent parasitism recorded was highest (43) in the ratio 1:5, followed by the ratios 1:10 (25%) and 1:15 (27%). Minimum per cent parasitism of 19% and 17% was recorded at the ratios 1:20 and 1:25, respectively (Fig.1). Per cent adult emergence from the cocoons formed at different ratios was high (93-98%). Amongst the progeny produced in the different ratios, 36.5 to 50% were females.

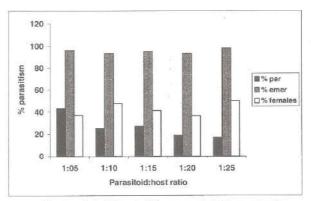


Fig. 1. Suitability of different parasitoid-host ratios for rearing of *Eriborus argenteopilosus*

4.4.2. Mass multiplication techniques for predatory dipterans, mites and their hosts

4.4.2.1 Predatory mites

Spider mites are being cultured on detached cow pea/field bean leaves on moist cotton pads and on cowpea/field bean seedlings raised in polyurethane cups. The phytoseiid mite, *Amblyseius longispinosus* is in turn being cultured on these. Biology of the red spider mite, *Tetranychus urticae* and *A. longispinosus* is being studied. The egg, protonymphal and deutonymphal periods of *T. urticae* in the laboratory were 2.6, 1.5 and 3.1 days, respectively. The total life cycle is completed in a little over 7 days. Various predator:prey ratios are under trial to determine the optimum ratio for the mass production of the predator.

4.4.2.2. Cecidomyiids

It was possible to multiply cecidomyiids on *Ferrisia virgata* cultured on pumpkins. Adult cecidomyiids on emergence mated and laid eggs on *F. virgata* when released in 1x1x1 ft. cages made of transparent acrylic sheets. Cecidomyiids were also collected from scales and aphid infested plants on a variety of plant hosts. When reared on *F. virgata*, cecidomyiids completed their life cycle in 13-15 days. The mean developmental periods for eggs, larvae (all four instars) and pupae were 3 days, 6-8 days and 4 days, respectively. Adult longevity was 4-5 days. Each female laid 40-50 eggs.

4.4.2.3. Predatory pentatomid

A rearing technique for *E. furcellata* is being developed on the larvae of *S. litura*. In the absence of adequate prey, adults and nymphs of the predator become cannibalistic. The first instar nymphs are phytophagous. They could be reared on the pods of field beans.

4.5. Bioecological studies on laboratory hosts and natural enemies

Studies on the feeding potential of the Spiralling whitefly predator, Cybocephalus sp.

Studies revealed that the females (n=2) during their life of 73 days fed on 143.5 nymphs at an average of 1.96 nymphs per day while males (n=4) during their life of 71.75 days fed on 135.2 nymphs at an average of 1.87 nymphs per day.

4.5.2. Evaluation of Eriborus argenteopilosus on chickpea and cotton

E. argenteopilosus was evaluated in cage studies on cotton and chickpea plants. On cotton plants, the parasitism ranged from 18 to 46%. At a ratio of 1:5, maximum parasitism (43.17) was recorded, followed by 1:10 ratio (31.27%) and minimum parasitism was in the ratio of 1:15. On chickpea plants, the parasitism ranged from 9 to 40% (Table 2). Variations were observed in the different replications and the optimum ratio could not be identified.

Table 2. Evaluation of Eriborus argenteopilosus

| Parasitoid: host | ratio | Per cent parasitism on | | |
|------------------|-------|------------------------|---------------|--|
| | | Cotton | Chickpea | |
| 1:5 | | 43.17 (41.32) | 21.47 (27.94) | |
| 1:10 | Ses I | 31.27 (34.15) | 9.13 (18.05) | |
| 1:15 | | 20.07 (26.96) | 29.00 (32.72) | |
| CD (P=0.05) | | 9.25 | 7.17 | |

Interaction between Campoletis chlorideae and Eriborus argenteopilosus (individual exposure)

Competitive interaction of these parasitoids was studied by exposing the host larvae individually to single prick of the female parasitoids. The larvae were either exposed to only one parasitoid or to one after the other at definite time intervals of 0, 6, 12, 18, 24 and 36 h.

4.5.3.1. Parasitism by Campoletis chlorideae in interaction with Eriborus argenteopilosus

Campoletis chlorideae, if allowed to parasitise alone, provided high parasitism (84%). If the larvae parasitised by C. chlorideae were parasitised by E. argenteopilosus after 18 h, 24 h or 48 h, per cent parasitism by C. chlorideae (80.75, 82.00 and 84.00%, respectively) was not affected significantly in comparison to parasitisation by C. chlorideae alone. However, if the larvae initially parasitised by C. chlorideae were parasitised by E. argenteopilosus within 12h, there was a significant reduction in C. chlorideae parasitism (Table 3).

If the larvae were parasitised by *E. argenteopilosus* before *C. chlorideae*, irrespective of the time interval, per cent parasitism by *C. chlorideae* reduced drastically (the differences being highly significant in comparison to parasitism by *C. chlorideae* alone).

When *E. argenteopilosus* was allowed to parasitize first, maximum parasitism by *C. chlorideae* was recorded after 0 h and 6 h (59.75 and 49.00%, respectively). Significant reduction in parasitism by *C. chlorideae* occurred after 12 h. Minimum parasitism was recorded after 48 h (2.00%).

4.5.3.2. Parasitism by Eriborus argenteopilosus in interaction with Campoletis chlorideae

Eriborus argenteopilosus, if allowed to parasitize alone, provided high parasitism (80%) (Table 3). If the larva parasitised by *E. argenteopilosus* was exposed to *C. chlorideae* at intervals of 0 to 48 h, parasitism by *E. argenteopilosus* was affected significantly in comparison (31.25, 41.0, 45.0, 54.75, 72.25 and 57.0%, respectively at 0, 6, 8, 12, 24 and 48 h). Parasitism by *C. chlorideae* on larvae initially exposed to *E. argenteopilosus* after 0 and 24 h were statistically on par (31 and 41%, respectively). Parasitism by *E. argenteopilosus*, followed by exposure to *C. chlorideae* after 12h, 18h and 48h was 45, 54.75 and 57%, respectively, which were all on par. The treatment with 24h time gap between *C. chlorideae* and *E. argenteopilosus* parasitisation provided 72% parasitism by *E. argenteopilosus*.

If larvae were exposed to *C. chlorideae* prior to *E. argenteopilosus*, irrespective of the time interval per cent parasitism reduced drastically (0-19.25%), the differences being highly significant in comparison to parasitism by *E. argenteopilosus* alone. There was no parasitism by *E. argenteopilosus* when the larva was exposed to *E. argenteopilosus* 24 and 48 h after *C. chlorideae*.

When *C. chlorideae* was allowed to parasitize first, maximum parasitism by *E. argenteopilosus* was recorded after 6 and 12 h interval (19.25 and 15.0, respectively), which were statistically on par. At 0 h and 12 h intervals, per cent parasitism by *E. argenteopilosus* was 6.75 and 7.25, respectively, which were statistically on par.

Table 3. Interaction between Campoletis chlorideae and Eriborus argenteopilosus (individual exposure)

| Treatments | Mean % parasitism by C. chlorideae | Mean % parasitism by E. argenteopilosus | Total per cent larval parasitism (by Cc and Ea) | Mean developmenta (from exposure to c formation - in days) | Mean developmental period (from exposure to cocoon formation - in days) | Mean % ad emergence | Mean % adult emergence |
|-------------|------------------------------------|---|---|--|---|------------------------|---------------------------|
| | | | | Cc | Ea | 3 | Ea |
| Cc alone | 84.00 (66.99)\$ | | 84.00 (66.98) | 8,40 | , | 06 | |
| Ce 0h Ea | 73.25 (59.26) | 6.75 (15.42) 8 | 80.00 (64.05) | 8.90 | 14.5 | 06 | 06 |
| Cc 6h Ea | 68.75 (56.45)* | 19.25 (26.21)° | 88.00 (71.54) | 9.00 | 14.5 | 16 | 92 |
| Cc 12h Ea | 70.00 (57.17) | 15.00 (23.00) ° | 85.00 (68.86) | 8.90 | 15.3 | 92 | 93 |
| Cc 18h Ea | .80.75 (64,40)* | 7.25 (14.79) 8 | 88.00 (71.33)* | 8.75 | 15.0 | 92 | 81 |
| Cc 24h Ea | 82.00 (65.33)* | 0.00 (4.05)" | 82.00 (65.33) | 8.99 | a | 92 | i. |
| Cc 48h Ea | 84.00 (67.00)\$ | 0.00 (4.05) | 84.00 (67.00)* | 8.75 | g. | 85 | , |
| Ea alone | | 80.00 (64.80)* | 80.00 (64.78)* | | 13.5 | 52 | 95 |
| Ea oh Cc | 59.75 (50.94)* | 31.25 (34.30) 4 | 91.00 (73.28) b | 11.44 | 16.5 | 92 | 81 |
| Ea 6h Ce | 49.00 (44.72)∞ | 41.00 (40.10) ^{4c} | 90.00 (72.61) | 9.00 | 13.3 | 92 | 92 |
| Ea 12h Cc | 45.00 (42.41)* | 45.00 (42.41)* | 90.00 (73.03) 5 | 8.90 | 14.0 | 91 | 92 |
| Ea 18h Cc | 33.25 (35.44) | 54,75 (48.04)* | 88.00 (70.38) | 9.10 | 14.25 | 68 | 06 |
| Ea 24h Cc | 11.75 (20.36) ^b | 72.25 (58.70) (| 84.00 (67.52) b | 9.50 | 13.45 | 83 | 91 |
| Ea 48h Ce | 2.00 (8.53)* | 57.00 (49.40)* | 59.00 (51.99)* | 8.90 | 14.0 | 85 | 06 |
| CD (P=0.05) | 4.69 | 7.45 | 98.6 | SN | NS | SS | N |

Figures in parantheses are angular transformed values; Values followed by the same letter are not statistically different. Cc - Campoletts chlorideae Ea - Eriborus argenteopilosus

When these two parasitoids were allowed to parasitize singly, their performance was statistically on par (84 and 80% parasitism, respectively). When *C. chlorideae* was allowed first followed by *E. argenteopilosus* at 0h, 6h, 12h, 24h and 48h, per cent parasitism by *C. chlorideae* was 73, 69, 70, 81, 82 and 84%, respectively. When a similar opportunity was provided for *E. argenteopilosus*, per cent parasitism by *E. argenteopilosus* was significantly less in comparison to *C. chlorideae* (31, 41, 45, 55, 72 and 57%, respectively).

When the host larvae were parasitised first by *E. argenteopilosus* and then at 0h, 6h, 12h, 18h, 24h and 48h interval by *C. chlorideae*, per cent parasitism by *C. chlorideae* was 60, 49, 45, 33, 12 and 2 per cent, respectively. However, when *E. argenteopilosus* followed *C. chlorideae*, per cent parasitism by *E. argenteopilosus* was significantly less in (7, 19, 15, 7, 0 and 0%, respectively).

4.5.4. Interaction between Campoletis chlorideae and Eriborus argenteopilosus (mass exposure)

To evaluate the competitive interaction between these two parasitoids through mass exposure, castor leaf bouquets were prepared and larvae of *S. litura* and female parasitoids were released. After 24 h, the larvae were collected back and reared individually in semi-synthetic diet. Treatments for this study were as detailed below-

- 1. Parasitism by C. chlorideae alone
- 2. Parasitism by E. argenteopilosus alone
- 3. Parasitism by C. chlorideae along with E. argenteopilosus
- 4. Parasitism by E. argenteopilosus along with C. chlorideae
- 5. Total parasitism by both parasitoids together

The per cent parasitism by *C. chlorideae* and *E. argenteopilosus* when released alone was 47.08 and 36.09, respectively (Fig. 2), which were on par. Performance of *C. chlorideae* when alone or when *E. argenteopilosus* was present, was statistically similar. However, the performance of *E. argenteopilosus* was affected when *C. chlorideae* was present (8.5%). When both parasitoids were present, the total larval parasitism obtained (62.5%) was on par with that by *C. chlorideae* alone.

4.5.5. Biology and feeding potential of Blaptostethus pallescens

The biology (Table 4) and feeding potential of this anthocorid (Fig. 3) were studied. Freshly hatched nymphs preferred plant material on the first two days. From the 3rd day, they started feeding on host eggs. Feeding rate generally was 4-11 eggs/day, occasionally higher (13 eggs/day). Feeding potential was higher between day 8 and day 14 of the nymphal period.

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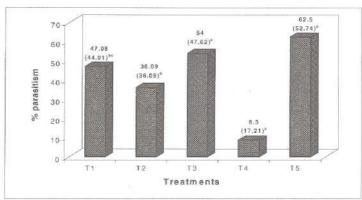


Fig. 2. : Performance of C. chlorideae and E. argenteopilosus singly and in combination. (studied through the mass exposure method)

T1: % parasitism by C. chlorideae singly

T2: % parasitism by E. argenteopilosus alone

T3: % parasitism by C. chlorideae along with E. argenteopilosus
T4: % parasitism by E. argenteopilosus along with C. chlorideae

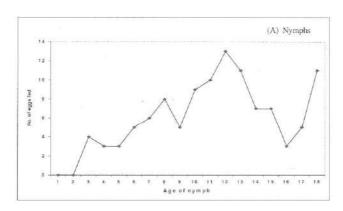
T5: % parasitism by C. chlorideae and E. argenteopilosus together

CD at 5% = 7.56; CD at 1% = 10.49

Table 4. Biological parameters of Blaptostethus pallescens

| Biological parameters | Mean | |
|----------------------------|--------------------|--|
| Incubation period | 4.5±0.22 days | |
| Nymphal period | 16.3 ±0.62 days | |
| Total developmental period | 19.9±0.4 days | |
| Longevity (male) | 64.4±5.82 days | |
| Longevity (female) | 53.2±5.06 days | |
| Progeny production | 143±30.05 / female | |
| Per cent female progeny | 57.8±1.6 % | |

The adult female had a higher feeding potential than the adult male. The adult male fed on 3-10 eggs/day, sometimes on 2 eggs/day or higher (18 to 20 eggs/day). Higher peaks (18 to 20 eggs per day) were observed in males lived that beyond 70 days. The adult female fed on about 4 to 13 eggs per day. The fresh adult female had a higher feeding potential (about 19 eggs/day). Based on the feeding potential, it was calculated that 9 cc of C. cephalonica eggs would be required for rearing 1000 B. pallescens.



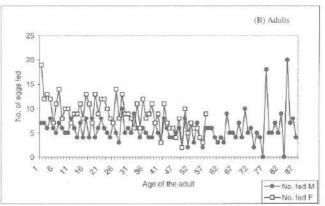


Fig 3. Feeding potential of Blaptostethus pallescens - M - Male F - Female

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

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

Field experiments were conducted at Satya Sai Cotton Mill, White Field, Bangalore, and in a farmer's field at Chintamani to find out the efficiency of L-tryptophan as an ovipostional attractant. More number of eggs were laid on L-tryptophan (0.66%) treated plants than untreated plants (Table 5). When the same formulations were tested in the laboratory in multiple choice tests, more number of eggs were laid on kairomone treated plants than untreated control, but there was not much difference between the various formulations.

Table 5. Oviposition by C. carnea on L-tryptophan treated cotton plants under field conditions

| Treatment | No. of eggs laid | |
|---------------------------------------|------------------|------------|
| | Field | Laboratory |
| L-Tryptophan 0.33% with 75 ml 2 N HCl | 3.00 | 23.6 |
| L-Tryptophan 0.66% with 75ml 2 N HCl | 3.00 | 24.0 |
| L-Tryptophan 0.66% with 150ml 2 N HCl | 3.75 | 24.6 |
| Control | 1.75 | 16.5 |
| CD (P=0.05) | | 4.9 |

4.6.2. Ovipositional response of C. carnea to kairomone treated cotton in field conditions

Studies were conducted to find out the efficiency of plant derived compounds like caryophyllene and linalool as ovipositional attractants in laboratory and field conditions. Both acted as ovipositional attractants and recorded more than untreated control, but no difference was observed in the ovipositional response between the different compounds tested (Table. 6).

Table 6. Ovipositional response of C. carnea to different compounds in multiple choice tests

| Compound | No of eggs laid | | |
|--------------------|-----------------|--------|--|
| | 0.1% | 0.2% | |
| β Caryophyllene | 3.125 | 4.250 | |
| Linalool | 2.750 | 2.750 | |
| L-Tryptophan 0.66% | 2.875 | 3.175 | |
| Control | 2.125 | 2.125 | |
| Base | 50.870 | 43.223 | |

4.6.3. Kairomonal formulations to increase the parasitizing efficiency of *Trichogramma chilonis* under field conditions

Corcyra egg cards treated with kairomonal formulations were tagged on cotton plants in a small area of $5 \times 3.5 \text{m}$ and untreated cards were tagged in another patch. Adults of T chilonis were released in the experimental area. There was higher parasitisation on the tricosane and pentacosane treated egg cards than control. However there was no variation between the different concentrations tested (Table 7.)

Table. 7. Parasitisation efficiency of *T. chilonis* on the kairomone treated eggs cards in the field conditions

| Compound | Percent eggs p | arasitised |
|-------------|----------------|------------|
| | 0.1% | 0,2% |
| Pentacosane | 13.33 | 13.18 |
| Tricosane | 13.20 | 13.33 |
| Control | 9.47 | 9.33 |

4.6.4. Laboratory studies on the effect of kairomonal formulations on the parasitizing efficiency of *T. chilonis*

Laboratory studies were conducted to find out the efficiency of kairomonal formulations to increase the parasitising ability of *T. chilonis* in '8' armed olfactometer. Kairomonal formulations, were prepared using the scales of *Corcyra cephalonica* along with Tricosane and Pentacosane at 0.1% and 0.2%. There was significant increase in parasitisation at 0.1%. However, the formulations were not effective at other concentrations (Table.8).

Table 8. Parasitisation by *T. chilonis* on the eggs of *C. cephalonica* treated with kairomones in 8 arm olfactometer

| Compound | Percentage eggs predated at | | | | | |
|------------------|-----------------------------|------|------|------|--|--|
| | 0.1% | 0.2% | 0.3% | 0.4% | | |
| Tricosane 0.1% | 31.4 | 28.4 | 25.2 | 28.4 | | |
| Pentacosane 0.1% | 29.0 | 21.4 | 26.8 | 30.8 | | |
| Control | 21.8 | 24.6 | 34.2 | 31.8 | | |
| CD at 5% | 4.6 | N.S | N.S | N.S | | |

4.6.5. Screening of kairomonal compounds for Trichogramma chilonis adults

Kairomonal compounds dissolved in hexane solution at 0.01%, 0.02%, 0.03%, 0.04% and 0.05% were tested in 8-arm olfactometer. Nonacosane and Hexacosane showed slightly higher parasitisation over control, but at lower concentrations none of the chemicals showed any attraction (Table 9).

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Table 9. Parasitization by *T. chilonis* on egg cards treated with kairomones in 8 arm olfactometer

| Compound | Per cent parasitisation at concentration | | | | |
|--------------|--|-------|--------|-------|-------|
| | 0.01% | 0.02% | 0.03% | 0.04% | 0.05% |
| Dodecane | 30.80 | 32.4% | 33.2% | 36.8% | 40.0 |
| Docosane | 34.80 | 27.2% | 32.4% | 38.0% | 36.4 |
| Eicosane | 25.20 | 26.4% | 31.2% | 35.2% | 37.6 |
| Hexacosane | 36.80 | 35.2% | 38.0% | 40.4% | 43.6 |
| Nonacosane | 33.27 | 29.6% | 31.6% | 45.2% | 35.6 |
| Pentacosane | 32.40 | 30.0% | 38.0% | 36.8% | 32.4 |
| Tricosane | 25.60 | 25.6% | 36.05% | 28.8% | 31.2 |
| Control | 25.60 | 24.0% | 34.0% | 21.8% | 35.2 |
| CD (P=0.05%) | NS | NS | NS | NS | NS |
| | 31 | | | | |

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

There was no significant difference in the predatory potential of C. carnea larvae on egg cards treated with kairomones at a concentration of 0.1%, but at 0.2%, pentacosane recorded marginal increase in predation compared to tricosane (Table 10).

Table 10. Predatory potential of C. carnea on eggs of C. cephalonica treated with kairomones

| Compound | Percent egg | Percent eggs preyed on a | | |
|-------------|-------------|--------------------------|--|--|
| | 0.1% | 0.2% | | |
| Tricosane | 10.84 | 11.77 | | |
| Pentacosane | 9.27 | 12.36 | | |
| Control | 10.42 | 7.57 | | |

4.6.7. Behavioral response of Chrysoperla carnea adults to kairomonal compounds

The behavioural response of adults of *C.carnea* to some of the kairomonal compounds, derived from the scales of *H. armigera* was studied through EAG and orientational response studies. The male *C.carnea* showed highest response to honey (reference) followed by dodecane. Pentacosane, octane and tricosane also recorded highest response. In the case of the females, honey recorded highest response. Pentacosane, dodecane recorded highest EAG response (Table 11).

Table. 11. EAG response of adult C. carnea to kairomonal compounds

| Compound | Male (- mv) | Female (- mv) |
|-------------------|-------------|---------------|
| Pentacosane | 0.868 | 0.696 |
| Docosane | 0.470 | 0.717 |
| Tricosane | 0.747 | 0.536 |
| Pentadecane | 0.579 | 0.483 |
| Eicosane | 0.633 | 0.481 |
| Nonacosane | 0.641 | 0.564 |
| Octane | 0.816 | 0.653 |
| Heptadecane | 0.495 | 0.584 |
| Octadecane | 0.495 | 0.479 |
| Dodecane | 0.409 | 0.869 |
| Honey (reference) | 1.301 | 1.050 |
| Air | 0.039 | 0.029 |

Orientational behaviour of adult of *C.carnea* to the above compounds was studied under multiple-choice conditions. Dodecane, tricosane, octane and octodecane recorded significantly more number of adults visiting the filter paper than the control.

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

During the period under study, two experiments were conducted on tritrophic interaction between *Trichogramma chilonis*, *Helicoverpa armigera* and cotton genotypes. The genotypes Gujarat Hybrid-6, Gujarat Hybrid-8, Gujarat Cotton 10, Abadhita, Sahana, CPD-423, CPD-428, CPD-431, CPD-447, DHH-11 and DHB-105 were evaluated under multiple-choice condition

in a polyhouse. Mean per cent parasitisation of *H. armigera* eggs on different genotypes varied from 22.22 to 48.88. Highest parasitisation was recorded on genotype G-cotton 10 (48.88) and CPD 428 (39.99%), closely followed by DHH-11, Abadhita and CPD-431. Minimum parasitization was recorded on Sahana (22.22%), followed by Gujarat Hybrid-6 and Gujarat Hybrid-8 (24.44%).

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

Eleven genotypes of cotton, *viz.* Gujarat Hybrid-6, Gujarat Hybrid-8, Gujarat cotton-10, Abadhita, Sahana, CPD-423, CPD-428, CPD-431, CPD-447, DHH-11and DHB-105 were evaluated for their attraction to *Trichogramma chilonis* in Y-tube olfactometer. The mean per cent response varied from 23,33 to 50.00 per cent. Highest population was attracted to the leaves of genotype CPD 428(50.00%), followed by CPD 423, CPD-447 and DHB 105. Lowest response was observed to Hybrid-6, Abadhita and CPD 431 (All 23.33%).

4.6.10. Relative response of Trichogramma chilonis to different chemical cues under multiple-choice olfactometer

Seven chemical volatiles (saturated hydrocarbons) of plant origin, viz. Dodecane, Tricosane, Pentacosane, Hexacosane, Heneicosane, Docosane and Cyclohexane, were evaluated in 8-arm glass olfactometer under multiple choice condition to find out the best synomone and its perception threshold for *T. chilonis*. All these compounds at 0.1% concentration were placed at the end of each arm and 80 *T. chilonis* adults were released at central chamber. Observations were recorded at 10 minutes interval on the number of *T. chilonis* adults reached the cues placed in different arms for 55 minutes. Highest number of *T. chilonis* was attracted to Pentacosane (14-17), followed by Heneicosane (10-12) and Tricosane (8-10). Least response was given to Cyclohexane (7-9). Response to control was in the range of 2-5 adults. Minimum response was noticed to all the cues after 5 minutes. It was highest after 25 minutes and declined after 45 minutes. Further net response in each cue has been worked out.

4.6.11. Enhancement of parasitization efficiency of *Trichogramma chilonis* by treating *C. cephalonica* eggs with kairomonal compounds

Seven kairomonal compounds, viz. Pentacosane, Heneicosane, Dodecane, Tricosane, Hexacosane, Docosane and Cyclohexane, were sprayed at 0.05% on Corcyra cephalonica egg strips (50 eggs each) and sprayed egg strips were placed in different arms of multiple choice olfactometer. Eighty adult females of T. chilonis were released for 30 minutes. Highest parasitization was recorded on eggs treated with Pentacosane (68%). Heneicosane (58.66%)

and Tricosane (56%) also recorded higher parasitization than control (54%). Egg strips treated with Hexacosane, Docosane and Cyclohexane recorded lower parasitization.

4.6.12. Electrophysiological responses of *Helicoverpa armigera* to leaves and bolls of different cotton varieties/hybrids

Electrophysiological response of adult females of *Helicoverpa armigera* to green volatiles released by leaves and bolls of eleven varieties /hybrids of cotton was studied through electroantennogram (EAG) studies. Highest mean absolute EAG response was shown towards volatiles released by leaves of G-Cotton-10 (-1.176mv), followed by DHB 105 (-1.005mv) and CPD 447(-0.824mv) (Table 12). Least response was given to variety Abadhita (-0.163mv) and Sahana (-0.204mv). Absolute net EAG response followed the same pattern. In case of relative net EAG response (compared to honey as standard), only G-Cotton-10 (0.454mv) HB 105(0.283mv) and CPD 447(0.283mv) exceeded standard compound, other responses were below standard compound.

Table 12. EAG responses of *H. armigera* to volatiles released by leaves and bolls of different varieties and hybrids of cotton

| Variety/ | Leav | ves | Bol | lls - |
|----------|--------------|--------------|--------------|--------------|
| hybrid | Ab. response | Net response | Ab. response | Net response |
| CPD 423 | -0.331 | -0.279 | -0.535 | -0.4446 |
| G-Cot-10 | -1.176 | -1.124 | -0.856 | -0.767 |
| Sahana | -0.256 | -0.204 | -0.358 | -0.269 |
| Abadhita | -0.215 | -0.163 | -0.541 | -0.450 |
| G-Hy-6 | -0.333 | -0.281 | -0.683 | -0.597 |
| G-Hy-8 | -0.359 | -0.307 | -0.682 | -0.596 |
| CPD 447 | -0.824 | -0.772 | -0.545 | -0.456 |
| CPD 431 | -0.650 | -0.598 | -0.577 | -0.488 |
| CPD 428 | -0.410 | -0.358 | -0.505 | -0,416 |
| DHH 11 | -0.386 | -0.334 | -0.463 | -0.374 |
| DHB 105 | -1.005 | -0.953 | 0.990 | -0.901 |
| Honey | -0.722 | -0.670 | -0.576 | -0.487 |
| Air | -0.052 | _ | -0.089 | _ |

In case of cotton bolls, maximum mean EAG response was exhibited towards DHH-11 (-990mv), followed by G-Cotton -10(-0.856mv), G-hybrid-8 (-0.683mv) and G-hybrid-8 (-0.682). Least absolute EAG response was given to the cues received from the variety Sahana. Similar trend was observed in case of absolute net response. The absolute net EAG response was highest towards DHH-11 (0.414mv), G-cotton-10 (0.280mv), G-Hy-6 (0.110mv) and G-Hy-8 (0.109mv) and the values exceeded the standard (honey).

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

Synomones released by the leaves of G. Hybrid-6, G-Hybrid-8, G-Cotton-10, Abadhita, Sahana, CPD-428, CPD-431, CPD-447, DHH-11, and DHB-105 were trapped in specially designed trap for two hours by passing pure air on the top of leaves. The hexane-extracted, concentrated volatiles were identified using GCMS. Out of 42 compounds identified from leaves, Alpha pinene, Beta pinene, Cyclohexane, Limonene, Trans-2-hexanal, Myrcene, Phenol 2,4-bis, Pentadecane, Hexadecane, Heptane, Heneicosane, Alpha humulene, Beta caryophyllene, Beta himachllene, Palmitic acid and Eicosane were present in most of the varieties. Alpha copaene, Bicyclo germacrene, 14-Beta-H-Pregna and Trans-Beta-Ocimene were present only in G-Hybrid-6. Similarly Benzothiazole Vangard BT, Cyclotridecane, Dodecane, Estragol, Hexatriacontane, Tridecane and 1,2 Benzene dicarboxylic acid were present only in G-Cot-10. Maximum plant volatiles were identified from G-hy-6 (25), followed by G-Cot-10.

From bolls of eight cotton varieties / hybrids, 27 volatiles were trapped. Among these, the most common compounds are Trans-2-Hexanal, 1,2, Benzene dicarboxylic acid, Phenol,2,4-bis, Pentadecane, Tetradecane, Tridecane, Cyclohexane, Eicosane, Heneicosane, Hexadecane, Limonene and Alpha pinene. Some of the compounds were found specifically in certain varieties, *viz.* Beta pinene, Decane and Octodecane (CPD 447); Beta ocimene, Hexatriacontane and Trans-caryophyllene (CPD 428); Docosane (G-Hy-8); Bicyclo germacrene (G-Hy-6) and Hexadecanoic acid (Sahana).

4.7. Artificial diets for host insects

4.7.1. Development of artificial diet for Opisina arenosella

Opisina arenosella was reared on three experimental diets based on coconut, wild date palm and toddy palm leaf powders in combination with defatted soya. The previously described diet by Jayanth & Sudha Nagarkatti was also tested. Defatted soya in combination with all three-leaf powders was found promising. Diet with toddy palm leaf powder recorded higher larval survival, adult emergence and fecundity. Two generations were studied during the period under report. The various growth parameters and duration of development in each

diet are presented in Table 13. Biochemical analysis of host leaves for protein, lipid and carbohydrate contents revealed that the diets were comparable to the natural host.

Table 13. Evaluation of different leaf powder based semi synthetic diets for Opisina arenosella

| Parameter | | Control | | TP+ | CN+ | WDP | CN+ | CN+ |
|--|--------------|--------------|---------------|----------------|----------------|---------------|---------------|----------------|
| | TP | CN | WDP | DS | DS | + DS | KBG | WG |
| Survival (%) | 100 | 100 | 100 | 100 | 90 | 90 | 82.8 | 84.6 |
| Pupal weight (mg) Male Female | 31.2 52.3 | 27,3 46,4 | 21.2 32.3 | 25.6 40.2 | 23.2 37.4 | 12.3 24.2 | 14.2 22.4 | 12.2 21.6 |
| Pupation (%) Adult emergence (%) | 95 91.2 | 95 87.40 | 93.10 85.5 | 86.40 59.40 | 82.80 55.80 | 79.40 54.0 | 63.0 37.80 | 61.20 39.60 |
| Female emergence (%) | 55.8 | 52.2 | 48.6 | 37.8 | 34.2 | 30.6 | 19.8 | 21.6 |
| Longevity (days) Male Female | 7,8 6.8 | 7.8 6.2 | 7.2 5.2 | 7.2 6.4 | 6.8 5.6 | 5.9 4.8 | 6.2 4.8 | 6.4 4.6 |
| Fecundity | 110.60 | 98.40 | 86.60 | 68.60 | 57.20 | 52.20 | 25,60 | 23.20 |

Mean of 2 generations

| TP + DS | Toddy palm leaf powder and defatted soya |
|----------|--|
| CN + DS | Coconut leaf powder and defatted soya |
| WDP + DS | Wild date palm leaf powder + defatted soya |
| CN + KBG | Coconut leaf powder + Kabuligram |
| CN + WG | Coconut leaf powder + Wheat germ |

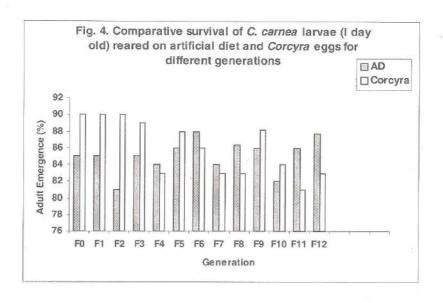
4,7.2. Development of artificial diet for Plutella xylostella

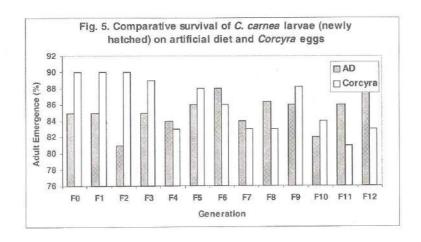
Semi-synthetic diets based on leaf powders of cabbage, cauliflower, knolkhol, radish and kidney beans in combination with defatted soya enriched with others (Cholesterol, Wesson's salt mixture, casein, etc.) were tried for the rearing of *P. xylostella*. Cabbage leaf powder diet in combination with defatted soya resulted in 15% survival of the larvae and 5% adult emergence. The other combinations did not support the development of the insect. Further studies are necessary to improve the diet. Biochemical analysis of host leaf components was done.

4.8. Studies on artificial diets for natural enemies

4.8.1. Artificial diet for rearing Chrysoperla carnea, Mallada boninensis and Mallada astur

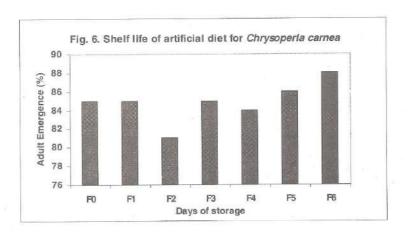
Chrysoperla carnea larva studing from neanate larve was successfully reared on artificial diet for 15 successive generations. The mean adult emergence (%) of *C. carnea* reared on artificial diet and *Corcyra* was 85.7 % and 86.0 %, respectively (Fig. 4). The diet was also tested for newly hatched *C. carnea* larvae for 12 successive generations. The mean survival and emergence were 85.0 % and 86.0 %, respectively (Fig. 5). Artificial diet reared *C. carnea* was found to lay eggs normally. The existing *Chrysoperla carnea* artificial diet could also be used for the rearing of *Mallada astur* and *M. boninensis*. The survival and adult emergence of these predators on artificial diet were 84.0 % and 74.0 % (*M. boninensis*) and 76.0 % and 72.0 % (*M. astur*), respectively.





4.8.2. Shelf life of artificial diet of Chrysoperla carnea

The artificial diet could be stored for up to 200 days at 5°C in refrigerator. The adult emergence ranged from 83 to 90 % for up to 90 days of storage and it started reducing after that. The per cent adult emergence was 68.7 % when the diet was stored for 200 days (Fig.6).



4.8.3. Toxicity of Spinosad 48SC to Chrysoperla carnea reared on artificial diet and Corcyra eggs

The residual toxicity of Spinosad 48 SC (0.031%) to Chrysoperla carnea reared on Corcyra eggs and artificial diet was evaluated. Spinosad 48 SC was highly toxic to adults of C. carnea reared on artificial diet and on Corcyra at 24 h causing 100 per cent mortality. It was toxic to first instar larvae of C. carnea for up to 72 hrs. In general, Spinosad was found to be relatively safer to third instar larva on natural and artificial diets.

4.8.4. Studies on the predatory efficiency of *Chrysoperla carnea* reared on artificial diet against tobacco aphid, *Myzus persicae* in comparison with other predators

First instar larvae of diet reared *C. carnea*, *Cheilomenes sexmaculata* and *Ischiodon scutelaris* were released @ 1:50 (predator-prey ratio) as per the densities of the aphids. One spray of monochrotophos (0.04 %) was kept as positive check. The mean aphid population/plant was lowest in monocrotophos treatment (193.3), followed by release of *C. sexmaculata* (287/plant), *C. carnea* (376/plant) and *I. scutellaris* (408.75), whereas it was 2765.85/plant in control. *C. carnea* reared on artificial diet was effective in suppressing the aphid population and comparable with other predators.

4.8.5. Artificial diet for anthocorids and coccinellids

Cardiastethus exiguus was reared on an artificial diet. The mean nymphal period and adult formation on the artificial diet and Corcyra egg were 19.0 days and 76.0 % and 18.8 days and 78.0 %, respectively.

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

4.9.1. Development of high temperature tolerant strains of *Trichogramma chilonis* and *Telenomus remus*

4.9.1.1. Trichogramma chilonis

The experiment was initiated during the year by exposing host eggs to *T. chilonis* by shifting parasitoids from 36°C to 36.5±1.5°C and RH 55-65% in BOD incubator. Continuous rearing was done for 55 generations and the results are presented in Table 14.

Table 14. Development of high temperature tolerant strain of T. chilonis

| Temperature (°C) | Generation | Per cent parasitism | Adult longevity (days) |
|------------------|------------|---------------------|------------------------|
| 36.5 ± 1.5 | Ī | 44 | 1 |
| | 10 | 41 | 1 |
| | 20 | 60 | 2 |
| | 30 | 65 | 3 |
| | 40 | 65 | 3 |
| | 50 | 80 | 4 |
| | 55 | 90 | 4-5 |

After 55 generations, the parasitoid is showing adaptability to $36.5\pm1.5^{\circ}$ C. The parasitism obtained in the first generation at this temperature was 41 per cent and survival was <1 day in comparison to less than 5.0 per cent parasitism by other susceptible strains. After 55 generations, parasitism was 90.0 per cent and survival >4 days.

4.9.1.2. Telenomus remus

The experiment was initiated during the year by exposing *Spodoptera litura* eggs to *T. remus* at 27°-36°C. At each temperature, parasitoids were reared for six generations before shifting to the next higher temperature in BOD incubator.

After 30 generations, parasitisation was 72.2 per cent and longevity was 7.8 days (Table 15). However, sex ratio, which was female biased up to 32°C, became male biased when parasitoids were shifted to 34°C. This strain could be useful for release in high temperature conditions against *S. litura*.

After 55 generations, the parasitoid is showing adaptability to $36\pm1.5^{\circ}$ C. The parasitism obtained in the first generation at this temperature was 41 per cent and survival was <1 day in comparison to less than 5.0 per cent parasitism by other susceptible strains. After 55 generations, parasitism was 90.0 per cent and survival >4 days.

Table 15. Development of high temperature tolerant strain of T. remus

| Parameter | | Te | emperature (° | C) | |
|---------------------------|--------|---------|---------------|--------|---------|
| | 27 | 30 | 32 | 34 | 36 |
| Per cent parasitisation | 88.3 | 86.2 | 78.6 | 78.2 | 72.2 |
| Developmental period | 14.3 | 11.5 | 10.5 | 9.3 | 7.2 |
| Adult longevity (in days) | 13.8 | 13.3 | 12.3 | 10.3 | 7.8 |
| Sex-ratio (Male:Female) | 2.6: 1 | 1.92: 1 | 1.88: 1 | 1: 1.5 | 1: 1.75 |

4.9.2. Selection of Trichogramma chilonis for tolerance to insecticides

During the year, exposure of *T. chilonis* to endosulfan at 0.09%, monocrotophos at 0.05 and fenvalerate at 0.001% was done. This experiment was started with 'Endogram' strain to develop multiple insecticide tolerant strain of *T. chilonis*. This strain has now become tolerant to 0.09% endosulfan, 0.05% monocrotophos and 0.002% fenvalerate. The parasitism is 90 - 95 per cent and survival 15-40 per cent after 6 hours of constant exposure to all insecticides (Table 16).

Table 16. Exposure of Trichogramma chilonis adults to insecticides

| Insecticide | Dosage (%) | Number of generations | Per cent parasitism | Per cent adult survival (after 6 h) |
|---------------|------------|-----------------------|------------------------|---|
| Endosulfan | 0.09 | 36 | 90 | 30 |
| Monocrotophos | 0.05 | 36 | 90 | 15 |
| Fenvalerate | 0.001 | 36 | 95 | 40 |

4.9.3. Selection of *Trichogramma chilonis* strain with high host searching ability for use against *Helicoverpa armigera* on tomato

The experiment was conducted by exposing *Trichogramma chilonis* in insect rearing cage (30 cm³). The parasitoids were released initially @ 500 adults per cage and egg ratio were 1F: 50 eggs. The parasitoid population was brought down to 30 adults per cage after 15 generations of exposure and regular maintenance was done in the cage itself in each generation. After 30 generations, an experiment was conducted by exposing the parasitoid @ 1, 2, 3, 4, 5 and 10 pairs per cage in parasitoid: egg ratio of 1F: 50 eggs. The parasitised egg card was

collected after 3 days and observed for per cent parasitism. This strain was compared with check species, *T. pretiosum*.

After 30 generations, the parasitoids were able to parasitise > 95% eggs when 30 adults were released from initial level of 40% when about 500 adults were released (Table 17). These parasitoids were used for further experiment.

Table 17. Development of high host searching strain of T. chilonis

| Generation (s) | Number of adults / cage | Number of egg / F | Per cent parasitisation |
|----------------|-------------------------|-------------------|-------------------------|
| 1 | 500 | 50 | 40 |
| - 5 | 400 | 50 | 95 |
| 10 | 100 | 50 | 60 |
| 15 | 30 | 50 | 60 |
| 20 | 30 | 50 | 90 |
| 25 | 30 | 50 | 90 |
| 30 | 30 | 50 | 95 |

Searching Ability Strain (SAS) parasitoids had significantly higher host searching ability and parasitised 50.6-77.0 per cent eggs compared to 4.0-34.0 per cent by check species, i.e. *T. pretiosum* (Table 18). The result has indicated that it is better to utilise SAS parasitoids instead of using traditional way of breeding parasitoids for field release.

Table 18. Parasitising ability of SAS and check species in varying release rates

| Release rate | Per cent parasitism | (parasitoid: egg ratio 1F: 50 eggs) | | |
|--------------|---------------------|--------------------------------------|--|--|
| | SAS parasitoid | Check species Trichogramma pretiosum | | |
| 1 pair | 53.6 | 4.0 | | |
| 2 pairs | 50.6 | 34.0 | | |
| 3 pairs | 60.0 | 30.4 | | |
| 4 pairs | 73.8 | 24.4 | | |
| 5 pairs | 77.0 | 11.2 | | |
| 10 pairs | 55.0 | 23.0 | | |

4.9.4. Effect of temperature and humidity on development of some species of trichogrammatids

The experiment was carried out in growth chamber at 18°, 20°, 25°, 30° and 35°C and at 40, 60 and 80% RH. The trichogrammatid species used were *Trichogrammatoidea armigera*, *Trichogramma achaeae*, *T. brasiliense*, *T. chilonis*, *T. evanescens* and *T. pretiosum*. About 30 adults of each species were kept in glass vials (15 x 2.5 cm) and *Corcyra cephalonica* eggs were provided @ 1F: 50 eggs/tube for 48 hours. After exposure, parasitoids were reared at the same temperature and humidity. Observations on per cent parasitism and developmental period were recorded.

The per cent parasitism ranged from 40.4 to 85.6 and was highest at 25°C and 60% RH. Humidity of 40 or 80% was not conducive for parasitoid efficacy. Among the species tried against *H. armigera* in various climatic conditions, *T. chilonis* and *T. brasiliense* performed better at temperatures between 25° and 35°C and *T. pretiosum* at 18° - 25°C. *Trichogramma achaeae* also parasitised significantly more eggs at higher temperatures compared to low temperature though it was not as effective as *T. chilonis* and *T. brasiliense*. *Trichogramma evanescens* was more effective at lower temperature than higher temperature (Table 19). Results indicated that *T. chilonis* and *T. brasiliense* can be considered in temperatures between 25° and 35°C, and *T. pretiosum* between 18° and 25°C for evaluation against *H. armigera*. The developmental period was 7.0–9.0 days at 30° and 35°C, 11.0-12.2 days at 25°C, 15.4 - 21.0 days at 20°C and 17.0 - 30.0 days at 18°C. At 18° and 35°C, many species failed to emerge, though some parasitisation was observed (Table 20).

Table 19. Effect of temperature and humidity on parasitism by various trichogrammatids used against H. armigera

| RH (%) 40 80 40 60 80 40 60 80 40 60 80 40 60 80 40 60 80 40 40 60 T. armigera - 0.0 9.0 6.0 10.0 6.6 10.0 40.4 28.0 17.0 11.0 T. arhaeae - 24.0 5.2 1.3 6.0 50.0 54.0 78.0 58.0 26.0 T. brasiltense - 8.6 18.2 8.0 17.0 18.0 40.0 81.2 40.0 50.0 77.0 T. evanescens - 6.0 39.0 1.5 46.6 48.0 77.2 44.0 5.0 17.0 T. pretitosum - 15.4 68.0 1.0 42.2 6.0 40.0 77.2 44.0 5.0 17.0 | Species | | | | | | Pe | r cent į | Per cent parasitism at | m at | | | | | | |
|---|----------------|----|------|------|-----|------|------|----------|------------------------|-------|------|------|------|------|------|------|
| 40 60 80 40 60 80 40 60 40 40 60 40< | | | J.81 | | | 20°C | | | 25°C | | | 30°C | | | 35°C | |
| e 2.0 9.0 6.0 10.0 6.6 16.0 40.4 28.0 17.0 re - 24.0 5.2 1.3 6.0 50.0 54.0 78.0 50.0 58.0 re - 8.6 18.2 8.0 17.0 18.0 42.0 81.2 40.0 28.0 re - 3.0 31.0 2.6 20.0 52.0 40.0 85.6 64.0 69.0 re - 6.0 39.0 1.5 46.6 48.0 37.0 77.2 44.0 5.0 re - 15.4 68.0 1.0 42.2 62.0 40.0 73.8 32.0 35.0 | RH (%) | 40 | 09 | 80 | 40 | 09 | 80 | 40 | 09 | 80 | 40 | 09 | 80 | 40 | 09 | 80 |
| se - 24.0 5.2 1.3 6.0 50.0 54.0 78.0 50.0 58.0 78.0 59.0 59.0 <td>T. armigera</td> <td>3.</td> <td>0.0</td> <td>0.0</td> <td>0.9</td> <td>10.0</td> <td>9.9</td> <td>16.0</td> <td>40.4</td> <td>28.0</td> <td>17.0</td> <td>11.0</td> <td>12.0</td> <td>15.0</td> <td>7.4</td> <td>2.0</td> | T. armigera | 3. | 0.0 | 0.0 | 0.9 | 10.0 | 9.9 | 16.0 | 40.4 | 28.0 | 17.0 | 11.0 | 12.0 | 15.0 | 7.4 | 2.0 |
| - 8.6 18.2 8.0 17.0 18.0 42.0 81.2 40.0 28.0 - 3.0 31.0 2.6 20.0 52.0 40.0 85.6 64.0 69.0 - 6.0 39.0 1.5 46.6 48.0 37.0 77.2 44.0 5.0 - 15.4 68.0 1.0 42.2 62.0 40.0 73.8 32.0 35.0 | T. achaeae | 1 | 24.0 | 5.2 | 1.3 | 0.9 | 50.0 | 54.0 | 78.0 | 90.09 | 58.0 | 26.0 | 0.61 | 34.0 | 19.0 | 2.6 |
| s 3.0 31.0 2.6 20.0 52.0 40.0 85.6 64.0 69.0 s - 6.0 39.0 1.5 46.6 48.0 37.0 77.2 44.0 5.0 - 15.4 68.0 1.0 42.2 62.0 40.0 73.8 32.0 35.0 | T. brasiliense | 6. | 8.6 | 18.2 | 8.0 | 17.0 | 18.0 | 42.0 | 81.2 | 40.0 | 28.0 | 77.0 | 36.0 | 0.89 | 42.0 | 5.4 |
| s 6.0 39.0 1.5 46.6 48.0 37.0 77.2 44.0 5.0 - 15.4 68.0 1.0 42.2 62.0 40.0 73.8 32.0 35.0 | T. chilonis | | 3.0 | 31.0 | 2.6 | 20.0 | 52.0 | 40.0 | 85.6 | 64.0 | 0.69 | 67.0 | 44.0 | 42.0 | 74.0 | 31.0 |
| . 15.4 68.0 1.0 42.2 62.0 40.0 73.8 32.0 35.0 | T. evanescens | 95 | 6.0 | 39.0 | 1.5 | 46.6 | 48.0 | 37.0 | 77.2 | 44.0 | 5.0 | 17.0 | 28.0 | 9.8 | 3.4 | 1.0 |
| | T. pretiosum | 2 | 15.4 | _ | 1.0 | 42.2 | 62.0 | 40.0 | | 32.0 | 35.0 | | 14.0 | 13.0 | 21.0 | 7 |

Table 20. Effect of temperature and humidity on developmental period of various trichogrammatids used against H. armigera

| Species | | | | | | Pe | r cent [| Per cent parasitism at | m at | | | | | | |
|----------------|----|------|------|------|------|------|----------|------------------------|------|-----|------|-----|-----|------|-----|
| ' | | 18°C | | | 20°C | | | 25°C | | | 30°C | | | 35°C | |
| RH (%) | 40 | 09 | 80 | 40 | 09 | 80 | 40 | 09 | 80 | 40 | 09 | 80 | 40 | 09 | 80 |
| T. armigera | 1 | NE | 20.6 | 21.0 | 18.2 | 20.2 | 12.0 | 11.0 | 11.0 | 0.6 | 0.6 | 9.0 | 8.0 | 0.6 | 7.3 |
| T. achaeae | 1) | 27.0 | 17.0 | 18.0 | 18.0 | 18.6 | 12.0 | 11.3 | 10.5 | 8.0 | 8.0 | 0.6 | 8.0 | 8.0 | NE |
| T. brasiliense | 9 | 7 | 29.8 | 18.0 | 15.4 | 18.8 | 12.0 | 12.0 | 12.2 | 8.0 | 0.6 | 0.6 | 8.0 | 8.0 | 8.2 |
| T. chilonis | | 27.2 | 18.0 | 18.0 | 17.6 | 18.0 | 12.0 | 11.0 | 11.0 | 8.0 | 8.0 | 8.0 | 0.6 | 7.0 | 7,0 |
| T. evanescens | 1 | , | 0.61 | 17.0 | 18.3 | 20.0 | 12.0 | 12.1 | 11.0 | 0.6 | 0.6 | 9.0 | 8.0 | NE | 8.0 |
| T. pretiosum | ¥ | 30.0 | 18.0 | 17.0 | 18.6 | 0.61 | 12.0 | 11.2 | 11.3 | 9.0 | 9.0 | 0.6 | 8.0 | 0.6 | 8.4 |

NE = No emergence, - = In progress

4.9.5. Functional response of *Trichogramma chilonis* to varying density of *Helicoverpa armigera* eggs

The results presented in Table 21 indicated that per cent parasitism by T. chilonis varied from 48.0 to 72.0 per cent when H. armigera egg density was 5 - 45 eggs per female. Superparasitism to the tune of 20 - 70 per cent was observed in this density range as adults per egg ranged from 1.15 - 1.62. Parasitism was significantly higher (60.8 - 78.0 per cent) at a density of 50 - 80 eggs / female and 1.01 - 1.17 adults were obtained in this range per egg. The results indicated that host egg: parasitoid ratio of 1: 50 - 60 eggs is sufficient for effective host utilization and parasitism and avoidance of superparasitism.

Table 21. Parasitizing efficiency of Trichogramma chilonis at varying host egg density

| Egg density | Per cent parasitism | No. of adults / parasitised egg | No. of eggs parasitised/ female |
|-------------|------------------------|------------------------------------|------------------------------------|
| 5 | 72.0 | 1.27 | 3.6 |
| 10 | 64.0 | 1.62 | 6.4 |
| 15 | 64.0 | 1.52 | 9.6 |
| 20 | 78.0 | 1.32 | 15.6 |
| 25 | 64.0 | 1.25 | 16.0 |
| 30 | 54.6 | 1.32 | 16.4 |
| 35 | 48.6 | 1.15 | 17.0 |
| 40 | 45.0 | 1.21 | 18.0 |
| 45 | 48.0 | 1.34 | 21.6 |
| 50 | 78.0 | 1.08 | 39.0 |
| 55 | 67.6 | 1.17 | 37.2 |
| 60 | 60.8 | 1.11 | 36.5 |
| 65 | - 68.3 | 1.01 | 44.4 |
| 70 | 67.8 | 1.07 | 47.5 |
| 75 | 65.6 | 1.12 | 49.2 |
| 80 | 64.2 | 1.04 | 51.4 |
| 85 | 52.7 | 1.01 | 44.8 |
| 90 | 47.1 | 1.09 | 42.4 |
| 95 | 41.5 | 1.06 | 39.5 |
| 100 | 35.8 | 1.01 | 35.4 |

4.10. Studies on insect pathogens

4.10.1. Survey for viruses of insect pests

Nucleopolyhedrosis viruses from the coconut skipper, *Gangara thyrsis*, the mottled emigrant white butterfly, *Catopsilia pyranthae* and a poxvirus from maize stem borer, *Chilo partellus* have been isolated for the first time from India and their pathogenicity proved.

A granulosis virus from the castor semilooper, Achaea janata was isolated and its pathogenicity against first and second instar larvae proved.

Suspected nuclear polyhedrosis viruses have been isolated from the coconut black headed caterpillar, *Opisina arenosella* and the paddy leaf roller, *Cnaphalocrocis medinalis*.

4.10.2. Enhancing the efficiency of in vivo production of insect virus

When larvae of *Gangara thyrsis* in their late fourth instar were exposed to 2×10^6 POB's/ml for large scale production of the virus, the yield of POB's by the female larvae (6.2 x 10^6 POB's) was 4-5 times more than the male larvae (1.5 x 10^6 POB's).

4.10.3. Cross infectivity

Studies were conducted to find out the cross infectivity of *Helicoverpa armigera* NPV to gingelly hawk moth, *Acherontia styx*. The hawk moth larvae were found susceptible to *H. armigera* NPV, but the virus isolated from *A. styx* with HaNPV on further inoculation to *H. armigera* failed to induce mortality.

4.10.4. Histopathology and safety of EPV of Chilo partellus

Histopathological study of EPV infected *Chilo partellus* revealed the fat bodies to be the most fávoured site of infection. *Chilo partellus* EPV was found safe to mulberry silkworm, *Bombyx mori*, *Chrysoperla carnea* and *Cotesia flavipes*.

4.10.5. Field survey collection of diseased larvae of Amsacta albistriga and Spilosoma obliqua and isolation of nucleopolyhedrosis

Larvae of *Amsacta albistriga* feeding on groundout, redgram, cowpea, castor, Calotropis and an unidentified weed belonging to Euphorbiaceae, which is used as an attractant, were collected from Doddahalli, Pandarangapura, Sannahalli, Pavagada (Tumkur district) and Davanagere (Harpenahalli). All the larvae were collected in large numbers and were brought to the laboratory for rearing.

Larvae of *Spilosoma obliqua* feeding on mulberry, field bean, and weeds were collected from Muthur, Janagamakotte, Devanganahalli (Shidlagatta taluk), Rajanakunte, GKVK, Thalagattapura (Bangalore taluk), Hoskote (Hoskote taluk), Hosahalli (Chikkabalapur taluk) and Thalagavara (Chintamani Taluk).

Larvae suspected to have NPV infection were separated and NPV was isolated using standard procedures and preserved in the refrigerator.

Isolation of entomopathogenic fungi from H. armigera, S. litura, P. xylostella and other hosts

4.11.1 Standardizing isolation technique for Nomuraea rileyi from dead cadavers

Different anti-bacterial and anti-fungal chemicals were screened for developing a semi-selective medium for isolation of *N. rileyi* from field infected cadavers. Among these, chloramphenicl and rose bengal were promising in restricting the growth of contaminating bacteria and fungi like *Aspergillus*, *Penicillium*, *Fusarium*, etc. SMAY medium incorporated with chloramphenicl (50 ppm) and rose bengal (100 ppm) can be used successfully for isolation of *N. rileyi* without contamination from field-infected larvae of *H. armigera* and *S. litura*.

4.11.2 Isolation of different isolates of N. rileyi from the pests of cotton ecosystem

Thirty-three isolates of *N. rileyi* were obtained from *Helicoverpa armigera* (18 isolates), *Spodoptera litura* (12 isolates), *Amsacta albistriga* (1 isolate), *Achaea janata* (1 isolate) and *Anticarsia irrorata* (1 isolate) from different cotton growing areas of Andhra Pradesh and Karnataka.

4.11.3 Isolation of other fungal pathogens from insects

Seven isolates of *Beauveria bassiana* were obtained from *S. litura*, *Hypothenemus hampei* (4 isolates), *Plocaederus ferrugineus* and an indeterminate treehopper. Three isolates of *Metarhizium anisopliae* were isolated from *Amsacta albistriga*, *Oryctes rhinoceros* and *P. ferrugineus*. Fourteen isolates of *Verticillium lecanii* were isolated from citrus green scale (5 isolates), coffee green scale (8 isolates) and coffee rust fungus. *Fusarium* sp. was isolated from rose aphid, *Macrosiphum rosaeiformis*.

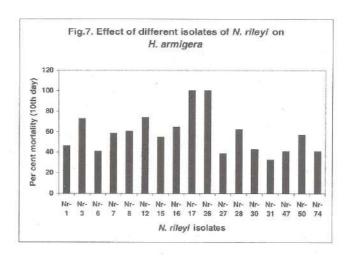
4.11.4 Growth, sporulation and colony characters of different isolates of fungal pathogens on various media

Growth and sporulation of different isolates of *B. bassiana*, *M. anisopliae* and *V. lecanii* were studied on PDA, MEA, CMA, OMA, SMAY, soya peptone broth, molasses

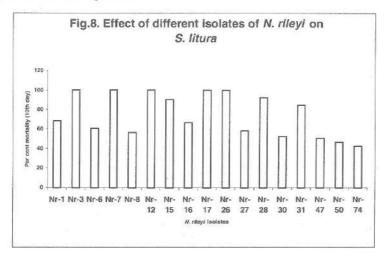
yeast broth, Asthana Hawker broth, malt extract broth, Sabouraud maltose yeast broth and nutrient broth. In *B. bassiana*, two distinct colony types, *viz.* mat like colonies with abundant aerial cottony mycelium (B.b-1 B.b-3, B.b-6, B.b-7) and flat powdery scattered colonies (B.b-2 B.b-4 and B.b-5, 5A, 5B, 5C, 5D) were noticed on agar media. B.b-1, B.b-2 and B.-3 isolates were identified as fast growing isolates. In *M. anisopliae*, M.a-1 M.a-2 and M.a-4 showed fast growth with scattered colonies, while M.a-3 produced uniform mat like colonies. Among *V. lecanii* isolates, V.l-1, V.l-2, V.l-2D, V.l-3 and V.l-3E showed faster growth. A distinct yellowish tinge was observed on the colonies of V.l-2, V.l-2A and V.l-2C. *B. bassiana* isolates showed maximum growth and sporulation on corn meal agar, soya peptone broth and Sabouraud maltose yeast broth. Potato dextrose agar and Oatmeal agar gave fast growth and high rate of sporulation of *M. anisopliae* and *V. lecanii*.

4.11.5. Screening of different isolates of fungal pathogens on *H. armigera*, *S. litura* and *P. xylostella*

Ten isolates of *B. bassiana*, 4 isolates of *M. anisopliae*, 14 isolates of *V. lecanii* and 34 isolates of *N. rileyi* were tested against third instar larvae of *H. armigera*, *S. litura* and *P. xylostella* under laboratory conditions. Against *H. amigera*, Nr-26 and Nr-17 of *N. rileyi* showed 100% mortality of the 3rd instar larvae @ 8.5 x 10⁸ conidia/ml (Fig.7). In *S. litura*, 100% mortality of the larvae was observed with Nr-3, Nr-7 and Nr-12, @ 8.5 x 10⁸ conidia/



ml (Fig. 8). *B. bassiana*, *M. anisopliae* and *V. lecanii* isolates showed lesser mortality rates of *H. amigera* and *S. litura* (7-42%). Maximum mortality (65.8%) of *P. xylostella* was observed with *B. bassiana* (B.b-4), followed by *M. anisopliae* (M.a-2) (64.3%), and *N. rileyi* (N.r-12) (62.8%) at 8.5-12.0 x 10⁷spores/ml.



4.11.6. Pathogenicity of Fusarium sp. to rose aphid

Fusarium sp. was isolated from rose aphid (M. rosaeiformis) and its pathogenicity to nymphs and adults was tested under net house conditions. Adult mortality of 73.6% and nymphal mortality of 63.8% were observed after four days of spraying with spore suspension containing 7.9 x 10⁶ spores/ml. Full fungal growth was observed on the dead nymphs and adults after five days. Pathogenicity of Fusarium sp. to rose leaves, stems and buds was not observed at 5.7X10⁹ spores/ml.

4.11.7. Mass production of entomofungal pathogens on solid and liquid substrates

Growth and sporulation of *B. bassiana*, *M. anisopliae* and *V. lecanii* was studied on oil cakes of neem, castor, pongamia, coconut and gingelly, farm yard manure, saw dust, dried silk worm pupal powder, spent malt, brewers yeast (Brewery wastes) and sorghum. These substrates were crushed, moistened, inoculated with the fungus and incubated at 25°C for 15 days. Among the oil cakes tested, maximum sporulation was observed with pongamia, followed by castor (Table 22). Dried silkworm pupal powder also served as a good substrate for *B. bassiana* and *M. anisopliae*, apart from sorghum and rice. Spent malt and brewer's yeast (10:1) gave good sporulation of *M. anisopliae*.

Table 22. Growth and sporulation of B. bassiana, M. anisopliae and V. lecanii on solid substrates

| Substrate | Growth and sporulation (cfu/g) | | | | | | |
|----------------------------------|--------------------------------|---------------------|---------------------|--|--|--|--|
| | B. bassiana | M. anisopliae | - V. lecanii | | | | |
| Neem cake | 4.9X10 ³ | 3.2X10 ³ | 3.9X10 ³ | | | | |
| Castor cake | - 2.0X10 ⁹ | 2.0X10 ⁹ | 1.0X109 | | | | |
| Pongamia cake | 3.0X10 ⁹ | 2.0X10 ⁹ | 1.5X109 | | | | |
| Coconut cake | 2.5X108 | 3.6X10 ⁷ | 3.4X10 ⁶ | | | | |
| Gingelly cake | 4.3X10 ⁷ | 3.9X10 ⁷ | 4.0X10 ⁶ | | | | |
| Farm yard manure | 3.1X10 ⁴ | 4.4X10 ⁵ | 3.6X10 ⁴ | | | | |
| Saw dust | 4.9X10 ³ | 3.2X10 ⁴ | 1.6X10 ³ | | | | |
| Silk worm pupal powder (Dried) | 2.7X10 ³ | 3.6X10° | 3.2X10 ⁵ | | | | |
| Spent malt (Brewery waste) | 5.9X10 ⁶ | 7.8X10 ⁷ | 4.6X106 | | | | |
| Brewers yeast (Brewery waste) | 1.8X10 ² | 3.4X10 ³ | 1.1X10 ² | | | | |
| Spent malt+ Brewers yeast (10:1) | 4.9X10 ⁷ | 1.1X10 ⁹ | 5.0X10 ⁶ | | | | |
| Sorghum grains | 3.4X10 ⁹ | 4.2X10° | 4.8X10° | | | | |

Several liquid media such as soya flour molasses medium, molasses yeast broth, cane sugar mineral broth, Asthana Hawker broth, malt extract broth, Sabouraud maltose yeast broth and nutrient broth were tested under shake culture conditions in flasks. *V. lecanii* showed conidial production in all liquid media. Maximum conidial and mycelial biomass of *V. lecanii* (28.34 g/l) was observed after 5 days in soy flour molasses medium, which contained 2.8 x 10¹⁵ conidia/ml. *B. bassiana* produced both conidia and lastospores in all the liquid media tested. Maximum mycelial, conidial and blastospore biomass of *B. bassiana* (28.04 g/l) was observed after 4 days in cane sugar mineral medium which contained 6.2 x 10⁷ conidia/ml and 2.5 x 10⁷ blastospores/ml. *M. anisopliae* produced only blastospores in all the liquid media.

4.11.8. Mass production of N. rileyi on solid and liquid substrates

Growth and sporulation of *N. rileyi* was studied on various solid substrates like sorghum, rice, wheat, maize, pearl millet, finger millet, oil cakes of neem, castor, pongamia, coconut and gingelly, farm yard manure, saw dust, dried silk worm pupal powder and spent malt (Brewery waste) along with 1.0% yeast extract. Maximum conidial production was observed in sorghum grains supplemented with 1% yeast extract, followed by rice. Growth and sporulation was poor on all other substrates.

Conidial germination of N. rileyi was the maximum (100%) in SMY broth, yeast extract (4%) and peptone (4%) after 24 hours. Among the different carbon sources tested for

mass production of *N. rileyi*, barley flour (4%), and among the nitrogen sources soy flour (2%)/dried silkworm pupal powder (2%) showed maximum sporulation. Barley- silkworm pupal-yeast extract medium showed maximum growth and sporulation (6.2×10^8 spores/ml).

Various liquid media like Sabouraud maltose yeast extract broth, carrot yeast extract broth, malt yeast extract broth, potato dextrose yeast extract broth, Czapek dox dextrose yeast extract broth, nutrient yeast extract broth and enrichment broth were tested as base material in shake and stationary cultures for mass production of *N. rileyi* along with their solid agar media. Growth and conidial production was poor in all liquid media compared with that on solid agar media. However, SMY broth and nutrient yeast extract broth showed maximum conidial production (7.4 x 10⁷ and 9.6 x 10⁶ spores/ml, respectively). Growth and conidial production of *N. rileyi* increased under dark conditions in SMY broth.

4.11.9. Development of talc based formulation of Verticillium lecanii

Verticillium lecanii was grown in soy-flour-molasses medium in laboratory grade fermentor (2 liter capacity) for five days. Maximum conidial and mycelial biomass of V. lecanii (22.032g/l) was observed after 3 days and it contained 4.1x10¹⁴ conidia/ml. The fungal biomass produced after 3 days in fermentor was mixed with sterilized talc in 1:1, 1:2 and 1:3 proportions and the formulation was dried for 3 days at 35°C and packed in sterilized polythene bags. The dried formulations contained 9.7 x 10¹¹, 5.4 x 10⁸ and 4.2 x 10⁴ cfu/g, respectively.

4.12. Studies on entomopathogenic nematodes (EPN)

4.12.1. Bioefficacy of EPN isolates against different insect pests

Among EPN isolates tested Steinernema carpocapsae and S. bicornutum were promising against S. litura causing 100% mortality 72h after exposure. Against A. ipsilon, S. feltiae, S. carpocapsae and H. bacteriophora were effective. S. glaseri recorded least mortality and the mortality increased with exposure time. Heterorhabditis indica, S. carpocapsae and S. bicornutum were found effective against all the insects tested. H. bacteriophora, H. indica, and S. bicornutum proved efficient, causing 60-100% mortality. S. bicornutum was very effective against P. operculella (80-100% mortality after 24 h). O. arenosella and P. xylostella were susceptible to all the isolates tested.

4.12.2. Progeny production of Steinernema spp. and Heterorhabditis spp.

Progeny production of different Steinernema spp. and Heterorhabditis spp. were evaluated in different lepidopteran insect pests. Maximum yield of all the isolates was observed in final instar larvae of G. mellonella. H. bacteriophora recorded highest yield (5.4 lakhs) in G. mellonella, followed by S. litura (3.56 lakhs/larva) and H. armigera (3.16 lakhs/larva).

Progeny production of *H. indica* 13.3 was higher in *H. armigera*, *O. arenosella*, *P. xylostella* and *P. operculella* when compared to *H. bacteriophora*. Of *Steinernema* isolates, *S. bicornutum* PDBC 3.2 yielded maximum in all the insects tested, followed by *S. carpocapsae*, *S. carpocapsae* PDBC 6.11, and *S. glaseri*.

Different initial inoculum levels were tested for final population levels of *S. carpocapsae*, *S. feltiae*, *S. glaseri* and *H. bacteriophora* in last instar *A. ipsilon* and *G. mellonella* larvae. Optimum initial inoculum of *S. carpocapsae* was 100 IJs in *A. ipsilon* and 50 in *G. mellonella*; and for *S. feltiae* it was 100 for *A. ipsilon* and 25 for *G. mellonella*. *S. glaseri* gave lower production in both insects, 125 IJs being the optimum for both. *H. bacteriophora* numbers increased as inoculum level increased in *A. ipsilon* whereas 75 IJ was optimum in *G. mellonella*. Overall, production levels were higher in *G. mellonella* compared to *A. ipsilon* (Table 23).

Table 23. Progeny production of EPN IJs of different isolates

| Nematode isolates/initial inoculum S. carpocapsae level | A. ipsilon | G. mellonella | | |
|---|------------|--------------------------------|--|--|
| 25 | 43,000 | 1,25,000 | | |
| 50 | 59,600 | 2,52,500 | | |
| 75 | 68,400 | 2,17,500 | | |
| 100 | 1,24,380 | 1,77,500 | | |
| 125 | 1,00,460 | 50,000 | | |
| S. feltiae | | | | |
| 25 | 47,680 | 1,76,500 | | |
| 50 | 67,830 | 1,33,000 | | |
| 75 | 1,85,000 | 1,75,500 1,21,500 72,000 | | |
| 100 | 1,97,850 | | | |
| 125 | 2,56,000 | | | |
| S. glaseri | | | | |
| 25 | 980 | 57,000 | | |
| 50 | 3450 | 48,400 44,000 | | |
| 75 | 3800 | | | |
| 100 | 27,400 | 45,000 | | |
| 125 | 29,680 | 48,570 | | |
| H. bacteriophora | | | | |
| 25 | 45,760 | 3,62,500 | | |
| 50 | 65,000 | 4,43,000 | | |
| 75 | 1,73,400 | 5,49,000 | | |
| 100 | 1,86,000 | 5,14,300 | | |
| 125 | 2,04,000 | 5,45,000 | | |

4.12.3. Mass production of EPN on artificial media

Different semi-solid artificial media, viz. Wouts, soy flour+egg yolk, soy flour+cholestrol and dog biscuit+beef extract, were tested with associated bacteria for the mass production of Steinernema sp. and H. indica. Prior inoculation of symbiotic bacteria enhanced the yield and rate of multiplication in artificial media. The standard Wouts medium was suitable for all nematodes with an average yield of 44 lakhs/250 ml flask. S. carpocapsae isolates multiplied in all the media which shows their higher mass production potential compared to H. indica (Table 24)

Table 24. In vitro mass production of EPNs

| Nematode isolates | Wout's | Soy flour + Egg yolk | Soyflour+ Cholesterol | Dog biscuit +beef extract |
|-------------------------|--------|-------------------------|--------------------------|------------------------------|
| S. carpocapsae PDBC 1.4 | 55.65 | 69.54 | 71.48 | 78.90 |
| S. carpocapsae PDBC 7.2 | 41.00 | 62.80 | 69.85 | 74.45 |
| H. indica PDBC 13,3 | 38.90 | Not multiplied | 64.78 | Not multiplied |

4.12.4. Viability and pathogenicity of formulated EPN

Shelf life of talc, talc+china clay and alginate formulations was tested in the laboratory at 15°C for three months (Table 25). Talc+china clay and alginate were found better in retaining the viability of IJs for a longer period than talc formulation. Per cent survival of IJs was maximum in talc china clay, followed by alginate encapsulation.

Table 25. Viability of S. carpocapsae PDBC 1.3 and H. indica 6.71 in different formulations

| Formulation of EPN | % Viability days after storage | | | | | | |
|------------------------------------|--------------------------------|------|------|------|------|------|--|
| | 15d | 30d | 45d | 60d | 75d | 90d | |
| S. carpocapsae PDBC EN 1.3 Talc | 63.2 | 33,2 | 0.4 | 0.0 | 0.0 | 0.0 | |
| Talc+ china clay | 100 | 98.4 | 98.0 | 94.8 | 92.0 | 88.0 | |
| Alginate | 100 | 99.2 | 97.2 | 92.8 | 89.6 | 88.0 | |
| H. indica PDBC EN 6.71 Talc | 57.2 | 31.2 | 0.0 | 0.0 | 0.0 | 0.0 | |
| Talc + china clay | 100 | 99.2 | 95.2 | 94.8 | 92.4 | 87.6 | |
| Alginate | 100 | 98.0 | 94.0 | 91.6 | 88.8 | 84.4 | |

4.13. Nematophagous fungi against plant parasitic nematodes

4.13.1. Field surveys for antagonistic agents against plant parasitic nematodes

Field surveys were carried out in vegetable and flower growing areas of Kolar and Hosur. A new isolate of obtained *Pseudomonas fluorescens*, one isolate each of *P. lilacinus* and *V. chlamydosporium* were isolated from root-knot nematode infested carnation and tomato rhizospheres.

4.13.2. An easy and rapid technique for screening antagonistic fungi against nematodes on host plant

An experiment was designed to evolve an easy and rapid screening technique using earthen pots, plastic pots and plastic trays with cups. The pot media used were autoclaved red soil with FYM (3:1), sand with FYM (3:1), coir pith, and vermiculite, and one-week-old

Table 26. Screening of *P. lilacinus* isolates against *M. incognita* in tomato under different pot conditions

| Type of pot | Composition of pot mixture | CFU/g of root + soil | | Egg mass parasitation (%) | | Nematode multiplication rate in rhizosphere | |
|------------------------|--|--|--|------------------------------|----------------------|--|--------------------------|
| | 3 | PL1 | PL2 | PL1 | PL2 | PLI | PL.2 |
| Earthen pot | Red soil + FYM Sand + FYM Coir pith Vermiculite | 1.4x10 ³ 2.3x10 ³ 2.8x10 ³ 2.9x10 ³ | 3.6x10 ³ 3.8x10 ³ 5.8x10 ³ 5.9x10 ³ | 17 21 26 27 | 24 28 38 38 | 2.8 2.6 2.5 2.5 | 2.5 2.4 2.2 2.1 |
| Plastic pot | Red soil + FYM Sand + FYM Coir pith Vermiculite | 1.1x10 ⁴ 1.8x10 ⁴ 2.5x10 ⁵ 2.8x10 ⁵ | 4.7x10 ⁴ 5.4x10 ⁴ 6.5x10 ⁵ 6.9x10 ⁵ | 19 22 42 49 | 27 29 64 69 | 2.4 2.5 2.4 2.0 | 1.9 1.8 1.8 1.6 |
| Plastic tray with cups | Red soil + FYM Sand + FYM Coir pith Vermiculite | 1.4x10 ⁴ 1.6x10 ⁴ 2.9x10 ⁵ 3.0x10 ⁵ | 4.9x10 ⁴ 5.6x10 ⁴ 7.5x10 ⁵ 8.0x10 ⁵ | 18 20 48 59 | 27 31 68 82 | 2.3 2.3 2.2 2.0 | 1.8 1.9 1.9 1.5 |
| Control | Red soil + FYM Sand + FYM Coir pith Vermiculite | - | 2 | | (#) (#) (#) | 3 | .5 .6 .9 |
| CD (P=0.05) | - 1 | 166.6 | 198.9 | 2.12 | 2.44 | 0 | .26 |

healthy and robust tomato seedlings (cv. Pusa Ruby) were transplanted. Plants were inoculated with freshly hatched 2nd stage juveniles of root-knot nematode, *Meloidogyne incognita* at 2 juveniles/g soil. Another set of pots was maintained separately and inoculated with the juveniles of reniform nematode, *Rotylenchulus reniformis* at the same rate. Two local isolates each of *Paecilomyces lilacinus* (PDBCPL1 and PDBCPL2) were added to the designated pot at 10⁶ spores/g pot medium.

Plastic trays with cups filled with vermiculite and coir pith gave consistent data on root colonization, parasitation and multiplication in rhizosphere of the fungal isolates followed by that in plastic pots (Tables 26, 27). The differences in efficacy of the fungal isolates against root-knot and reniform nematodes on tomato were distinctly observed in plastic trays with coir pith or vermiculite than in earthen pots or the pots filled with sand or red soil with FYM. Similarly, repeatability of the observations was more distinct in plastic trays with rooting media (coir pith and vermiculite) than in soil media. The distinct advantages of using

Table 27. Screening of *P. lilacinus* isolates against *R. reniformis* in tomato under different pot conditions

| Type of pot | Composition of pot mixture | + | g of root soil | Egg mass + Female parasitation (%) | | Nematode multiplication rate in rhizosphere | |
|------------------------|--|--|--|------------------------------------|----------------------|--|--------------------------|
| Therei | | PL1 | PL2 | PLI | PL2 | PLI | PL2 |
| Earthen pot | Red soil + FYM Sand + FYM Coir pith Vermiculite | 0.8x10 ³ 1.1x10 ³ 1.3x10 ³ 1.5x10 ³ | 1.3x10 ³ 1.4x10 ³ 2.8x10 ³ 2.9x10 ³ | 14 17 21 26 | 22 23 30 32 | 2.4 2.2 2.2 2.1 | 2.0 2.0 1.8 1.6 |
| Plastic pot | Red soil + FYM Sand + FYM Coir pith Vermiculite | 0.9x10 ⁴ 1.2x10 ⁴ 1.6x10 ⁵ 1.8x10 ⁵ | 1.5x10 ⁴ 1.7x10 ⁴ 2.9x10 ⁵ 3.9x10 ⁵ | 19 23 36 39 | 24 26 44 54 | 2.3 2.3 2.2 2.3 | 1.9 1.5 1.4 |
| Plastic tray with cups | Red soil + FYM Sand + FYM Coir pith Vermiculite | 1.1x10 ⁴ 1.2x10 ⁴ 1.8x10 ⁵ 2.0x10 ⁵ | 2.3x10 ⁴ 3.2x10 ⁴ 4.0x10 ⁵ 4.0x10 ⁵ | 18 20 39 42 | 28 29 51 58 | 2.3 2.3 2.2 1,8 | 1.7 1.4 1.2 1.0 |
| Control | Red soil + FYM Sand + FYM Coir pith Vermiculite | | | - | | 2.8 2.6 2.5 | |
| CD (P=0.05%) | (4) | 122.6 | 187.8 | 2.44 | 2.87 | 0.3 | |

plastic trays or pots with vermiculite or coir pith media include screening under uniform environmental conditions; space, time and input conservation; repeatability; possibility to include any number of replicates and isolates; and the possibility of examining the suitability of any abiotic factors such as soil type, temperature, pH, etc. for the antagonistic fungil bacteria. Also the nematode inoculum requirement can be met easily, especially in case of citrus, lesion and burrowing nematodes. This technique helps to restore the virulence of the isolates that are repeatedly cultured in laboratory, by recycling them through the host nematode without the complexity of cross contamination. The major disadvantages generally are plant mortality, and lean and lanky plant stand if not exposed to sunlight properly.

4.13.3. Substrate media modifications

Different agro-industrial wastes were evaluated for mass production of spores of P. lilacinus and V. chlamydosporium under laboratory conditions. In general, sporulation was better in solid media than in liquid media (Table 28). Further, the media were modified using

Table 28. Spore production of P. lilacinus and V. chlamydosporium on different substrates

| Solid media | P. lilacinus | V. chlamydosporium |
|-----------------------------------|--------------|--------------------|
| Paddy grain | 108.9 | 107-8 |
| Sorghum grain | 109 | 108 |
| Bran | 106 | 106 |
| Seed meal | 108 | 106-8 |
| Oil cakes | 105-6 | 104-6 |
| Weed leaves | 10^{4} | 104 |
| Coffee waste | 107 | 106 |
| Malt waste | . 108 | 108 |
| Corn cob powder | 104-6 | 10^{3} |
| Liquid media | | |
| Molasses | . 108 | 107 |
| Tapioca broth | 106 | 106 |
| Media modifications | | |
| Paddy grain + Chitin | 1012 | 1011 |
| Sorghum grain + Chitin | 1011-12 | 1010-11 |
| Bran + Chitin | 109-10 | 109 |
| Paddy grain + CaCO ₃ | 1010-11 | 1010 |
| Sorghum grain + CaCO ₃ | 1011 | 1010-11 |
| Bran + CaCO ₄ | 1010-11 | 1010 |
| Tapioca broth + CaCO ₃ | 109-10 | 109 |

CaCO₃ and chitin and examined for spore production. *Paecilomyces lilacinus* and *V. chlamydosporium* grew readily in media containing commercially available, low-cost ingredients such as cotton seed meal, groundnut seed meal and corn cob powder. Supplementation with calcium carbonate or chitin recorded higher growth and sporulation of *Paecilomyces lilacinus* and *Verticillium chlamydosporium*.

4.13.4. Formulations and spore viability studies

Viability studies on *Paecilomyces lilacinus* spores multiplied on sorghum grain and in potato broth and formulated in talc after drying to 6-12% moisture indicated that aerial spores were more robust and viable than submerged spores at low moisture levels.

4.13.5. Isolation and partial characterization of nematoxins from selected antagonistic fungi

Culture filtrates of *P. lilacinus, V. chlamydosporium* and *V. lecanii* are reported to have inhibitory and adverse effects on hatching, emergence and root infection of root-knot nematodes, but the bio-active compounds are not identified. In this experiment, one part of culture filtrates was subjected to silica-alumina column chromatography, organic solvent extraction (ethyl acetate-methanol-chloroform) and air drying, while another part was used for protein precipitation. The precipitates were collected and bioassayed against egg masses and juveniles of *M. incognita*. Both precipitates showed 80-90% egg hatching and 60-70% root infection by juveniles.

4.13.6. Standardisation of DNA extraction, purification and amplification (PCR) for enterobacteria and rhizobacteria

Extraction of bacterial DNA using lysis buffer, followed by purification through ethanol precipitation and amplification using Taq polymerase and forward and reverse dNTPs have been standardised for the enterobacterium, *Photorhabdus* sp. from *Heterorhabditis indica* and rhizobacterium, *Pseudomonas fluorescens*, obtained from root-knot nematode suppressive soil.

4.13.7. Field evaluation of antagonistic fungi, P. lilacinus and V. chlamydosporium for the management of M. incognita in papaya

Integrated application of antagonistic fungi, *P. lilacinus* and *V. chlamydosporium* with air-dried FYM/neem cake followed by light irrigation favoured better fungal establishment and parasitisation on the egg masses of the root-knot nematode in papaya as compared to their individual application and carbofuran (Table 29).

Table 29. Efficacy of *P. lilacinus* and *V. chlamydosporium* in combination with FYM and neem cake against *M. incognita* on papaya

| Treatment | Dose (g/plant) | RKI | Healthy root (%) | Egg - parasitation (%) | CFU/g root+soil |
|-------------------------|-------------------|-----|------------------|------------------------------|--------------------|
| P. lilacinus (PL) | 20 | 2.9 | 62 | 14.8 | 1182 |
| V. chlamydosporium (VC) | 20 | 3.0 | 60 | 11.2 | 744 |
| FYM | 250 | 3.4 | 60 | 6.8 | _* |
| NC | 100 | 2.6 | 63 | 8.0 | ->0 |
| PL+FYM | | 1.5 | 74 | 51 | 2420 |
| VC+FYM | | 1.6 | 67 | 44 | 1668 |
| PL+NC | | 1.0 | 88 | 63 | 2256 |
| VC+NC | | 1.2 | 91 | 52 | 1312 |
| Carbofuran | 2.0kg ai/ha | 2.2 | 57 | _* | - |
| Control | | 3.8 | 39 | 5.4 | _* |

^{*} Negligible (<5% or 100 spores); Plant density 1500-2000/acre; cost of fungus per Kg ~ Rs.60 and neem cake, Rs.3.50 to 4.00.

4.13.8. Efficacy of selected antagonistic fungi against Meloidogyne incognita and Rotylenchulus reniformis infecting cowpea

Local isolates of P. lilacinus and V. chlamydosporium were evaluated for efficacy against M. incognita and R. reniformis, infecting cowpea under glasshouse conditions. Two types of soils, red laterite (6.6 pH, 6 millimoles EC) and sandy loam (8.3pH, 9 millimoles EC), were used in the experiment. Pots containing these soils were inoculated separately with freshly hatched second stage juveniles of M. incognita and R. reniformis at 2 J_2/g soil. The pots were amended with treatments including talc formulations of P. lilacinus and V. chlamydosporium at $4x10^9$ -spores/kg soil, followed by sowing of cowpea seeds.

Multiplication of *M. incognita* was lowest in red laterite soil amended with *P. lilacinus*, while that of *R. reniformis* was lowest in sandy loam soil amended with *V. chlamydosporium*. Per cent increase in nodulation over inoculated check was higher in sandy loam soil amended with *P. lilacinus* or *V. chlamydosporium*. Further, the amendment with antagonistic fungi in both soils reduced multiplication rates of *R. reniformis* and *M. incognita*, and enhanced rhizobial nodulation. Root-knot index in case of *M. incognita* and number of females of reniform nematode per cm root, were significantly reduced by amendment with antagonistic

fungi. Parasitisation by *P. lilacinus* on eggs and egg masses of both nematodes was higher in red laterite soil compared to *V. chlamydosporium*, which recorded higher parasitisation in sandy loam soil. However, the colony forming units of both fungi were recovered in higher number in sandy loam compared to red laterite soil. The colony forming units of *P. lilacinus* and *V. chlamydosporium* recorded on roots did not exhibit significant variation between the two soil types. *Paecilomyces lilacinus* could be recommended for the control of *M. incognita* and *R. reniformis* in red laterite soils, and *V. chlamydosporium* for sandy loam soil.

4.13.9. Field evaluation of *Paecilomyces lilacinus* formulations with different moisture levels and their combinations with neem cake against *M. incognita* in chrysanthemum

This experiment was carried out in a farmer's field in Kolar district of Karnataka, with high incidence of root-knot nematode, *Meloidogyne incognita*, to evaluate the spore viability in four formulations of *P. lilacinus* at different moisture levels, and their field efficacy singly and in combination with neem cake, using carbofuran as check. The preparation of *P. lilacinus* used in the field consisted of aerial spores cultured on sorghum grain, and submerged spores, grown in a liquid medium.

Aerial spores were more robust than submerged spores over a period of 60 days after formulation. The two formulations of this fungus under study, talc and pesta granules, applied at 2 doses, 10 and 15 kg/ha to the root-knot nematode infested chrysanthemum field correspondingly reduced root gall index, nematode populations and enhanced floral yield by 12 per cent. Further, combined use of these formulations with neem cake enhanced fungal propagules in rhizosphere for longer time, fungal infectivity and chrysanthemum flower yield (by 23-28 per cent).

4.13.10. Dose optimization of antagonistic fungi against root-knot and reniform nematodes in tomato under microplot conditions

An experiment was conducted in naturally infested fields of tomato with root-knot and reniform nematodes in Doddaballapura, Bangalore. Microplots of 2x2m size were laid out and treated with *P. lilacinus* and *V. chlamydosporium* formulations (containing 2x10° spores/g) at 1.0, 2.0, 4.0, 6.0 and 8.0 kg/acre before transplantation. There was a positive correlation between dose of fungal application and percent egg mass parasitization and fungal propagules, while there was a negative correlation between dose and nematode population and root galls on fresh root. There was no significant difference between the two doses, 6 and 8kg in terms of observations recorded (Table 30 & 31).

Table 30. Effect of different doses of *P. lilacinus* and *V. chlamydosporium* on root galls, *M. incognita* populations, fungal parasitization of egg masses and propagules

| Treatment | (Kg/acre) (0-5 R parasitizat | Eggmass parasitization | | pagules FU)/g | Yield Increase | | |
|------------------------|------------------------------|---------------------------|------|------------------|---------------------|---------------------|-------|
| scale | scale) | n (%) | Root | Soil | (%) | | |
| Control | - | 4.2 | 3.8 | - | 2.2x10 ⁴ | 3.1x10 ^s | - |
| Carbofuran | 33 | 2.8 | 2.5 | - | 2.9x10 ⁴ | 2.9x10 ^s | 11.8 |
| V. chlamydosp orium | 1.0 | 3.4 | 2.7 | 16.5 | 1.1x10 ² | 2.1x10 ³ | 2.5 |
| | 2.0 | 3.0 | 2.4 | 18.0 | 1.5x10 ³ | 6.3x10 ³ | 6.8 |
| | 4.0 | 2.4 | 1.8 | 26.0 | 9,2x10 ³ | 3.9x10 ⁴ | 10.2 |
| | 6.0 | 2.0 | 1.4 | 32.5 | 6.2x10 ⁴ | 9.2x10 ⁴ | 15.4 |
| - | 8.0 | 1.3 | 1.2 | 41.0 | 7.8x10 ⁴ | 1.2x10 ⁵ | 16.9 |
| P. lilacinus | 1.0 | 3.2 | 2.3 | 12.0 | 1.6x10 ² | 4.1x10 ³ | 3.9 |
| | 2.0 | 3.0 | 2.0 | 22.0 | 2.3x10 ³ | 8.2x10 ³ | 6.7 |
| | 4.0 | 2.2 | 1.6 | 34.0 | 1.9x10 ⁴ | 5.9x10 ⁴ | 12.9 |
| | 6.0 | 1.8 | 1.3 | 42.0 | 8.0x10 ⁴ | 1.4x10 ⁵ | 16.7 |
| | 8.0 | 1.1 | 0.8 | 49,5 | 9.9x10 ^a | 5.2x10 ⁵ | 18.0* |
| CD (P=0.05%) | | 0.05 | 0.08 | 1.26' | 108 | 800 | 0.87 |

Table 31. Effect of different doses of *P. lilacinus* and *V. chlamydosporium* on root galls, *R. reniformis* populations, fungal parasitization of females and propagules

| Treatment | Dose NM (Kg/acre) R | | Eggmass parasitization n | Pro (C | Percent Yield | |
|--------------------|------------------------|--------|--------------------------------|---------------------|---------------------|----------|
| | | scale) | (%) | Root | Soil | Increase |
| Control | 2 | 3.8 | . = | 2.2×10 ⁴ | 3.1x10 ⁵ | - |
| Carbofuran | 3.3 | 2.5 | - | 2.9x10 ⁴ | 2.9x10 ⁵ | 11.8 |
| V. chlamydosporium | 1.0 | 2.7 | 16.5 | 1.9x10 ² | 2.9x10 ³ | 3.5 |
| | 2.0 | 2.4 | 18.0 | 2.5x10 ³ | 5.5x10 ³ | 7.3 |
| | 4.0 | 1.8 | 26.0 | $9.0x10^3$ | 4.9x10 ⁴ | 9.9 |
| | 6.0 | 1.4 | 32.5 | 5.6x10 ⁴ | 9.9x10 ⁴ | 14.8 |
| | 8.0 | 1,2 | 41.0 | 7.0x10 ⁴ | 2.2x10 ⁵ | 15.0 |
| P. lilacinus | 1.0 | 2.3 | 12.0 | 1.9x10 ² | 4.9x10 ³ | 2.8 |
| | 2.0 | 2.0 | 22.0 | 3.3x10 ³ | 7.8x10 ³ | 6.9 |
| | 4.0 | 1.6 | 34.0 | 2.9x10 ⁴ | 6.6x10 ⁴ | 12.6 |
| | 6.0 | 1.3 | 42.0 | 7.6x10 ⁴ | 3.4x10 ⁵ | 15.0 |
| | 8.0 | 0.8 | 49.5 | 9.2x10 ⁴ | 5.9x10 ^s | 16.0 |
| CD (P=0.05%) | | 0.04 | 2.88 | 248.54 | 366.44 | 1.90 |

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

4.14.1. Natural incidence of water hyacinth pathogens

Through regular surveys, more isolates of different pathogens of water hyacinth (*Eichhornia crassipes*) were collected. *Alternaria eicchorniae*, *A. alternata* and *Cercospora* spp. were obtained repeatedly. The fag end of the south-west monsoon (August onwards) was found to be conducive to epiphytotics of these pathogens in and around Bangalore (Table 32).

Table 32. Natural incidence of some important pathogens of water hyacinth in water bodies in and around Bangalore

| Fungal species | Water body | Incidence (%) |
|--------------------------|-----------------|---------------|
| Alternaria eichhorniae | Hebbal, | 15 |
| | Yelahanka · | 10 |
| | Jakkur | 10 |
| A. alternata | Hebbal | 26 |
| | Yelahanka | 15 |
| Cercospora spp. | Hebbal | 15 |
| | Jakkur | 15 |
| Lasiodiplodia theobromae | Hebbal | 5 |
| Fusarium spp. | Hebbal | 2 |
| Drechslera spp. | All above lakes | 1 |
| Phoma spp. | | |
| Nigrospora spp. | | |

4.14.2. Host range of Alternaria spp. and Cercospora sp.

Pathogenicity of the fungi and phytotoxicity of their metabolites were tested as part of the host range testing.

The test plants, namely, cotton, okra, chickpea, pigeonpea, rice, castor, rose, coconut, citrus, coffee, mango and guava belonging to 10 different families, viz. Malvaceae, Papilionaceae, Poaceae, Euphorbiaceae, Rosaceae, Palmae, Rutaceae, Rubiaceae, Anacardiaceae and Myrtaceae, did not show susceptibility to any of the pathogens tested. However, okra showed symptoms of phytotoxicity to metabolites of *Alternaria* spp..

4.14.3. Trials on the suppression of water hyacinth by selected pathogens

In trials conducted, *Cercospora rodmanii*, *Alternaria eichhorniae* and *A. alternata* could kill the plants within two months of the application of inoculum.

4.14.4. Mass production of Alternaria and Cercospora spp.

Studies on growth characteristics, sporulation and spore characteristics were done for at least two isolates of each pathogen. Both solid and liquid media were used in the experiments. Alternaria spp. and Cercospora sp. were multiplied in potato dextrose broth (PDB) in shake-cultures and the biomass was used to prepare talc-based formulations of 1×10^8 potency containing basically mycelia.

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

4.15.1. Host cultures

Cultures of Corcyra cephalonica, Spodoptera litura, Phthorimaea operculella, Opisina arenosella, Chilo partellus, Agrotis ipsilon, Sesamia inferens, Helicoverpa armigera, Earias vittella, Mythimna separata, Achaea janata, Liriomyza trifolii, Plutella xylostella, Aphis craccivora, Aleurodicus dispersus, Ferrisia virgata, Maconellicoccus hirsutus, Planococcus citri, P. lilacinus, P. minor, Dysmicoccus sp., Hemiberlesia lataniae, Pinnaspis strachani, Coccus sp. are being maintained on natural food or artificial diet.

4.15.2. Parasitoids

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

4.15.3. Predators

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

4.15.4. Insect pathogens

Nuclear polyhedrosis viruses of *H. armigera* and *S. litura* and granulosis virus of *P. xylostella* are being maintained on their host insects. A culture of *Nomuraea rileyi*, a fungal

pathogen is maintained. Seven varieties of *B. thuringiensis* (aizawai, entomocidus, gallerie, israelensis, kurstaki, sotto and thuringiensis) are maintained on Nutrient Agar and Poly medium Repository in the Division of Entomology at IARI New Delhi.

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

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

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

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

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

4.16. Shipments of host insects and natural enemies

During the reporting period, 68 cultures of various host insects and 135 cultures of natural enemies were sent to coordinating centres and other research organizations as nucleus cultures to facilitate their multiplication and establishment. Twenty-five multicellular trays were supplied to different centres for the multiplication of host cultures.

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

Sixteen major and minor pests of sugarcane were identified in consultation with the concerned scientists. The relevant information on their identification and symptoms of damage was coded to suit the programme (software). Different control measures for these pests are to be computerised.

Modification of 'BIORICE' is in progress according to the suggestions of different users. 'BIORICE' manual is almost ready.

4.17.1. Development of National Information system on Biological Suppression of croppests

CD version of the software "PDBC INFOBASE" was created and made auto-run. Addition of multimedia components in the software is under progress.

4.17.2. Knowledge Base System on Helicoverpa armigera and its natural enemies

Helicoverpa armigera is a major pest on several important crops in India and the world. "Helico-Info", a software developed in MS-Access 97, gives details about the taxonomy of the pest, its host plants, its distribution in India, its natural enemies and detailed bio-control measures to be undertaken for the pest in a particular crop. Visuals of command buttons, text box, labels and images have been added into the programming to make it user-friendly.

4.17.3. Decision Support System on Identification of Potential Natural Enemies and Safer Pesticides to Natural Enemies

The software "Safer Pesticides in Biocontrol", developed in Visual Basic 6.0 helps the user to identify safer pesticides for use based on the crop, pest and natural enemy.

4.17a. Indian Agricultural Research Institute, New Delhi

4.17a.1.Field efficacy of PUSA Bt (TVPKL) – a new WDP formulation of Bacillus thuringiensis, against Helicoverpa armigera

A water dispersible powder (WDP) formulation based on *Bacillus thuringiensis*, (PUSA *Bt* TVPKL) was tested against gram pod borer, *Helicoverpa armigera* in gram field. Two commercially available *Bt* formulations, Dipel 8L and HIL *Btk*, neem seed kernal extract (NSKE), chlorpyriphos (20 EC), deltamethrin, and Match (5 EC) were compared with this. All the *Bt* formulations and NSKE were statistically on par. Match 5 EC was significantly better than all the other treatments (Table 32a).

4.17a.2. Maintenance of Bacillus thuringiensis

Seven varieties of *Bacillus thuringiensis*, viz. aizawai, entomocidus, galleriae, israelensis, kurstaki, sotto and thuringiensis, were maintained in Nutrient Agar and Polymedium throughout the period under report.

Table 32a. Field efficacy of WDP formulation "PUSA Bt (TVPKL)", commercial preparations of B. thuringiensis and chemical insecticides against H. armigera

| Treatment | Per cent pod damage |
|-----------------------|---------------------|
| Dipel – 8L | 8.31 (16.68) |
| WDP Formulation | 7.63 (15.93) |
| HIL Bik | 9.25 (17.52) |
| NSKE 5% | 6.77 (14.98) |
| Chlorpyriphos (0.05%) | 7.79 (16.13) |
| Deltamethrin (0.004%) | 7.60 (15.92) |
| Match 5EC | 2.30 (7.91) |
| Control | 11.9 (20.11) |
| CD (P=0.1) | 5.23 |

Figures in parentheses are arc sine transformed values

4.17b. Govind Ballabh Pant University of Agricultural Sciences & Technology, Pantnagar

4.17b.1.Biodiversity in Trichoderma and Pseudomonas

Two hundred and sixty two isolates of *Trichoderma* and fluorescent pseudomonads were isolated and characterized for their antagonistic potential from varying climatic conditions. Acidic soil was found abundant in fungal micro-organisms specially *Trichoderma* spp. whereas, alkaline soil had mainly fluorescent pseudomonads. Soil taken from neutral pH yielded both in almost same frequency.

4.17b.2. Standardization of mass multiplication method for antagonists

Different substrates including sorghum grains, wheat grains, Jhangora grains (Echinochloa frumentaceum) and pearl millet (Pennisetum americanum) were evaluated as substrates for mass production of Trichoderma. Jhangora and pearl millet were locally available, cheaper and more efficient. Addition of Farm Yard Manure (FYM) powder to jhangora/pearl millet grains (1:3) reduced cost of production. Addition of FYM-powder to talc-CMC based formulation also improved performance and tolerance to temperature and UV light.

For soil application, a method was developed to get FYM colonized by Trichoderma. Waste material left after grinding of spore powder was used to mix in compost pit itself. It helps in fast degradation of FYM and colonization. Spore concentration may go as high as 10^8 g 1 colonized FYM. This FYM is directly applied in field followed by watering. This technology is becoming very popular among farmers.

4.17b.3. Effect of sugar concentration of medium on growth and sporulation of Trichoderma

Three different doses, viz. 20g, 10g and 5g glucose/l of medium (solid and liquid both) were tested to see their impact on growth and sporulation. Glucose concentration at 2.0% level (w/v) recorded the maximum mycelial dry weight. Maximum chlamydospore formation occurred at 1.0% concentration, while conidia development was maximum at 2.0% dextrose concentration.

4.17b.4.Effect of Temperature on growth and sporulation of Trichoderma

Trichoderma was highly sensitive to high temperatures. Its temperature optima appeared to be 25-30°C. Growth was extremely slow at 35°C and ceased after three days at this temperature. In addition, morphological differences were apparent at various temperatures. At 35°C, it produced abnormal compact colonies with irregular margin. Maximum mycelial weight and conidia formation was recorded at 28°C, while chlamydospores were produced abundantly at 30-32°C.

4.17b.5.Effect of pH on growth and sporulation of Trichoderma

The pH optima for the growth of *Trichoderma* appeared to be 6.0 -7.0 (Table 32b). It covered the whole plate in 4 days at these pH levels, but at pH 8.0 the growth was extremely slow and showed compact colonies having irregular margins. Maximum mycelial weight was recorded at 6.5 pH. Conidia formation was maximum at pH 6.0 and 6.5. Maximum chlamydospores were produced at pH 7.0 -7.5, but there was drastic decrease in spore formation at pH 8.0.

Table 32b. Effect of pH on growth and sporulation of Trichoderma

| рН | Sporulation | | | |
|-------------|-----------------------------|-----------------|---------------------------|--------------------|
| | Dry mycelial weight (mg) | Conidia (10°/g) | Chlamydospores (106/g) | Linear growth (mm) |
| 5.0 | 130.67 | 6.49 | 5.24 | 21.33 |
| 5.5 | 153.00 | 59.74 | 7,35 | 27.67 |
| 6.0 | 219.67 | 1277.33 | 0.73 | 35.33 |
| 6.5 | 276.33 | 1286.33 | 7.65 | 50.00 |
| 7.0 | 196.33 | 1026.00 | 7.65 | 49.67 |
| 7.5 | 154.33 | 10.61 | 75.80 | 33.33 |
| 8.0 | 115.33 | 0.45 | 13.88 | 24.33 |
| 8.5 | 91.33 | 0.005 | 0.72 | 11.33 |
| CD (P=0.05) | 14.22 | 240.67 | 5.62 | 7.55 |

Germination of propagules

Mycelial fragments started germinating after 6-8 h of incubation, while conidia took 16-20 h. In case of chlamydospores, germination started after 30-36hrs of incubation. Mycelial fragments formed more germ tubes (2-6 germ tubes) depending upon their length. Germination of conidia was generally through single germ tube, while chlamydospores formed more than one germ tube (1-5).

Shelf-life of propagules

Mycelium based formulations had poor shelf-life and viability was reduced to half after three months of storage at room temperature whereas, it varied between 62.62% and 72.56% when stored at 4°C and -20°C, respectively. After 9 months, no viable propagule was observed at room temperature, while in refrigerator and deep freeze there was drastic decrease in viability. Conidia based formulation had more than 80% viability for five months at room temperature, for 7 months at 4°C and 9 months at -20°C. Chlamydospores exhibited comparatively longer shelf-life (>80% viability after 9 months at room temperature). At low temperatures, it remained viable for more than 12 months.

4.17b.6.Management of diseases by seed treatment (Normal seed treatment vs. Seed biopriming)

The efficacy of normal seed treatment and seed bio-priming was studied in glasshouse on tomato and brinjal. In normal treatment seeds were treated with bioagents using slurry method, while for bio-priming seeds were incubated at 28°C in moist chamber until just prior to radicle emergence and then sown in plastic pots containing field soil inoculated with pathogens. Seed bio-priming with all the propagules resulted in better seed germination and disease control than normal seed treatment. In tomato, mycelium based formulation resulted in 29.86% increase in seed germination with bio-priming, while it was 26.84% with normal seed treatment. In conidia and chlamydospores also, bio-priming was more effective. Disease control was maximum with chlamydospores (72.46%) when applied as normal seed treatment. In bio-priming, seed treatment with mycelium resulted in better protection (63.11%) than other propagules. In brinjal also, maximum seed germination was observed in mycelium treatment and maximum disease control with chlamydospores.

4.17b.7. Management of diseases by soil treatment

Soil treatment with all the propagules resulted in significant increase in seed germination and disease control in tomato and brinjal. Mycelial fragments gave better response than others. In tomato, there was increase in seed germination by 74.57% with mycelium and in brinjal by 33.53%. In tomato, maximum disease control was observed with mycelial fragments

(56.87%) and there was no significant difference with conidia and chlamydospores, but in brinjal, conidia based formulation exhibited better response (Table 32c).

Table 32c. Efficacy of Trichoderma formulations by soil treatment

Tomato

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-------------|--------------------|-----------------------------|---------------------------------|------------------------|
| T-M | 91.06 (72.66) | 74.57 | 13.40 (21.46) | 56.87 |
| T-co | 82.40 (65.22) | 57.79 | 17.68 (24.72) | 43.09 |
| T-chl | 74.10 (59.44) | 42.06 | 17.71 (24.83) | 42.99 |
| Control | 52.16 (46.24) | - | 31.07 (33.85) | - |
| CD (P=0.05) | 3.67 | | 4.72 | |

Values in parentheses are angular transformations

Brinjal

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-------------|-----------------|-----------------------------|---------------------------------|------------------------|
| T-M | 85.82 (67.96) | 33.53 | 25.23 (30.12) | 45.68 |
| Т-со | 80.08 (63.50) | 24.59 | 16.53 (23.96) | 64.41 |
| T-chl | 75.60 (60.42) | 17.62 | 25.23 (30.12) | 45.68 |
| Control | 64.27 (53.31) | , - | 46.45 (42.95) | - |
| CD (P=0.05) | 3.89 | | 4.72 | |

Values in parentheses are angular transformations

4.17b.8.Management of chickpea wilt complex

The application of propagules significantly increased seed germination. The highest seed germination (87.81%) was recorded when seeds were treated with chlamydospores-based formulation. Disease control was maximum (66.87%) in the plots where mycelial fragments based formulation was used as seed treatment. Conidia-and chlamydospores-based formulations also exhibited significant disease control (Table 32d).

Table 32d. Field efficacy of Trichoderma formulations Chickpea

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control |
|-------------|-----------------|-----------------------------|---------------------------------|-----------------|
| T-M | 86.69 (68.64) | 17.84 | 16.06 (23.48) | 66.87 |
| Т-со | 82.24 (65.09) | 11.54 | 27.40 (31.48) | 43.49 |
| T-chl | 87.81 (69.83) | 19.09 | 22.52 (28.31) | 53.55 |
| Control | 73.73 (59.23) | 1+1 | 48.49 (44.13) | - |
| CD (P=0.05) | 6.64 | | 6.10 | |

Values in parentheses are angular transformations

4.17b.9.Root rot and wilt complex of pea

Highest seed germination (87%) was recorded in mycelial fragments based formulation treated plots, other treatments being almost equally effective. Minimum disease was observed when seeds were treated with chlamydospore-based formulations. Other treatments also reduced the disease significantly (Table 32e).

Table 32e. Field efficacy of Trichoderma formulations

Pea

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-------------|-----------------|-----------------------------|---------------------------------|------------------------|
| T-M · | 87.00 (68.90) | 39.33 | 17.77 (24.86) | 56.33 |
| T-co | 71.44 (57.70) | 14.41 | 23.75 (29.13) | 41.68 |
| T-chl | 78.64 (62.50) | 25.94 | 15.98 (23.48) | 60.73 |
| Control | 62.44 (52.23) | - | 40.70 (39.63) | 12 |
| CD (P=0.05) | 4.79 | | 3.20 | |

Values in parentheses are angular transformations

4.17b.10.Lentil wilt complex

Maximum seed germination (88.23%) was recorded with mycelial fragments based formulation and it was significantly superior to conidial-and- chlamydospores-based

formulations (Table 32f). Minimum seedling mortality was observed in conidia treated plots (16.69%), significantly less than untreated control.

Table 32f. Field efficacy of Trichoderma formulations

Lentil

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-------------|--------------------|-----------------------------|---------------------------------|------------------------|
| T-M | 88.23 (70.06) | . 25.14 | 26.57 (30.99) | 45.27 |
| T-co | 77.65 (61.86) | 10.14 | 16.69 (23.93) | 65.62 |
| T-chl | 84.95 (67,25) | 20.49 | 22.52 (28.32) | 53,61 |
| Control | 70.50 (57.22) | - | 48.55 (44.16) | - |
| CD (P=0,05) | 2.87 | | 5.39 | |

Values in parentheses are angular transformations

4.17b.11.Seed and root rot of soybean

Seed germination was maximum (85.06%) when mycelial fragments-based formulation was applied. There was no significant difference in the germination in the case of conidia and chlamydospores treated plots. Post-emergence mortality was minimum (24.82%) when mycelial fragments-based formulation was applied against control (47.30%) (Table-32g).

Table 32g. Field efficacy of Trichoderma formulations

Soybean

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-------------|-----------------|-----------------------------|---------------------------------|------------------------|
| T-M | 85.06 (67.36) | 24.99 | 24.83 (29.84) | 47.50 |
| T-co | 72.48 (58.37) | 06.50 | 27.02 (31.31) | 42.87 |
| T-chl | 72.53 (58.44) | 06.58 | 29.31 (32.75) | 38.03 |
| Control | 68.05 (55.59) | - | 47.30 (43.45) | - |
| CD (P=0.05) | 4.93 | | 2.68 | |

Amongst the propagules, conidia appeared to be the best for development of formulations. Although mycelial fragments showed better bioefficacy, their shelf-life was very low. Likewise, chlamydospores had longer shelf-life, but took more time for germination. Although they gave almost similar results as conidia and mycelial fragments when applied as seed bio-priming, they were not so effective as seedling treatment and foliar spray.

4.17b.12.Development of mixed formulation

A mixed formulation was developed using most efficient and compatible isolates of fluorescent *Pseudomonas* (PBAP-27) and *Trichoderma* (PBAT-43). In this mixed formulation equal *cfu* of the biocontrol agents were maintained.

4.17b.13. Shelf-life of biocontrol agents

In formulations

Viability of mixed and individual formulations (percentage of viable propagules (cfu)/g) did not vary much. At room temperature, both individual and mixed formulations lost viability faster (20% or less after one year), but remained >50 viable in deep freeze. Chickpea, pea, tomato and brinjal seeds water with individual and mixed formulations has more viability and shelf life (60-75% after 7 months) under refrigeration than at room temperature.

4.17b.14.Efficacy under glass house condition

Plant growth promotion

In tomato, there was increase in seed germination and plant vigour when seeds were treated with individual or mixed formulation. Root length, shoot length and plant dry weight were almost equal in all the treatments and significantly different from control (Table 32h).

In brinjal, there was significant difference in seed germination, shoot length, root length and plant dry weight among different treatments (Table 32h).

Similar effects on seed germination and plant vigour were observed in other crops like chilli, chickpea, pea and soybean with the treatment of individual as well mixed formulations (Table 32h). In most of the cases mixed formulation was effective than individual isolates, giving greater seed germination and plant vigour.

Table 32h. Growth promoting effect of mixed formulation of *Trichoderma* and *Pseudomonas* under greenhouse condition

Tomato

| Treatment | Germination (%) | Increase in germination (%) | Shoot Length . (cm) | Increase in shoot length (%) | Increase in Root length shoot length (cm) | Increase in Plant dry Increase in root length wt. (g) plant dry (%) weight (%) | Plant dry wt. (g) | Increase in plant dry weight (%) |
|-------------|-----------------|-----------------------------------|------------------------|------------------------------------|--|--|----------------------|--|
| T-alone | 78.46 (62.36) | 13.80 | 22.90 | 54.10 | 11.33 | 81.86 | 0.25 | 78.57 |
| PsF-alone | 82.89 (65.62) | 20.23 | 22.80 | 34.82 | 11.70 | 87.80 | 0.31 | 121.42 |
| Mixed | 88.34 (70.08) | 28.14 | 22.53 | 51.61 | 11.10 | 78.17 | 0.22 | 57.14 |
| Control | 68.94 (56.14) | r | 14.86 | , | 6.23 | | 0.14 | |
| CD (P=0.05) | 3.34 | | 4.30 | | 1.44 | | 0.04 | |

Values in parentheses are angular transformations

Brinjal

| 92.76 (68.44) 24.84 17.83 32.07 8.76 82.91 (65.61) 04.58 20.90 54.81 9.70 86.35 (74.54) 16.21 21.10 56.29 11.93 1 74.30 (59.44) - 13.50 - 5.66 4.57 - 4.26 0.64 | Treatment | Germination (%) | Increase in germination (%) | Shoot Length (cm) | Increase in shoot length (%) | Root lengt (cm) | Increase in root length (%) | Plant dry wt. (g) | Increase in plant dry weight (%) |
|---|-------------|--------------------|-----------------------------------|----------------------|------------------------------------|--------------------|-----------------------------------|----------------------|--|
| 86.35 (74.54) 04.58 20.90 54.81 9.70 86.35 (74.54) 16.21 21.10 56.29 11.93 1 74.30 (59.44) - 13.50 - 5.65 66 66 66.85 (50.64) | T-alone | 92.76 (68.44) | 24.84 | 17.83 | 32.07 | 8.76 | 54.77 | 0.16 | 33.33 |
| 86.35 (74.54) 16.21 21.10 56.29 11.93 74.30 (59.44) - 13.50 - 5.66 0.05) | PsF-alone | 82.91 (65.61) | 04.58 | 20.90 | 54.81 | 9.70 | 71.37 | 0.28 | 133.33 |
| 74.30 (59.44) - 13.50 - 4.57 - 4.57 | Mixed | 86.35 (74.54) | 16.21 | 21.10 | 56.29 | 11.93 | 110.77 | 0.22 | 83.33 |
| 4.57 | Control | 74.30 (59.44) | , | 13.50 | 10 | 5.66 | | 0.12 | |
| 04:4 | CD (P=0.05) | 4.57 | | 4.26 | | 0.84 | | 0.04 | |

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| Treatment | Germination (%) | Increase in germination (%) | Shoot Length Inc (cm) shoot | Increase in shoot length (%) | Increase in Root length Increase in Plant dry Increase in shoot length (cm) root length wt. (g) plant dry (%) (%) | Increase in root length (%) | Plant dry wt. (g) | Increase in plant dry weight (%) |
|--------------|--------------------|-----------------------------------|--------------------------------|------------------------------------|---|-----------------------------------|----------------------|--|
| T-alone | 92.63 (65.42) | 28.29 | 17.13 | 64.71 | 6.20 | 31.07 | 0.14 | 75.00 |
| PsF-alone | 80.30 (63.67) | 11.21 | 18.00 | 73.07 | 8.10 | 71.24 | 0.19 | 137.50 |
| Mixed | 82.65 (74.43) | 14.47 | 18.23 | 75.28 | 8.83 | 98.98 | 0.24 | 200.00 |
| Control | 72.20 (58.21) | • | 10.40 | , | 4.73 | 1 | 0.08 | î |
| CD (P= 0.05) | 4.28 | | 1.65 | | 19.0 | | 0.54 | |

Values in parentheses are angular transformations

Thickpea

| Treatment | Germination (%) | Increase in germination (%) | Shoot Length (cm) | Increase in Root length Increstoot length (%) | Root length (cm) | Increase in root length (%) | Plant dry wt. (g) | |
|-------------|--------------------|-----------------------------------|----------------------|---|---------------------|-----------------------------------|----------------------|-------|
| T-alone | 92.68 (74.45) | 18.54 | 13.36 | 39.74 | 6.50 | 24.28 | 0.12 | 71.42 |
| PsF-alone | 83.21 (76.14) | 06.43 | 14.33 | 49.89 | 6.93 | 32.50 | 0.12 | 71.42 |
| Mixed | 94.00 (65.85) | 20.23 | 15.23 | 59.30 | 8.33 | 59.27 | 0.13 | 85.71 |
| Control | 78.18 (62.17) | .1 | 9:26 | | 5.23 | , | 0.07 | 3 |
| CD (P=0.05) | 5.11 | | 3.80 | | 0.54 | | 0.03 | 0.04 |

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| Treatment | Germination (%) | Increase in germination (%) | (cm) | shoot length (%) | (cm) | root length (%) | riant dry wt. (g) | moreuse in Koot coughn increase in riant dry increase in shoot length (cm) root length wt. (g) plant dry (%) (%) |
|--------------|--------------------|-----------------------------------|-------|---------------------|------|--------------------|----------------------|--|
| T-alone | 82.89 (65.60) | 98.80 | 16.86 | 34.23 | 7.90 | 42.08 | 0.14 | 75.00 |
| PsF-alone | 87.06 (69.02) | 14.34 | 20.76 | 65.28 | 8.23 | 48.02 | 0.16 | 100.00 |
| Mixed | 92.78 (74.60) | 21.85 | 21.30 | 69.58 | 8.33 | 49.82 | 0.18 | 125.00 |
| Control | 76.14 (60.81) | ı | 12.56 | į. | 5.56 | 1 | 80.0 | r |
| CD (P= 0.05) | 5.04 | | 3.01 | | 0.54 | | 0.02 | |

| Treatment | Germination (%) | Increase in germination (%) | Shoot Lengtl (cm) | shoot length (cm) | Root length (cm) | Increase in root length (%) | Plant dry wt. (g) | Increase in plant dry weight (%) |
|-------------|--------------------|-----------------------------------|----------------------|-------------------|---------------------|-----------------------------------|----------------------|--|
| T-alone | 82.22 (65.11) | 12.75 | 13.90 | 21.60 | 5.53 | 10.60 | 0.15 | 19:99 |
| PsF-alone | 86.70 (66.79) | 18.89 | 15.90 | 39.10 | 5.90 | 18.00 | 0.17 | 88.89 |
| Mixed | 84.41 68.70) | 15.75 | 16.73 | 46.54 | 6.00 | 20.00 | 0.16 | 77.78 |
| Control | 72.92 (58.66) | | 11.43 | 100 | 5.00 | =Ex | 60.0 | |
| CD (P=0.05) | 4.17 | | 3.70 | | 0.39 | | 0.03 | |

4.17b.15.Disease control under field conditions

The efficacy of formulations on seed germination, seedling growth and mortality of chickpea, pea, soybean and lentil is summarized in Table 32i.

Table 32i. Control of different diseases by seed treatment with TH, PsF and their mixed formulation (@ 5.0 g/kg seed)

Chickpea wilt

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-----------|--------------------|-----------------------------|---------------------------------|---------------------|
| T-alone | 85.30 (67.51) | 21.85 | 28.40 (32.17) | 52.50 |
| PsF-alone | 92.70 (74.37) | 32.42 | 37.80 (37.92) | 36.78 |
| Mixed | 94.60 (76.76) | 35.14 | 24.00 (29.32) | 59.86 |
| Control | 70.00 (56.81) | - | 59.80 (50.63) | 871 |
| CD at 5% | 4.20 | | 3.62 | |

Values in parentheses are angular transformations

Root rot and wilt complex of Pea

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-----------|-----------------|-----------------------------|---------------------------------|------------------------|
| T-alone | 80.40 (63.75) | 49,44 | 34.20 (35.80) | 45.88 |
| PsF-alone | 88.30 (65.38) | 64.12 | 28.30 (32.16) | 55.22 |
| Mixed | 82.60 (70.02) | 53.53 | 20.40 (26.81) | 67.72 |
| Control | 53.80 (47.17) | - | 63.20 (52.68) | 20 40 |
| CD at 5% | 3.41 | | 2.92 | |

Values in parentheses are angular transformations

Seed and root rot of soybean

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-----------|-----------------|-----------------------------|---------------------------------|------------------------|
| T-alone | 77.58 (61.77) | 31.00 | 28.14 (32.01) | 58.18 |
| PsF-alone | 80.40 (66.45) | 35.76 | 32.34 (34.65) | 51.94 |
| Mixed | 84.01 (63.74) | 41.46 | 16.15 (23.64) | 76.00 |
| Control | 59.22 (50.32) | - | 67.30 (55.13) | - |
| CD at 5% | 3.22 | | 3.32 | |

Pre- and post-emergence damping-off of Chilli

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-----------|-----------------|-----------------------------|---------------------------------|------------------------|
| T-alone | 70.25 (56.97) | 39.80 | 32.25 (34.59) | 54.37 |
| PsF-alone | 72.34 (58.27) | 43.96 | 25.57 (30.34) | 63.82 |
| Mixed | 86.49 (68.47) | 72.11 | 20.40 (26.83) | 71.13 |
| Control | 50.25 (45.14) | - | 70.68 (57.22) | - |
| CD at 5% | 3.20 | | 2.86 | |

Values in parentheses are angular transformations

Pre- and post-emergence damping-off of Tomato

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-----------|--------------------|-----------------------------|---------------------------------|---------------------|
| T-alone | 70.53 (57.12) | 18.39 | 28.24 (32.09) | 58.20 |
| PsF-alone | 78.60 (62.45) | 31.91 | 32.56 (34.78) | 51.81 |
| Mixed | 90.56 (72.20) | 52.02 | 22.14 (28.05) | 67.23 |
| Control | 59.57 (50.52) | | 67.57 (55.29) | - |
| CD at 5% | 3.24 | | 2.85 | |

Values in parentheses are angular transformations

Pre- and post-emergence damping-off of Brinjal

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-----------|-----------------|-----------------------------|---------------------------------|---------------------|
| T-alone | 85.18 (67.46) | 36.04 | 21.03 (27.28) | 55.71 |
| PsF-alone | 72.50 (58.38) | 15.79 | 16.92 (24.27) | 64.37 |
| Mixed | 93.73 (75.62) | 49.70 | 11.59 (19.89) | 75.59 |
| Control | 62.61 (52.30) | | 47.49 (43.55) | 1 2 |
| CD at 5% | 4.16 | | 3.07 | |

Mixed formulation gave highest germination and least post-emergence mortality in chickpea, lentil and soybean (Table 32j). But in pea, *Trichoderma* alone gave highest germination. In all crops, individual formulations of either *Trichoderma* or *Pseudomonas* gave better overall disease control than mixed formulations.

Table 32j. Field efficacy of mixed formulation

In Chickpea

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control |
|-----------|-----------------|-----------------------------|---------------------------------|-----------------|
| T-alone | 75.98 (60.68) | 30.62 | 33.16 (35.15) | 22.38 |
| PsF-alone | 82.84 (65.57) | 36.36 | 23.33 (28.85) | 45.38 |
| Mixed | 88.25 (70.00) | 40.26 | 14.35 (22.22) | 66.40 |
| Control | 52.72 (46.56) | - | 42.72 (40.81) | 12 |
| CD at 5% | 3.81 | | 2.55 | |

Values in parentheses are angular transformations

In Pea

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-----------|--------------------|-----------------------------|---------------------------------|------------------------|
| T-alone | 88.83 (63.60) | 38.99 | 37.90 (37.98) | 21.41 |
| PsF-alone | 82.91 (65.62) | 29.72 | 28.33 (32.15) | 41.26 |
| Mixed | 80.21 (70.49) | 25.50 | 21.32 (27.49) | 55.79 |
| Control | 63.91 (53.08) | - | 48.23 (43.98) | 5 |
| CD at 5% | 2.25 | | 2.93 | |

Values in parentheses are angular transformations

In Lentil

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|-----------|-----------------|-----------------------------|---------------------------------|------------------------|
| T-alone | 84.85 (67.21) | 21.70 | 28.19 (32.04) | 28.23 |
| PsF-alone | 72.44 (58.34) | 03.90 | 26.43 (30.93) | 32.71 |
| Mixed | 92.65 (74.42) | 32.88 | 20.38 (26.82) | 48.11 |
| Control | 69.72 (56.63) | | 39.28 (38.80) | 7 |
| CD at 5% | 4.66 | | 3.55 | |

In Soybean

| Treatment | Germination (%) | Increase in germination (%) | Post emergence mortality (%) | Disease control (%) |
|--------------|--------------------|-----------------------------|---------------------------------|---------------------|
| T-alone | 73.69 (59.19) | 47.14 | 24.99 (29.96) | 44.95 |
| PsF-alone | 83.28 (61.00) | 66.29 | 32.61 (34.81) | 28.17 |
| Mixed | 76.48 (65.91) | 52.71 | 23.75 (29.12) | 47.68 |
| Control | 50,08 (45,04) | - | 45.40 (42.36) | - |
| CD (P= 0.05) | 2.42 | | 3.08 | |

Values in parentheses are angular transformations

4.17b.16.On-farm demonstration

The effectiveness of formulations was demonstrated in farmers' field as a component of IPM. The crops covered along with the area during kharif 2002 are rice (340 ha), capsicum (12 ha) and soybean (10 ha), ginger (32 ha) and potato (6 ha) and in rabi season, potato (80 ha), tomato (2 ha), capsicum (8 ha), pea (10 ha), chickpea (4 ha), lentil (2 ha), wheat (28 ha) and radish (4 ha).

4.18 Biological suppression of sugarcane pests

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

Natural enemies of sugarcane borers and their seasonal activity were studied at Behram village (Dist. Nawansahar) during April 2001 to March 2002. The mean parasitisation of various stages of sugarcane borers by different parasitioids is presented in Table 33.

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

4.18.2.1 Population dynamics of shoot borer and natural enemies

Shoot borer was active throughout April 2001–March 2002 at Coimbatore with fortnightly incidence rates of 0.3-6.4% and no distinct peak period of activity. The tachinid parasitoid, *Sturmiopsis inferens* was also active almost throughout the year with incidence levels of 0.0-11.4%. Higher activity of the parasitoid was not restricted to any specific part of the year. *Cotesia flavipes* was recorded in one fortnight only. Incidence of granulosis virus at higher levels was noticed. Weather parameters were not correlated to either shoot borer or *S. inferens* activity. The parasitoid showed density-independent fluctuations in relation to shoot borer.

| Pest | Stage | No. collected and reared | Parasitoid | Parasitism (%) | Period of activity |
|-------------------------|----------|-----------------------------|---|-----------------------------|---|
| Chilo infusequellus | Egg mass | 62 | Trichogramma chilonis T. chilotraeae Total | 9.7 8.1 17.8 | May, June, July May, June, July |
| | Larva | 182 | Cotesta flavipes Stenobracon nicevillei Sturniopsis inferens Total | 11.0 8.8 4.4 24.0 | May, July July, Aug., Sept Jan., Feb., Sept |
| | Pupa | 56 | Total | 0.0 | |
| C. auricilius | Egg mass | 25 | T. chilonis Total | 12.0 | April, Aug., Sept. |
| | Larva | 195 | Cotesia flavipes Sturmiopsis inferens S. nicevillei Total | 13.3 14.9 7.8 36.0 | July, Aug., Sept. March Jan., Feb., Sept., Oct. Sept., Oct. |
| | Pupa | 20 | Tetrastichus sp. Total | 2.9 | Feb. |
| Scirpophaga excerptalis | Egg mass | | Telenomus dignoides Trichogramma japontaum T. chilonis Total | 45.2 5.5 4.1 54.8 | April, June, July June, July June, July |
| - | Larva | 172 | Rhaconotus scirpophagae S. nicevillei Isotima javensis Total | 30.2 16.3 12.8 593 | July, Aug., Sept., Oct. July, Aug., Sept., Oct. Aug., Sept. |
| | Pupa | 45 | Total | 0.0 | |
| Acigona steniellus | Egg mass | 22 | T. chilonis Total | 9.1 | Aug. |
| 1 44 | Larva | 125 | S. nicevillei C. flavipes Total | 12.0 20.0 32.0 | Sept., Oct. Aug., Sept. |
| | Pupa | 81 | Terrastichus israeli Total | 5.5 | Sept. |

4.18.2.2 Field evaluation Sturmiopsis inferens, against shoot borer

The parasitoid was evaluated in seven different field trials in half-acre plots of 40-65-day-old sugarcane crop. The parasitoid was released at dosage equivalents of 10-38 gravid females per acre over a one-week period (Table 34). Deadheart counts were recorded prior to release and 30 days after release. Larvae collected from both plots 30 days after release, were reared in the laboratory for parasitoid recovery. In one trial, there was considerable reduction in shoot borer incidence following releases whereas control plots showed increased incidence. In one trial, shoot borer incidence decreased in both plots, but the decrease was more prominent in release plots. The trend was not clear-cut in the remaining trials. Parasitoid was recovered in both control and treatment plots in moderate intensities. In four out of seven trials, parasitism rates were slightly higher in release plots than in control.

Table 34. Field evaluation of Sturmiopsis inferens against shoot borer

| Trial No. | Dosage of | | ease DH %) | Post-rele | ase DH 6) | Post-release | parasitism %) |
|--------------|-------------------|---------|---------------|-----------|--------------|--------------|------------------|
| | release (E/ac) | Release | Control | Release | Control | Release | Control |
| 1 | 18 | 2.6 | 6.0 | 2.0 | 1.6 | 6.1 | 4.5. |
| 2 | 24 | 4.8 | 5.4 | 0.7 | 2.4 | 6.1 | 2.8 |
| 3 | 10 | 3.3 | 5.6 | 1.4 | 3.2 | 5.1 | 0.0 |
| 4 | 18 | 1.1 | 2.8 | 1.1 | 6.8 | 1.2 | 1.1 |
| 5 | 38 | 6.6 | 1.2 | 3.4 | 4.4 | 2.7 | 3.3 |
| 6 | 10 | 1.0 | 1.2 | 1.4 | 2.8 | 1.6 | 4.9 |
| 7 | 20 | 3.4 | 4.2 | 1.1 | 1.0 | 3.0 | 0.0 |

4.18.2.3. Laboratory parasitisation studies on Sturmiopsis inferens

Adults emerging in the laboratory culture showed male-biased ratios in seven months whereas in the rest it was female biased. The mating rates of females were generally high (50.0-95.5%) with only one month showing 50.0% mating rate.

Parasitisation rates in the laboratory on shoot borer larvae varied from 0.0 to 16.6% by Scaramuzza or King's technique, which did not differ in their suitability. One batch of rearing on top borer showed higher (37.2%) parasitisation rate.

4.18.3. Field studies on Trichogramma chilonis against early shoot borer (PAU, Ludhiana)

Large scale studies on the efficacy of Trichogramma chilonis against early shoot

borer, *Chilo infuscatellus* were carried out in farmers' fields at Chak Hakim (Dist. Kapurthala) and Khera (Dist. Kapurthala). The results are summarized in Table 35.

Table 35. Efficacy of Trichogramma chilonis against Chilo infuscatellus in Punjab

| Treatment | Period of release/ Date of insecticide application | | * Incidence o infuscatellus infuscatellus | at | | percent egg infuscatellu locations | |
|---|--|---------------|---|----------------|----------------|--|------|
| | | Chak | Khera Hakim | Mean | Chak Hakim | Khera | Mean |
| T, Release of T. chilonis | * Mid April to June end | 4.6 | 5.3 (53.8) | 5.10 (49.5) | 56.3 (51.7) | 55.6 | 56.0 |
| T ₂ Chemical control (Padan 4G @ 25 kg/ha) | 45 DAP | 5.5 (46.1) | 4.8 (54.3) | 5.2 (50.2) | 4.8 | 4.5 | 4.5 |
| T ₃ Control | | 10.2 | 10.5 | 10.4 | 5.9 | 5.6 | 5.8 |

^{*} Releases made @ 50,000/ha at 10 days interval

Mean parasitism of egg masses of *C. infuscatellus* collected in parasitoid released fields at both locations was very high (56.0%), as compared to control (5.8%) and chemical control (4.5%).

4.18.4. Field studies on Trichogramma chilonis (SBI, Coimbatore)

Last year the study was done on 45 days, 4 months and 6 months old crop. It was continued this year to assess the loss of the parasitoid left as cards in the field on 8-month and 10-month-old crop. The dispersal ability of *T. chilonis* in the field was also studied. Natural activity of *T. chilonis* was observed with *C. cephalonica* trap cards throughout 2001-2002 except during December 2001 and January 2002. The maximum parasitism observed was

4.18.5. Field evaluation of T. chilonis against internode borer (SBI, Coimbatore)

Ten trials against internode borer under progress were completed during this year. In addition, two trials were taken at Elavampalayam under Sakthi Sugars Factory. The parasitoid was released @ 2 cc/ac at fortnightly intervals and the data on the incidence and intensity

^{**} Based on 5 units of 100 shoots each

Figures in parentheses are per cent reduction in damage over control

were recorded at monthly intervals. In general, there was a reduction of INB population in the parasitoid released plots.

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

Trichogramma japonicum was evaluated for the control of top borer, S. excerptalis at three locations in Distt. Kapurthala, viz. Khera, Chak Hakim and Nangal, and compared with chemical control and untreated control. The plot size was 0.4 ha for each treatment at each location. The parasitoid, T. japonicum was released four times during May-July @50,000/ ha.

The incidence of the second brood was low in all the treatments at all the locations (1.8 to 2.8 per cent) (Table 36). The incidence of the 3rd brood was very high in the control (22.6 to 23.4%). The incidence of the top borer in release fields varied from 10.6 to 12.2% at different locations. The reduction in damage over control was 50.7%. Similarly, the incidence of top borer in chemical control plots varied from 10.4 to 11.2% at different locations. The reduction in damage over control was 51.5 per cent. Egg parasitism was very high in release plots (73.8-75.8%) (Table 37) and control (56.0 to 65.2%), but low in chemical control fields (9.4 to 10.6%).

Table 36: Evaluation of *Trichogramma japonicum* for the control of *Scirpophaga excerptalis* in Punjab

| Treatment* | ** Incid | ence of S. | excerptal | is at differe | ent location | 1S | | D |
|---|-------------|--------------|-------------|---------------|--------------|--------------|----------------------------|-----------------------|
| | Chak | Hakim | Kh | ега | Me | an | Mean | Per cent reduction |
| | II brood | III brood | II brood | III brood | II brood | III brood | (3 rd brood) | in damage |
| T ₁ Release of T. chilonis | 2.8 | 12.2 | 2.2 | 11.0 | 2.2 | 10.6 | 11.3 | 50.7 |
| T ₂ Chemical control (Furadan 4G @ 25 kg/ha) | 2.2 | 11.2 | 1.8 | 10.8 | 2.8 | 10.4 | 11.1 | 51.5 |
| T, Control | 2.6 | 23.4 | 2.0 | 22.6 | 2.6 | 22.8 | 22.9 | |

^{*} Parasitoids released on 9.5, 29.6, 6.7 and 11.7 and insecticide applied on 29.06.2001

^{**} Incidence of 2nd and 3rd brood recorded in June and October, respectively

Table 37. Parasitism in Scirpophaga excerptalis in different treatments/locations in Punjab during 2001

| Parasitoids | | Pr | arasitism by | different | Parasitism by different parasitoids at different locations | ifferent loca | ations | | |
|-------------------------|-------|--------------------------|--------------|-----------|--|---------------|--------|--------------|--------|
| | P | Parasitoid released plot | d plot | Inse | Insecticide treated plot | plot | | Control plot | |
| | Khera | Chak Hakim | Nangal | Khera | Chak Hakim | Nangal | Khera | Chak Hakim | Nangal |
| Egg parasitoids | | | | | | | | | |
| Telenomus dignoides | 52.2 | 51.9 | 51.7 | 7.1 | 6.3 | 5.7 | 52.0 | 53.8 | 53.3 |
| Trichogramma japonicum | 17.4 | 18.5 | 20.7 | 0.0 | 3.1 | 2.8 | 0.0 | 3.8 | 3.3 |
| T. chilonis | 4.3 | 3.4 | 3,4 | 3.5 | 0.0 | 0.0 | 4.0 | 7.6 | 3.3 |
| Total | 74.0 | 73.8 | 75.8 | 10.6 | 9.4 | 9.5 | 56.0 | 65.2 | 6.09 |
| Larval parasitoids | | | | | | | | | |
| Rhaconotus scirpophagae | 15.0 | 16.3 | 16.2 | 0.0 | 3.2 | 3.3 | 17.9 | 17.1 | 16.7 |
| Stenobracon nicevillei | 12.5 | 11.6 | 13.5 | 3.6 | 0.0 | 0.0 | 12.8 | 11.4 | 11.9 |
| Isotima javensis | 10.0 | 9.3 | 10.8 | 3.6 | 3.2 | 3.3 | 10.3 | 9.8 | 9.5 |
| Total | 37.5 | 37.2 | 40.5 | 7.2 | 6,4 | 9.9 | 41.0 | 37.1 | 38.1 |

4.18.7. Studies on Beauveria brongniartii against white grubs (SBI, Coimbatore)

4.18.7.1. Field evaluation of Beauveria brongniartii

The fungus cultured on molasses and formulated on press-mud was evaluated in the field at three dosages, *i.e.* 10^{12} , 10^{13} and 10^{14} spores/acre (Table 38) and in combination with carbosulfan (Marshall) and imidachloprid (Confidor). Grubs collected from treated plots showed no clear-cut trend in their numbers, though the numbers collected in the plots that received the lowest dosage of fungus were slightly higher. Grubs collected from fungus treated plots showed higher infection rates than those collected from insecticide-treated plots or combination plots. Grubs from control plots showed some infection.

Table 38. Field evaluation of Beauveria brongniartii and insecticides

| Treatment | Mean post-treatment grub number | Mean per cent infection due to the fungus |
|---|------------------------------------|---|
| Fungus 10 ¹² spores/ac | 43.7 | 3.5 |
| Fungus 1013 spores/ac | 24.7 | 8.8 |
| Fungus 1014 spores/ac | 13.3 | 20.0 |
| Marshall 25 EC (dosage) | 15.0 | 4.4 |
| Confidor 17.8 SKL (dosage) | 20.7 | 0.0 |
| Fungus 1012 spores/ac+F.D. Marshall | 22.3 | 0.0 |
| Fungus 1012 spores/ac+H.D. Marshall | 33.3 | 3.0 |
| Fungus 1012 spores/ac+F.D. Confidor | 29.7 | 0.7 |
| Fungus 10 ¹² spores/ac+H.D. Confidor | 22.7 | 1.4 |
| Control | 19.3 | 3.5 |

4.18.7.2. Field persistence of Beauveria brongniartii

White grubs were collected in the crop season of 2001-02 from farmers' fields in which the fungus was evaluated against the pest during 1998-2001. These grubs, when maintained in the laboratory on sugarcane roots, showed infection levels higher than those collected from untreated plots. Grubs collected form the present season plots also showed infection levels higher than that in control. Infection levels of grubs from different years, however, did not show any trend.

4.18.7.3. Method of dispensation of formulated Beauveria brongniartii

The press mud formulated fungus was applied in bulk quantities in farmers' fields by direct application to the furrows, aqueous suspension and through irrigation water. Grubs collected from these plots showed generally low levels of infection (0-4%). The fungus dispensed through irrigation water did not cause infection of grubs.

4.18.7.4. Natural incidence of Beauveria brongniartii

White grubs collected from farmers' fields in Chagallu Sugar Factory, Andhra Pradesh, showed 20.7% infection due to *Beauveria* sp. whose identity is being confirmed. A single grub showed symptoms of both *Beauveria* sp. and the bacterium *Bacillus popilliae*.

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

4.18.8.1. Host-parasitoid relationship

Two parameters, namely host preference and orientation, were used to assess the host-parasitoid relationship. Last year's study with shoot borer (SB), internode borer (INB) and *C. cephalonica* was extended to include *C. partellus* eggs among the choices offered. Shoot borer eggs were preferred most (96.5%), followed by INB eggs (92.4%). *C. cephalonica* eggs were parasitized to the extent of 83.8%.

4.18.8.2. Orientation

When C. partellus reared T. chilonis was exposed to INB and Shoot Borer (SB) eggs in a Y tube, the per cent of parasitoids that moved towards SB eggs was higher. The increased response towards SB eggs was more pronounced when the parasitoid was passed through shoot borer eggs.

4.18.8.3. Parasitization

T. chilonis cultured on C. cephalonica parasitized 94.2% of Chilo infuscatellus eggs, while that passed through C. infuscatellus parasitized 93.8%. T. chilonis passed through C. infuscatellus parasitized 90.4% of C. cephalonica. However, the per cent adult emergence did not vary much.

4.18.9. Laboratory studies

1. Bioassay studies

When the fungus formulated with press mud or lignite was bioassayed against third stage grubs, the press mud formulation showed slightly higher (66.7%) infection level than lignite formulation (50.0%).

2. Effect of pH of media on growth of entomogenous fungi

A pH range of 4-10 maintained in PDA media did not seriously affect the biomass of *Beauveria bassiana*, *B. brongniartii*, and *Metarhizium anisopliae* (Table 39), with the exception of *B. brongniartii* which gave a slightly lower biomass at pH 4. Spore production by the three fungi also did not show a strong trend, though there was higher production at lower pH in *M. anisopliae* (Table 40).

Table 39. Effect of pH level of media on biomass of three entomogenous fungi

| pH | | Biomass (g) | |
|---------|------------------------|--------------------|------------------------|
| | Beauveria brongniartii | Beauveria bassiana | Metarhizium anisopliae |
| 4 | 0.58 | 1.94 | 0.78 |
| 5 | 1.25 | 1.98 | 0.56 |
| 6 | 0.97 | 1.77 | 0.69 |
| 7 | 1.29 | 1.88 | 0.69 |
| 8 | 1.37 | 1.72 | 0.58 |
| 9 | 1.33 | 1.63 | 0.65 |
| 10 | 1.32 | 1.56 | 0.71 |
| Control | 0.99 | 1.83 | 0.75 |

Table 40. Effect of pH level of media on spore production of three entomogenous fungi

| pH | | Spore production (x109) | |
|---------|------------------------|-------------------------|------------------------|
| | Beauveria brongniartii | Beauveria bassiana | Metarhizium anisopliae |
| 4 | 6.8 | 9.2 | 7.3 |
| 5 | 9.2 | 8.3 | 16.3 |
| 6 | 12.0 | 8.5 | 15.9 |
| 7 | 7.5 | 7.8 | 8,9 |
| 8 | 9.1 | 9.6 | 7.6 |
| 9 | 6.0 | 7.6 | 6.9 |
| 10 | 6.4 | 6.5 | 10.8 |
| Control | 7.5 | 7.5 | 8.9 |

3. Safety tests

The three entomogenous fungi did not affect the emergence rates of Trichogramma chilonis when parasitised host eggs were treated with them at 10^6 and 10^8 spores/ml

(Table 41). The fungi caused some mortality in the lycosid spider *Hippasa greenalliae* and considerable mortality in *Cotesia flavipes* adults.

Table 41. Safety tests of three entomogenous fungi against natural enemies

| Natural enemy | 1 | Per cent eff | ect at two | different c | oncentratio | ons (spores/ | ml) |
|---|------------------|--------------|------------------|-----------------|-------------------|--------------|--------|
| | Beauve brongn | 0.77% | Beauve bassia | A1762 | Metarh anisopi | | Contro |
| | 106 | 10^{8} | 106 | 10 ⁸ | 106 | 108 - | Contro |
| Trichogramma chilonis (% emergence) | 95.8 | 96.5 | 96.6 | 90.8 | 92.4 | 94.6 | 88.4 |
| Hippasa greenalliae (% mortality) | Ö | 28 | 8 | 8 | 8 | 12 | 0.0 |
| Cotesia flavipes (% mortality) | 20 | 18 | 22 | 44 | 26 | 26 | 0 |

When mulberry leaves treated with the three fungi at $10^5 - 10^8$ spores/ml were fed to the mulberry silkworm larvae for one day, *B. brongniartii* did not cause any mortality (Table 42). The other two fungi showed a dosage-dependent mortality of larvae and the effect was more pronounced for *M. anisopliae* than for *B. bassiana*.

Table 42. Safety of three entomogenous fungi to third instar silkworm, Bombyx mori

| Concentration | 9 | Per cent mortality of larva | e* |
|-----------------|------------------------|-----------------------------|------------------------|
| (spores/ml) | Beauveria brongniartii | Beauveria bassiana | Metarhizium anisopliae |
| 108 | 0 | 30,8 | 49.9 |
| 107 | 0 | 3.9 | 26.2 |
| 106 | 0 | 3.1 | 15.8 |
| 10 ^s | 0 | 0 | 2.8 |
| Control | 0 | 0 | 0 |

^{*} Cumulative mortality 15 days after treatment by treated leaf feeding method

Against the honey bee *Apis indica*, *B. brongniartii* caused higher mortality when adults were directly treated than when they were exposed to treated surface in cages (Table 43). However, the other two fungi showed the opposite trend.

Table 43. Safety of three entomogenous fungi to Apis indica

| Method of treatment | | Per cent mo | rtality of bees* | |
|--|---------------------------|-----------------------|---------------------------|---------|
| | Beauveria brongniartii | Beauveria bassiana | Metarhizium anisopliae | Control |
| Adults impregnated after freeze inactivation | 26.9 | 51.0 | 46.0 | 0 |
| Adults released in treated cages | 2.15 | 65.0 | 62.0 | 0 |

^{*} Cumulative mortality 18 days after treatment

4.18.10. Demonstration of effectiveness of *Trichogramma chilonis* against *Chilo auricilius* (PAU, Ludhiana)

The efficacy of *Trichogramma chilonis* for the control of stalk borer was demonstrated at village Karni Khera (Distt Ferozpur) over an area of 40 ha. Eleven releases of *T chilonis* were made at weekly interval during August-October @ 50,000/ha. The incidence of the stalk borer was 4.27 per cent in the released fields and 10.85 per cent in the control. The reduction in incidence of stalk borer in released field was 60.82 per cent over control. Mean parasitism of egg masses in release fields was 79.50 per cent and 6.17 per cent in the control.

Large scale field demonstrations were also carried out in collaboration with two sugar mills of the state. The egg parasitoid, *T. chilonis* was released @ 50,000 per ha at 10 days interval during July - October. The results are presented in Table 44.

Table 44. Large scale demonstration of biocontrol based IPM on sugarcane in the Punjab during 2001

| Mill area | Area | In | cidence of stalk bore | r (%) |
|--|--------------------|------|-----------------------|----------------------------------|
| | covered (Acres) | IPM | Control | Reduction in damage over control |
| Doaba Coop. Sugar Mills Ltd. Nawanshahar | 1500 | 6.21 | 16.74 | 62.90 |
| Morinda Coop. Sugar Mills Ltd. Morinda | 2000 | 3.16 | 6.69 | 52,76 |
| Mean | | 4.68 | 11.71 | 60.03 |

^{*} Trichogramma chilonis was released @ 50,000 per ha at 10 days interval during July to October

4.19 Biological suppression of cotton pests

4.19.1. Bio-intensive integrated management of cotton pests

4.19.1.1. GAU, Anand

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

T1: (IPM Module)

- Hand picking of pest stages and putting them in wire screen cage twice during peak incidence.
- ii. Interplanting of maize
- One release of Chrysoperla carnea @ 14,000 larvae (2-3 days old) /h/week synchronizing with the appearance of the pests.
- iv. Releases of Trichogramma chilonis @ 1,50,000 as per pest incidence.
- v. Application of 1 Kg/ha Bt when any one of the bollworms is seen. If Helicoverpa is seen apply $HaNPV @ 3 X 10^{12} POB/ha$. Apply systemic insecticide spray if necessary for sucking pests. PDBC supplied Bt and HaNPV from single source.
- T2: Insecticidal control (Recommended insecticides)
- T3: Untreated control

The bud and boll damage was significantly lower in IPM module than control and insecticidal treatments (Table 45). The bollworm damage to the locules was significantly low

Table 45. Effect of biointensive IPM on cotton pests

| Treatment | Suck | ing pests/ | 15 leaves | Per c | ent damag | e by boll w | orms | Yield |
|--------------|-------------------|-----------------|----------------|------------------|------------------|------------------|------------------|-------|
| | Aphid* | Jassid* | White | Bud** | Boll** | Loc | ules | kg/ha |
| | | | fly* | 25,000 | 1000000 | E.V.** | P.G.** | |
| IPM | 6.61 (42.69) | 2.01 (3.04) | 2.05 (3.20) | 12.91 (4.99) | 18.25 (9.81) | 15.07 (6.76) | 26.52 (19.94) | 2567 |
| Insecticides | 7.17 (50.41) | 2.32 (4.38) | 2.46 (5.05) | 15.80 (7.41) | 23.93 (16.45) | 19.50 (11.14) | 33.07 (29.77) | 1736 |
| Control | 13.50 (181.25) | 3,53 (11,46) | 3.18 (9.11) | 22.95 (15.20) | 32.66 (29.12) | 29.70 (24.55) | 39.17 (39.89) | 1260 |
| CD (P=0.05) | 1.173 | 0.226 | 0.245 | 0.829 | 1.682 | 2.554 | 1.263 | 154 |

^{*} $\sqrt{X+1}$ transformation ** Arc sine per cent transformations Figures in parentheses are retransformed values.

in IPM block. The damage due to *E. vittella* and *P. gossypiella* and the population of sucking pests were significantly lower in IPM module as compared to control. Since IPM plots received less spray of chemical insecticides many of the bioagents were conserved (Table 46).

Table 46. Effect of biointensive IPM on egg and larval parasitism of bollworms

| Parasitoid | IPM | Insecticide | Control |
|--------------------------------------|-------|-------------|---------|
| Eggs parasite by T. chilonis | 26.00 | 6.50 | 13.00 |
| Larval parasitism by R. aligarhensis | 19.00 | 5.90 | 12.15 |
| Larval pupal parasitism by Agathis | 30.00 | 22.00 | 25.00 |

Bollworm parasitoids Aleiodes aligharensi, T. chilonis and Agathis caused higher parasitisation in IPM module, but were greatly hampered due to application of chemical insecticide. Population of Chrysoperla, Menochilus, Geocoris and staphylinids was higher in IPM. The yield in IPM module (2567 kg/ha) was significantly superior to control (1260 kg/ha). Intercropping of maize with cotton enhanced the activity of M. sexmaculatus (3.60 /plant) in IPM block, compared to control (1.50 /plant).

4.19.1.2. TNAU, Coimbatore

A field trial was conducted in Thondamuthur village, Coimbatore district with the variety LRA 5166 – under irrigated condition in black cotton soil with the following treatments.

T, - IPM module

The pest stages were hand picked and put in wire screen cage (3'x3'x3') thrice during peak incidence; maize was inter-planted. Since this is the second year cowpea border crop was planted; One release of *Chrysoperla carnea* @ 14,000 larvae/ha was made on the 75th day; *Trichogramma chilonis* cards @ 1,50,00/ha/week was released on the 60th day. Six times at 15 days interval; *Bt* (Delfin) @ 1 kg/ha was sprayed on 80th day. Application of HaNPV @ 3 x 10¹² POB/ha was made at 90th day, 105 and 120th days. Systemic insecticide was applied against aphids on 45 DAS and 60 DAS.

T2 - Insecticidal control

Eight rounds of sprays with recommended insecticides.

T₂ - Untreated check (Control)

At 60 DAS there was no significant difference in the number of aphids among the plots (Table 47). At 90 DAS the lowest number of aphids were seen in IPM module (14.2 / 5 plants), compared to untreated check. The lowest number of whiteflies on 105 DAS was seen

Table 47. Incidence of sucking pests of cotton in the experimental plots (Number/5 plants)

| | Aphids | ids | | | Whiteflies | es | | Jas | Jassids | | runps | |
|--------------------------|--------|-------------|-------------------|-------|------------|-------------------|-------------------|------------------|---------|-----|-------|------|
| | | | | | DAS | | | | | | | |
| 09 | - | 75 | 06 | 75 | 06 | 501 | 30 | 45 | 09 | 09 | 75 | 96 |
| IPM module 20.2 | 153 | 20.2" 21.6" | 14.2" | 26.1⁴ | 23.35 | 23.35 11.4* | 5.18 | 4.2" | 13.4 | 4.0 | 8.9 | 0.3 |
| ontrol | 20 | 22.0⁴ | 60.1 ^b | 28.2 | 11.11 | 42.3 ^b | 8.1. | 9.2 ^b | 12.4 | 0.9 | 1.2 | 9.0 |
| Universited control 26.2 | 23 | | | _ | 42.2h | | 49.0° 16.2° 19.2° | 19.2° | 13.2 | 2.1 | 2.2 | 11.6 |
| + | | | | | | | | | SN | NS | SN | NS |

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

Table 48. Helicovera armigera larval population in the experimental plots

| Treatments | | Mean of lar | Mean of larvae (8) on 5 plants | | |
|----------------------|--------|-------------|--------------------------------|--------|---------|
| | 75 DAS | 90DAS | 105DAS | 120DAS | 135 DAS |
| IPM module | 21.2 | 19.8b | 13.2a | 11.4a | 16.2a |
| Treacticidal control | 26.2 | 11.2a | 14.3a | 18.2b | 28.3b |
| Illsectional control | | | 10.47 | 40.30 | 36.8h |
| Untreated control | 27.2 | 31.2c | 44.30 | 49.30 | 20.00 |
| CD (P=0,05) | SN | | | | |

Data are means of 10 values; Means followed by similar letters in a column are not statistically different by DMRT P=0.05

in IPM plot (11.7 / 5 plants). Jassids and thrips occurred as minor pests. Whitefly incidence continued for up to 105 days.

Helicoverpa armigera was the major pest damaging squares and bolls from 90 and 135 DAS, the lowest numbers were observed in IPM module and the highest in untreated check on 135 DAS (Table 48). Earias vittella occurred between 86 to 115 DAS. Pectinophora gossypiella occurred between 105 to 150 DAS (Table 49).

Table 49. Incidence of different bollworm species in cotton

| Treatments | Bollworm | | Mean | number / | 5 plants | | |
|---------------------|----------------------------------|------|------------------|-------------------|--------------|-----|------------|
| | | 75 | 90 | 105 | 120 | 135 | 150 |
| IPM Module | Earias vittella P.gossypiella | 3.2* | 4.8ª | 21.3° | 21.6 2.0 | 2.6 | 3.2 |
| Insecticidal module | Earias vittella P.gossypiella | 3.04 | 2.8ª | 78.3 ^b | 14.3 1.0 | 2.3 | 3.0 3.6 |
| Untreated control | Earias vittella P.gossypiella | 4.24 | 8.4 ^b | 18.3ª | 28.3 13.2 | 8.3 | 4.1 |
| CD (P=0.05) | 1 | | | | | | NS |

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

There was no significant difference in the per cent damage of bolls on the 75 DAS. Boll damage was the lowest in IPM module plot from 90 DAS to 135 DAS. Insecticidal control was the second best on 105 DAS and 135 DAS (Table 50).

Table 50. Per cent square and boll damage and yield of cotton under different treatments

| Treatments | М | lean per cent | damage of bol | lls (DAS) | | Kapas yield (kg/ha) |
|----------------------|-------|-------------------|---------------|-----------|-------|------------------------|
| | 75 | 90 | 105 | 120 | 135 | 2 8 3 |
| IPM module | 28,2ª | 22.3" | 14.2" | 11.6° | 12.2* | 2116.21 |
| Insecticidal control | 27.2 | 34.2° | 23.16 | 10.2° | 27.3 | 1785.1 ^b |
| Untreated check | 28.14 | 28.2 ^b | 30,2° | 44.2b | 34.8° | 982.2° |

Data are means of 10 values; Means followed by similar letters in a column are not statistically different by DMRT P=0.05

The highest kapas yield (2116 kg/ha) was obtained from IPM module plot followed by insecticidal control plot (1785 kg/ha) and untreated check.

Parasitism

Per cent egg parasitism was highest in IPM module and larval parasitism of all bollworms was lowest in insecticidal control plot (Table 51).

Table 51. Occurrence of natural enemies and extent of parasitism of bollworms

| Treatments | | r cent egg arasitism | | | parasitism Harvae) | % | Pre | dators plants | /50 |
|----------------------|-------------------|-------------------------|-------|--------------------|-----------------------|--------|------|---------------|------|
| | Ha | Εv | Pg | На | Εv | Pg | Ha | Εv | Pg |
| IPM module | 15.8 ^b | 18.3° | 17.15 | 11.16 ^b | 13.12° | 26.10° | 12.0 | 12.8 | 11.2 |
| Insecticidal control | 7.1ª | 4.2 ^b | 31.0e | 1.20° | 0.60 | 1.21ª | i.e. | - | |
| Untreated check | 6.1 | 1.1¢ | 2.1ª | 3.10a | 4.20 ^b | 8.105 | 12.0 | 14.1 | 9.8 |
| CD (P=0.05%) | | | | | | | NS | NS | NS |

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

Maize (intercrop) in the BIPM block also supported more natural enemies than untreated check.

4.19.1.3. MPKV, Pune

A field experiment was conducted on research farm of cotton improvement project, MPKV, Rahuri, using variety NHH-44 (Nanded-44) with the following treatments.

T1- IPM module

Hand picking of pest stages and putting them in wire screen cage twice during peak incidence; inter-planting of maize; one release of *Chrysoperla carnea* @ 14,000 larvae/ha at the appearance of the pests; releases of *Trichogramma chilonis* @ 1,50,000 adults/ha/week as per pest incidence; application of 1 kg/ha *Bt* at the appearance of *Earias* spp.; spraying of *HaNPV* @ 3x10¹² POBs/ha against *H. armigera*

T2- Insecticidal control as per state recommendation

T3- Untreated control

The data on jassids and whiteflies in various treatments did not show significant differences. However, aphid population in biocontrol block was significantly less than other treatments. The data on locule damage and bad kapas was non-significant; however, locule damage was low in chemical control and bad kapas more in the biocontrol block. Higher yield was observed in chemical control (748 kg/ha), which was on par with biocontrol (Table 52).

Table 52. Efficacy of BIPM module against sucking pests and bollworms in cotton

| Treatment | Av. pes | t population/ | 15 leaves | Locule | Bad | Yield |
|-------------------|------------------|---------------|------------|---------------|--------------|---------|
| | Jassid nymphs | Aphids | Whiteflies | damage (%) | kapas (%) | (kg/ha) |
| Chemical control | 4.90 | 42.4 | 2.90 | 30.44 | 28.13 | 748 |
| Biocontrol Module | 5.10 | 33.5 | 2.53 | 35.70 | 27.15 | 650 |
| Untreated control | 5.33 | 64,5 | 3.30 | 36.44 | 31.66 | 452 |
| CD (P=0.05) | NS | 12.68 | NS | NS | NS - | 105.21 |

4.19.1.4. ANGRAU, Hyderabad

The impact of bio-intensive management practices on cotton pest complex was studied at Agricultural Research Station, Warangal, with the following modules (var.NA1588).

T1: BIPM module

- i. Hand picking of pest stages and putting them in wire screen cage
- ii. Sowing of maize as intercrop 10 days after main crop
- One release of Chrysoperla carnea @ 14,000 larvae/ha synchronizing with the occurrence of bollworms
- Eight releases of T. chilonis each @ 1,50,000/ha/week synchronizing with the appearance of eggs of bollworm.
- Need based application of HaNPV @ 3 x 10¹² POB/ha (500LE/ha) and systemic insecticides against sucking pests.

T2: Insecticidal control (recommended insecticides)

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

T3: Untreated control

Infestation of jassids, whiteflies and aphid infestation was low in both BIPM and insecticidal control as compared to untreated control (Table 53). BIPM recorded less number of whiteflies and equal number of aphids, while jassids were less in insecticidal control. Population of eggs and larvae of *H. armigera* was higher in BIPM and insecticidal control than in control. Bollworm damage was lowest in insecticidal control, followed by BIPM module. Population of coccinellids, spiders and lacewings (both eggs and adults) was higher in BIPM module and control, than insecticidal control. Insecticidal control gave higher kapas yield followed by BIPM module. BIPM module gave better monetary returns and cost-benefit ratio than insecticidal control.

Table 53. Incidence of insect pests, natural enemies and yield in cotton under different treatments

| Particulars | BIPM | Insecticidal Control | Control |
|--------------------------------|--------|----------------------|---|
| Sucking Pests | | | |
| a. Jassids (No./plants) | 6.20 | 3.45 | 8.75 |
| b. White flies (No./Plant) | 21.75 | 33.50 | 55.50 |
| c. Aphids (% infested plants) | 4.50 | 4.50 | 6.20 |
| Bollworms | | | 112000000000000000000000000000000000000 |
| a. Eggs of H. armigera/plant | 3.71 | 3.70 | 2.95 |
| b. Larvae of H. armigera/plant | 3.60 | 3.70 | 2.95 |
| Damage (%) | | | |
| a. Squares | 59,60 | 45.10 | 70.25 |
| b. Bolls | 39.80 | 31.50 | 62.40 |
| Natural Enemies | | | (Caracas) |
| a. Coccinellids/plant | 0.25 | 0.04 | 0.35 |
| b. Spiders/plant | 2.51 | 0.10 | 3,30 |
| c. Eggs of lacewings/plant | 0.31 | 0.03 | 0.11 |
| d. Adults of lacewings/plant | 0.18 | 0.01 | 0.05 |
| Yield | | - | 10.0005/1 |
| Kapas (kg/ha) | 1457 | 1610 | 815 |
| Total Returns (Rs.) | 22512* | 15160 | 13040 |
| Cost Benefit Ratio | 1:1.73 | 1:0.22 | _ |

^{*} Inclusive of returns from inter crop (Maize)

4.19.1.5. PAU, Ludhiana

The experiment for the management of cotton pests was carried out in a farmer's field at Khuban (Ferozpur District). In the biocontrol module, twelve releases of *T. chilonis* were made at weekly interval during July-September @ 1,50,000/ha. Two sprays of imidacloprid (Confidor 200 SL) were given @ 100 ml/ha for the control of jassid. Biocontrol was compared with farmer's practice, in which two sprays for the control of cotton jassid and nineteen sprays for the control of cotton bollworms were given.

Incidence of bollworms among intact fruiting bodies was lower (33.9%) in farmer's practice as compared to biocontrol (40.7%). Similarly, the incidence of bollworms among green bolls was lower (12.7%) in farmers' practice than biocontrol (36.3%). The yield was higher (9.75 q/ha) in farmers' practice as compared to biocontrol (5.20 q/ha). In biocontrol plot, 0 - 16.1 per cent (mean =7.8%) eggs of *H. armigera* were parasitized by *T. chilonis*. However, in farmers' practice, very low (0.6%) parasitism was observed.

Incidence of bollworms was lower and yield was higher in T. chilonis + insecticides and insecticides alone as compared to control (Table 54). Mean parasitism of H. armigera was nil to very low (0.9%) in insecticide treatment and control. When T. chilonis was integrated with insecticides, parasitism was 0 - 15.3 per cent (mean = 7.7 per cent) on different dates of observation.

Table 54. Integration of *Trichogramma chilonis* with insecticides for the control of cotton bollworms

| Treatment | Incidence of bo | ollworms (%) | Yield |
|---------------------------------|-----------------|--------------|--------|
| | Fruiting bodies | Green bolls | (q/ha) |
| T. chilonis + insecticides (T1) | 11.8 | 2.7 | 10.60 |
| Insecticides (T2) | 14.1 | 6.2 | 9.50 |
| Control (T3) | 50.7 | 48.8 | 3.75 |

- Note: 1. Nine insecticidal sprays were given in T₁ and T₂ for the control of bollworms and two sprays for the control of cotton leafhopper in T₁, T₂ and T₃
 - Twelve releases of T. chilonis were made @ 1,50,000/ha/week during July to September in T_i
 - Incidence of bollworms based on six observations for fruiting bodies and two for green bolls

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

The efficacy of inundative release of *T. chilonis* in combination with *Chrysoperla carnea* against cotton pest complex was evaluated at Agronomy Farm., B. A. College of Agriculture Anand with the following treatments.

- T1: T. chilonis @ 1,50,000/ha/week releases synchronised with the appearance of bollworms and C. carnea @ 14,000 / ha twice a week.
- T2: Insecticidal control (Recommended insecticide)

T3: Untreated control

The bud and boll damage (5.36 and 11.05%, respectively) was significantly low in release plot over control (15.05 and 29.11, respectively) as well as insecticidal treatments. The bollworm damage to the locules was also significantly lower in release plot. The damage due to *E. vittella* in the released plot, insecticides and control plot was 8.19, 11.14 and 24.55 per cent, respectively, and the damage due to *P. gossypiella* was 21.98, 29.77 and 39.89 per cent, respectively.

The population of sucking pests was also significantly lower in release plot as compared to control due to release of *Chrysoperla*. The population of aphid, leafhopper, and whitefly in release plot was 46.20, 3.41 and 3.41 per 15 leaves, respectively, whereas in insecticide treated plot it was 50.55,4.38 and 5.05 per 25 leaves, respectively. In untreated control, the respective values were 181.25, 11.25 and 9.11 per 15 leaves. Since release plot received no spray of chemical insecticides, bio-agents were conserved, mainly, bollworm parasitoids *Aleiodes alighavensi*, *T. chilonis* and *Agathis* (18.00, 27.00 and 30.50 per cent parasitism, respectively). The predators *Chrysoperla*, *Menochilus*, *Geocoris* and staphylinids were also present in large numbers. The yield in release plot (2305 kg/ha) was significantly superior over control (1332 kg/ha).

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

The efficacy of inundative release of *T. chilonis* in combination with *Chrysoperla carnea* against cotton pest complex @ 14,000/ha once (T1), or twice (T2) was evaluated with an untreated control.

Pre cent bud and boll damage, damage due to *E. vittella* and pink bollworm and sucking pest population were lower and the yield was higher in biocontrol plots than control (Table 55). Population of predators and bollworm parasitoids was also higher in released plots than control.

Table 55. Efficacy of inundative releases of *C. carnea* and *T. chilonis* against cotton pest complex

| Treatment | | Per cent c | lamage | | Popula | ition / 15 l | eaves | |
|---|-------|------------|--------------------|----------------------|------------------|---------------|-------|------------------|
| | Buds | Bolls | Earias vittella | Pink boll worm | Aphids Hopper | Leaf flies | White | Yield (kg/ha) |
| T. chilonis + C. carnea @14000/ha once | 10.84 | 21.24 | 14.90 | 34.25 | 57.06 | 4.90 | 5.25 | 1536 |
| T .chilonis + C. carnea @ 14000/ha twice | 7.12 | 17.43 | 11.81 | 30.03 | 51.13 | 3.97 | 3.93 | 1820 |
| Control | 15.15 | 29.12 | 24.53 | 39.89 | 178.02 | 11.46 | 9.11 | 1313 |

4.19.4. Evaluation of Bt products against cotton bollworm complex (TNAU, Coimbatore)

This trial was conducted on irrigated LRA 5166 cotton at Thondamuthur village, Coimbatore district. All the *Bt* treatments gave significantly less boll damage than the untreated check (Table 56). The highest yield was obtained from endosulfan treated plots, on par with delfin 1000 gm/ha. Other *Bt* treatments were also superior to untreated check (Table 56).

Table 56. Effect of Bt and insecticide on cotton bollworm complex and yield

| Treatment | | Per | cent boll dam | age | | *** ** |
|----------------------|-------------------|--------------------|---------------------|--------------------|----------|-------------------|
| | Pre- treatment | | 71 | DAT | | Yield kg/ha |
| | | I spray | II spray | III spray | IV spray | |
| Delfin 1000 g/ha | 8,61 | 5.32 ^{ab} | 10.03ab | 12.32 ^b | 4.32° | 1810° |
| Biolep 1000 g/ha | 9,80 | 5.12ab | 11.21 ^{bc} | 11.31 ^b | 6.02* | 1702 ^b |
| Spicthurin 1000 g/ha | 8.42 | 5.32ab | 12.22tc | 13.21 ^b | 5.014 | 1753 ^b |
| Spicbio 500 ml/ha | 8.32 | 4.16 ^a | 9.12ª | 14.33 ^b | 6.13a | 1738ь |
| Endosulfan 0.07% | 5.16 | 4.02ª | 11.42ab | 9.16 ^a | 4.32° | 18.88ª |
| Untreated control | 5.32 | 7.13 ^b | 14.36° | 18.22° | 11.16° | 1243° |
| | | | | | | |

Data are means of 4 values; Means followed by similar letters in a column are not statistically different, P=0.05

The larval population in *Bt* treated plots was significantly less than that in untreated check (Table 57). *Earias vittella* population among the experimental plots was not significantly different. The highest number of predators were observed in *B.t.* treated plots and lowest in endosulfan treated plots. The highest larval parasitism of *H. armigera* was observed in Spicthurin and Spic-Bio treated plots and the lowest in endosulfan treated plots and untreated check.

Table 57. Mean larval population of bollworm complex (Number / 5 plant)

| Treatments | Number of 5 plants @ DAS | | | | | | | | | |
|-----------------|--------------------------|-------|-------------------|------------|------|-----|-----|-------------------|-------------------|-------------------|
| | H. armigera | | | Earias sp. | | | | | Pg | |
| | 70 | 80 | 90 | 100 | 60 | 70 | 80 | 90 | 100 | 120 |
| Delfin | 13.12 | 11.8° | 3.24 | 0.6° | 2.3ª | 2.4 | 0.8 | 2.30° | 18.2 ^b | 3.10 |
| Biolep | 13.9° | 12.2° | 4.2 | 0.2ª | 2.3ª | 1.8 | 1.2 | 2.40° | 19.26 | 4.20 |
| Spiethurin | 13.8° | 12.14 | 4.8ª | 0.4ª | 2.9ª | 2.1 | 1.2 | 11.2 ^b | 11.2ª | 4.20° |
| Spic-Bio | 15.21 | 12.2* | 3,2ª | 1.0 | 2.8 | 2.3 | 1.0 | 18.2° | 11.6ª | 4.60 |
| Endosulfan | 13.2° | 12.3ª | 1.0ª | 1.14 | 4.9b | 1.3 | 1.4 | 2.10a | 11.8* | 4.90° |
| Untreated check | 16.1¢ | 31.2b | 13.2 ^b | 6.2b | 2.8 | 1.6 | 1.6 | 3.10 | 9.2 | 13.8 ^b |
| CD (P=0.05) | | | | | | NS | NS | | | |

Data are means of four values. Means followed by similar letters in a column are not statistically different, P=0.05

4.19.5. Identification of host plants harbouring arthropod natural enemies

4.19.5.1. TNAU, Coimbatore

Natural enemies of cotton pests were observed on maize, cauliflower and tomato in the neighboring fields. Abutilon indicum, Solanum nigrum, Chrozophore rottlari, Hibiscus ficulensis, bund grasses and Aristolochia sp. harboured natural enemies.

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

The following host plants were found harboring natural enemies.

| ost | | |
|-----|--|--|
| | | |
| | | |

Natural enemies recorded

| Rustica tobacco | Mirid bug, Rhinocoris sp., Bracon sp., Geocoris sp. |
|-----------------|--|
| Bidi tobacco | Mirid bug, Rhinocoris sp., Bracon sp., Geocoris sp. |
| Sunnhemp | Geocoris sp. |
| Marigold | Trichogramma, Geocoris, Nabis, Rhinocoris and crab spider |
| Maize | M. sexmaculatus, Xanthogramma, Geocoris sp., Anthocorid, C. carnea |
| Matsgandha | Trichogramma, C. carnea |
| Cassia | Trichogramma, C. carnea |
| Starburr | Trichogramma, C. carnea |
| Parthenium | Trichogramma, C. carnea |
| Duranta | Trichogramma, C. carnea |

4.19.5.2. ANGRAU, Hyderabad

Periodical surveys were carried out in and around the cotton growing areas of Rangareddy, Warangal and Mahaboobnagar districts to record the host plants harbouring arthropod natural enemies. Eggs and caterpillars of *Earias* sp. on bhendi; *Helicoverpa* on tomato, brinjal, chickpea, pigeonpea, sorghum, castor and parthenium and *Spodoptera* on castor and cabbage were collected. Larvae of *S. litura*, selected from castor, were parasitized by *Cotesia* sp., but none of the other samples gave rise to any parasitoids probably due to indiscriminate use of pesticides.

4.19.6. Efficacy of Heterorhabditis indica and Steinernema carpocapsae against Helicoverpa armigera in cotton

The efficacy of Heterorhabditis indica and Steinernema carpocapsae against H. armigera @ 0.5 billion/h, 1.0 billion/h and 2.0 billion/h, was evaluated with farmer's practice and an untreated control for comparison. H. indica and S. carpocapsae both @ 2.0 billion/h were effective against H. armigera and recorded up to 64.35 and 55.64 % larval mortality, respectively, after 4 days of treatment. Both these treatments recorded higher yield (2465 and 2388 kg/h, respectively) as compared to farmers' practice and control

4.19.7. Colonization and establishment of $Chelonus\ blackburni$ in cotton (ANGRAU, Hyderabad)

With a view to establish C. blackburni in cotton ecosystem, 4 releases of laboratory

bred *C. blackburni* were made @ 5000/ha at 15 days interval during the activity of bollworms at Agricultural Research Station, Warangal. Periodically eggs and larval stages of the pests were collected and observed for parasitoid emergence. However, so far the parasitoid has failed to establish in cotton ecosystem.

4.20. Biological suppression of tobacco pests

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

Talc based entomopathogenic nematode (EPN), *Steinernema carpocapsae* at three different doses, *viz.*, @ 1 lakh, 2 lakh and 4 lakh IJs (infective juveniles)/m², *SI*NPV alone @ 1.5 x 10¹² PIB/ha and *SI*NPV (1.5 x 10¹² PIB/ha) + *Steinernema* 1 lakh IJs were evaluated in comparison with chlorpyriphos (0.05%) for their efficacy against late second instar larvae of *S. litura* in tobacco nursery.

Ten days after transplanting the EPN formulations at three doses were broadcast on the beds with sand and watered. After application of nematodes and before spraying of *SI*NPV and chlorpyriphos, laboratory reared late second instar larvae @ 30 per m² bed were released and beds were caged with nylon nets, to avoid predation. The data is presented in Table 58.

Table 58. Effect of entomopathogenic nematodes on survival of *Spodoptera litura* larvae and seedling damage

| Treatment | Mean number of seedlings damaged (days) | | Mean number of larvae survived | |
|-------------------------------------|---|--------|-----------------------------------|--|
| | 2 | 9 | | |
| S. carpocapsae@ 1x 10 5 IJs | 28.66 | 37.33 | 21.33 | |
| S. carpocapsae@ 2x 10 5 IJs | 18.00 | 31.66 | 15.99 | |
| S. carpocapsae@ 4x 10 5 IJs | 12.33 | 22.00 | 12.98 | |
| SlNPV + Sc 1 lakh @ 1.5x 1012PIB/ha | 9.66 | 15.33 | 9.29 | |
| SINPV 1.5x10 ¹² PIB/ha | 10.33 | 16,00 | 10.63 | |
| Chlorpyriphos (0.05%) | 1.33 | 3.66 | 0.00 | |
| Control | 96.33 | 121.66 | 27.99 | |
| CD (P=0.05) | 2.28 | 1.14 | 0.10 | |

All the treatments were significantly superior to control in protecting tobacco seedlings from S. litura. Chlorpyriphos was significantly superior to all other treatments with 1.33 and

3.66 seedlings damaged at 2 and 9 days after application, respectively. The best treatment was $SINPV + Sc\ 1$ lakh (9.66 & 15.33), followed by $SINPV\ (10.33\ \&\ 16.00)$ and $Sc\ 4$ lakh (12.33 & 22.00) which were on par with each other.

Larval population/ m^2 was also significantly less than control in all treatments. Cent percent larval mortality was recorded in chlorpyriphos treated plot. Among the other treatments, SINPV + Sc~1 lakh (9.29/ m^2) supported minimum number of larvae followed by SINPV (10.63) and Sc~4 lakh (12.9).

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

Nursery

FCV germplasm accessions under Bell series (9 nos.) and Coker series (17 nos.) raised in the nursery at Katheru farm under non-chemical plant protection measures were screened for incidence of *S. litura*, *H. armigera* and their natural enemies.

Under Bell series highest per cent parasitisation of *S. litura* larvae was noticed on Bell No.9 (33%), followed by Bell No.110 and 61-9 (27%) and ranged from 15 to 25 on others. Under Coker series, accession No.258 (38%) and No. 48 (33%) recorded maximum parasitism, on others the parasitisation ranged from 4 to 30%.

Field crop

Population of aphid predators was the maximum (51/plant) on Bell No.61-10, followed by Bell No. 3 (35), and ranged from 12 to 28/plant on others. Highest total parasitisation of *H. armigera* was observed on Bell No.10 (12%). On others it ranged from 3 to 5 per cent. In Coker series, accession No.511 (mm) (36) and accession No. 140 (36) supported maximum predator population. *H. armigera* parasitisation was 0 to 20% on various accessions, the maximum being on no.511 (mm) (20%).

The important S. litura parasitoids recorded were Peribaea orbata, Chelonus and Euplectrus. On H. armigera, important parasitoids were Carcelia and Goniophthalmus. Aphid predators were Cheilomenes sexmaculata and Coccinella transversalis.

4.21. Biological suppression of pulse crop pests

4.21.1. Bio-Intensive pest management in pigeonpea with special reference to pod borer complex

4.21.1.1 GAU, Anand

Large scale demonstrations of Bt - HaNPV- Bt -HaNPV in one-hectare plot using the

var. BDN 2 gave higher yield as well as decreased *H. armigera* larval population, per cent pod borer damage and grain damage as compared to control (Table 59).

Table 59. Efficacy of Bt-HaNPV-Bt-HaNPV against pigeonpea pod borer complex

| Character | IPM | Control | STD | Error | 't' |
|-------------------|------|---------|--------|-------|-------|
| Larval population | 3.13 | 7.25 | 2.36 | 0.59 | -6.98 |
| % Pod damage | 6.53 | 9.00 | 0.05 | -0.25 | -9.92 |
| % Grain damage | 3.36 | 5.76 | 0.04 | 0.41 | -5.11 |
| Yield (kg/ha) | 1380 | 799 | 150.58 | 75.29 | 772 |

4.21.1.2 TNAU, Coimbatore

This trial was conducted at Poluvampatti village, Coimbatore district, on Co-5 redgram, under irrigated condition

Treatments

T, - HaNPV - NSKE - HaNPV - NSKE

T, - Bt - NSKE - Bt - NSKE

T, - NSKE (4 rounds)

T₄ - Endosulfan

T - Control

Plot size: 50m²; Replications: 4

The peak pod borer damage was the lowest in HaNPV - NSKE alternation (9.28) (Table 60), which was on a par with Bt - NSKE alternation. NSKE alone resulted in 17.01% damage (Table 60). In control plot 21.2% damage was noted. Maximum yield (1612 kg/ha) was obtained from HaNPV - NSKE alternation, followed by Bt - NSKE alternation (1533 kg/ha), which was significantly different from the other treatments. In comparison, the yield from untreated check plot was 842 kg/ha. The standard yield of this variety is 1500 kg/ha. Besides H armigera, pod fly and pod wasp were the other major pod borers. Pod fly numbers were the lowest (11.3) in HaNPV - NSKE alternation as against 19.5 in control (Table 61). In endosulfan plot 10% larvae were found. Similar trend was seen on 135 DAS. At harvest time plume moth damage alone was seen in all the plots.

Table 60. Effect of IPM treatments on Helicoverpa armigera larval population and total pod borer damage and yield of pigeonpea (CO5)

| Treatments | Pre- | Pre-treatment No./10 plants | Н | armigera No./1 | H. armigera larval population No./10 plants | ation | Peak pod borer damage % | % pod borer damage at harvest/ 10 | Grain yield (kg/ha) |
|---------------------------|------|--------------------------------|------|-------------------|--|-------|-------------------------------|---|------------------------|
| | Eggs | Larvae | 85 | 100 | 115 | 130 | | | |
| Hanpv-nske- Hanpv-nske | 26 | 13.2 | 7.1* | 11.2 | 17.86ab | 3.Iª | 9.28 ^b | 4.31" | 1612° |
| Bt-NSKE-Bt-NSKE | 24 | 14.3 | 9.2" | 13.1 | 14.28 | 2.1ª | 8.61⁴ | 5.31* | 1533 ^b |
| NSKE | 19 | 16.1 | 11.6 | 19.1b | 19.21 ^b | 13.26 | 17.01° | 8.32 ^b | 1124 |
| Endosulfan | 27 | 19.2 | 8.9 | 9.3 | 21.22b | 1.20 | 7.82 | 11.315 | 1264 |
| Untreated check | 24 | 18.4 | 23.2 | 29.6 | 33.12° | 36.21 | 21.22 ^d | 16.41 | 842° |
| CD (P=0.05) | SN | NS | | | | | | | |

Damage caused by all pod borer species in 10 plants; Data are means of 4 values; Means followed by similar letters in a column are not statistically different by DMRT, P=0.05

Table 61. Occurrence of various pod borers in pigecopea BIPM plots

| Treatments | 7 DAT (85 DAS) | 85 DAS) | | | Nos./10 plants at maturation (135 DAS) | (135 DAS) | matura (S) | rtion | | Harve | Harvest time | 0 |
|-----------------------|------------------|---------|------|------|---|------------------|---------------|-------------------------------|-------|------------------|--------------|------|
| | No. / 10 plants* | plants* | | | No | No. / 10 plants* | ants* | | _ | No. / 10 plants* |) plant | 000 |
| | Ha | Pf | Pw | Pm | Ha | Pf | Pw | Pm | На | Pf | Pw | Pm |
| HaNPV-NSKE-HaNPV-NSKE | 8.94 | 11.3 | 1.2 | 2.04 | 3.106 | 0.66≥ | 0.03* | 3.106 0.668 0.034 0.31* | 3.1* | | 157 | 2.82 |
| Bt-NSKE-Bt-NSKE | 9.2 ^b | 11.0 | 11.6 | 2.5 | 2.10 | 2.10 0.44 1.53 | 1.53 | 0.61* | 2.3ª | | T. | 3.16 |
| NSKE | 11.6 | 18.79 | 0.5 | 2.46 | 13.20 | 2.20₺ | 0.10 | 2.20 0.10 0.42 | 47.4 | k | G. | 2.2 |
| Endosulfan | 7.12 | 10.1 | 0.74 | .9.0 | 1.20 | 1.30 | 0.02 | 1.20 | 3.8 | ¥, | | 2.9 |
| Control | 23.2 | 19.5 | 25.3 | 13.4 | | 11.4 | 3.10 | 36.214 11.4° 3.10 2.12° 10.2° | 10.2° | | 1 | 11.3 |

Ha - Helicoverpa armigera; Pf - Melanagromyza spp.; Pw - Pod wasp; Pm - Plume moth; *Data are means of four values, each value is total number / 10 plants; Means followed by similar letters in a column are not statistically different

4.21.1.3. ANGRAU, Hyderabad

The following sequences of bio-control based components were tested with 5 replications in pigeonpea variety "Asha", for management of pod borer complex.

T1: HaNPV-NSKE-HaNPV-NSKE

T2: Bt-NSKE-Bt-NSKE

T3: NSKE 4 sprays

T4: Endosulfan 3 sprays

T5: Untreated Control

Among these, alternate sprays of HaNPV and NSKE (HaNPV-NSKE-HaNPV-NSKE) resulted in better suppression of pod borers (Table 62). Least cumulative H. armigera larval population (9.50) and per cent pod damage (19.25) was recorded in HaNPV-NSKE treatment as compared to control (32.50 and 41.5, respectively). Damage by pod wasp (7.50) and pod fly (4.75 per cent) was also lower in the same treatment. Higher yield (715 kg/ha) was recorded in HaNPV-NSKE alternate sprays than control (375 kg/ha). Overall HaNPV-NSKE-HaNPV-NSKE treatment fared well in suppressing the pod borer complex and was almost on par with insecticidal check.

Table 62. Effect of BIPM treatments on the incidence of pod borer complex and yield

| Treatment | H. armig | era population | Per c | ent pod dama; | ge by | Yield |
|---------------------------|-------------------|-----------------|------------------|------------------|-----------------|---------|
| | Pre- treatment | Cumulative | На | Pw | Pf | (kg/ha) |
| HaNPV-NSKE- HaNPV-NSKE | 23.50 (4.89) | 9.50 (3.16) | 19.25 (26.01) | 7.50 (15.77) | 4.75 (12.54) | 715.0 |
| Bt-NSKE- Bt-NSKE | 23.00 (5.14) | 16.25 (4.09) | 23.00 (28.64) | 10.25 (18.62) | 6.50 (14.76) | 675.0 |
| NSKE (4 sprays) | 26.00 (5.14) | 22.75 (4.81) | 27.00 (31.28) | 11.50 (19.80) | 7.50 (15.85) | 602.0 |
| Endosulfan | 27.75 | 10.25 | 15.50 | 4.75 | 4.50 | 772.5 |
| (3 sprays) | (5.30) | (3.27) | (23.17) | (12.54) | (12.23) | |
| Control | 25.25 | 32.50 | 41.50 | 19.00 | 16.25 | 375 |
| | (5.06) | (5.74) | (40.10) | (25.82) | (23.77) | |
| CD (P=0.05) | NS | 0,36 | 2.28 | 2.80 | 1.65 | 71.7 |

Pooled data recorded 7 days after each spray; Ha: H. armigera; Pw: Pod wasp and Pf: Pod fly

4.21.2. NPV based management of H. armigera (TNAU, Coimbatore)

This trial was conducted at Poluvampatti village, Coimbatore district on Co-5 redgram variety.

The treatments are

- HaNPV + 10% crude sugar + 10% NSKE + 0.1% egg yolk + 0.1% Ranipal

- HaNPV + 0.5% Teepol

HaNPV - NSKE alternation T,

HaNPV - endosulfan alternation

Endosulfan

Control

Dosages

: 1.5 x 1012 POB/ha HaNPV

: 350 g/ha Endosulfan

: 5%

NSKE

: Trichoderma @ 4.0 g/kg seed Seed treatment Spray equipment : Controlled droplet application

: 12.5 1/ha Spray fluid : 100 m² Plot size Design RBD

: 4 Replication

A cloth screen was used all around the plots to prevent spray drift. The treatments were applied in the evening hours. The first spray was taken up on 60 DAS, then subsequent sprays were given at 15 days intervals. Helicoverpa larval population was above ETL on 56 DAS. The larval populations were counted on 7 DAT. Helicoverpa larval population 7 days post-treatment was significantly less in Treatment No.1 (11.32) (Table 63). The larval population was 27.81 in endosulfan treated plots, which was significantly less than untreated check.

Pod borer damage was the lowest in HaNPV - endosulfan alternation following all three sprays. The mean pod damage was lowest in HaNPV - endosulfan treatment (3.24). The highest grain yield (1638 kg/ha) was obtained from HaNPV - Endosulfan alternation followed by HaNPV - NSKE alternation (1532 kg/ha). Treatments one and two yielded 1366 and 1312 kg/ha, respectively which were on a par (Table 64) as compared to only 792 kg/ha from untreated check.

Table 63. Effect of treatments on H. armigera larval populations on pigeonpea

| T | Mea | n No. of larvae / 10 | plants |
|---|--------------------|----------------------|-----------|
| Treatments | 67 DAS | 82 DAS | 97 DAS |
| | I spray | II spray | III spray |
| HaNPV + 10% crude sugar + 10% NSKE + 0.1% egg yolk | 11.32 ^s | 11.61 ^b | 13.12 |
| HaNPV + 0.5% teepol | 18.02bc | 15.21 | 9.32s |
| | 18.32¢ | 18.31ab | 16.01° |
| HaNPV – NSKE alternation | 14.82 ^b | 15.31° | 16.01° |
| HaNPV - endosulfan alternation | 27.81 ^d | 21.21b | 20.224 |
| Endosulfan | 27.81 | | 37.02° |
| Control | 32.13° | 26.01° | 37.02 |

Data are means of 4 values; Means followed by similar letters in a column are not statistically different, P=0.05

Table 64. Effect of NPV based management on pod borer damage and pigeonpea yield

| Treatments | Per cent pod borer | | pod borer da 7 DAT | mage | Pod damage (%) | Yield (kg/ha) |
|--|-----------------------------|--------------------|-----------------------|--------------|----------------------|-------------------|
| | damage pre- treatment | I Spray | II Spray | III Spray | (70) | |
| HaNPV + 10% crude sugar + 10% NSKE + 0.1% egg yolk | 55.21 | 26.32° | 16.12° | 13.12ь | 12.61° | 1366° |
| HaNPV + 0.5% teepol | 66.21 | 28.32 ^d | 10.21 ⁿ | 9.316 | 11.31° | |
| HaNPV - NSKE alternation | 68.21 | 21.116 | 11.31* | 11.216 | 7.668 | 1532b |
| HaNPV – endosulfan alternation | 61.31 | 16.21ª | 14.31 ^{ab} | 3.24 | 5.02ª | 1638" |
| 112277 200000 0000000 | 58,31 | 23.21 ^b | 13.21 | 37.21° | 16.09 ^{cd} | 1100 ^a |
| Endosulfan Untreated check | 63.21 | 58.32° | 66.31 ^d | 38.11° | 28.62° | 792° |

Data are means of 4 values; Means followed by similar letters in a column are not statistically different (P=0.05)

4.21.3. Effect of entomopathogenic nematode Heterorhabditis sp. against Mylabris pustulata and Helicoverpa armigera in pigeonpea (GAU, Anand)

To evaluate the efficacy of entomopathogenic nematode *Heterorhabditis* sp. against *Mylabris pustulata* and *Helicoverpa armigera* in pigeonpea an experiment was laid out at Dhavat village (Baroda district). The treatments used were *Heterorhabditis* sp. @ 0.5 billion/h, 1.0 billion/h and 2.0 billion/h with an untreated control.

Heterorhabditis @ 2.0 billion/h was the best giving 59.44 % larval mortality after 10 days of treatment and also recorded highest yield as compared to control and other treatments (Table 65). Population of Mylabris pustulata was not observed.

Table 65: Evaluation of entomopathogenic nematode in pigeonpea

| Treatment | Prerelease counts/3 branches/ | | rval mortalit ra after (day | | Mean | Yield (kg./ha) |
|--|-------------------------------------|-------------------|--------------------------------|------------------|------------------|-------------------|
| | 10 plants | 3 | 7 | 10 | | (Kg./III) |
| Heterorhabditis sp. @ 0.5 billion / ha | 76 | 28.57 (22.87)* | 36.13 (34.77) | 39.52 (40.49) | 34.74 (32.47) | 735 |
| Heterorhabditis sp. @ 1.0 billion/ ha | 69 | 29.74 (24.61) | 41.90 (44.60) | 44.40 (48.95) | 38.68 (39.06) | 800 |
| Heterorhabditis sp. @ 2.0 billion/ ha | 74 | 37.19 (36.54) | 48.86 (56.72) | 50.44 (59.44) | 45.50 (50.87) | 871 |
| Untreated Control | 62 | 11.29 | 14.26 (3.83) | 13.39 (6.07) | 12.98 (5.36) | 524 (5.05) |
| CD (P=0.05) | | | | | 1.38 | 43.88 |

^{*} Figures in parentheses are re-transformed values, outside are arcsine per cent transformation

4.21.4. Incidence of *Maruca vitrata*, other pests and their natural enemies in pigeonpea in relation to crop phenology (ANGRAU, Hyderabad)

With a view to have information on appearance of the pest in pigeonpea crop in this area and to record natural enemy fauna, a trial was laid out at Agricultural Research Station, Warangal. Maximum pest population was observed during flower bud stage of the crop. Several parasitoids, viz. Cotesia sp., Bracon sp., Chelonus sp., Brachymeria sp. and Tetrastichus sp. were recorded. A good number of predators such as mantids, coccinellids, ants and spiders were found to be regulating the pest population at various stages.

Table 66. Effect of Biocontrol methods and insecticide application on leaf folder and stem borer damage

| Treatments | % dan | % damage by leaf folder | af folder | | % da | % damage by stem borer | stem bo | rer | | Yield |
|--|-----------|---|--------------------|--|--------------------|------------------------|-------------------|--------------------|-------------------|---------|
| | | | | % | % Dead hearts | arts | | % White ears | ears | (kg/ha) |
| | 30 DAS | 37 DAS | 44 DAS | 30 DAS | 37 DAS | 44 DAS | 80 DAS | 87 DAS | 94 DAS | |
| T. japonicum 50,000/ha+ T. chilonis 50,000/ha | 28.12 | 16.12b 16.28b 14.31b 21.82a | 16.28 ^b | 14.31 | 21.82ª | •16.9 | 5.02* | 6.12 | 3.116 | 3904 |
| T. japonicum 1,00,000/ha+ 28.2 T. chilonis 1,00,000/ha | 28.2 | 18.26 ^b | 16.12 ⁶ | 9.21ª | 23.12 | 9.21ª 23.12ª 16.02b | 4.01ª | 6.21° | 4,12 ⁶ | 3980₽ |
| B.t. (Delfin) 1 kg/ha | 29.16 | 21.02° 18.12° 19.12° 19.06° 11.21° | 18.12 ^b | 19.12° | 19.06 | 11.21 | 5.12ª | 7.2" | 8.12° | 36285 |
| Monocrotophos I lit/ha -2rounds phosphamidon 300 ml/ha | 28.28 | 11.66 | 4.32ª | 23.21 ^b 25.21 ^b 12.01° | 25.21 ⁶ | 12.01° | 9.02 ^b | 6.12ª | 0.62 | 3710 |
| Untreated check | 30.02 | 30.02 36.12° 42.22 23.02° 32.12° 36.02° 30.12° 28.12° | 42.22 | 23.02 | 32.12° | 36.02€ | 30.12° | 28.12 ^b | 9.12€ | 3148° |

Data are means of five values; Means followed by similar letters in a column are not significantly different DMRT, P=0.05

Per cent parasitism of stem borer eggs by *Trichogramma* @ 100000/ha on 80 DAS (8.3) was at a par with *Trichogramma* @ 50000/ha (8.2%). The lowest parasitism was observed in insecticide plots (0.61%), which was lower than the untreated check (Table 67).

Table 67. Per cent parasitism of stem borer eggs by Trichogramma sp.

| Treatments | | % parasitism | |
|--|-------------------|-------------------|-------------------|
| | 30 DAS | 44 DAS | 80 DAS |
| T. japonicum 50,000/ha + T. chilonis 50,000/ha | 11.1 ^b | 13.2° | 8.2° |
| T. japonicum 1,00,000/ha+T. chilonis 1,00,000/ha | 13.2 ^b | 22.6 ^d | 8.3° |
| Bt (Delfin) 1 kg/ha | 2.8 ^u | 11.I¢ | 3.4 ^b |
| Monocrotophos 1 lit/ha – 2 rounds phosphamidon 300 ml/ha | 18.3° | 1.01* | 0.613 |
| Untreated check | 4.1" | 3.12 ^b | 2.21 ^h |

Values are means of five values; Means followed by same letter are not significantly different by DMRT, P=0.05

4.22.1.2. MPKV, Pune

Field evaluation of integrated use of *Trichogramma japonicum*, *T. chilonis* and *Bacillus thuringiensis* against rice stem borer and leaf folder was done on the Research Farm of Agricultural Research Station, Karjat on transplanted rice variety 'Karjat –2' with the following treatments.

- T1. T. japonicum @ 50,000 adults/ha/release and T. chilonis @ 50,000 adults / ha / release 3 simultaneous releases at weekly interval
- T2. *T. japonicum* @ 1,00,000 adults/ha/release + *T. chilonis* @ 1,00,000 adults / ha / release 3 simultaneous releases at weekly interval
- T3. Bt application (Delfin WG @ 1 kg/ha) 2 times at 15 days interval
- T4. Chemical control: Two sprays of monocrotophos @ 1 lit/ha at 15 days interval and one spray of phosphamidon @ 300 ml/ha
- T5. Untreated control

Three releases of T. japonicum + T. chilonis @ 1,00,000 adults of each/ha/release was found to be most effective treatment in reducing infestation of leaf folder as well as stem borer in paddy and recorded maximum yield and parasitism (Table 68).

Table 68. Efficacy of *Trichogramma japonicum*, *T. chilonis* and *B.t.* against paddy stem borer and leaf folder

| Treatments | Leaf folder infestation (%) | Stem borer infestation | Yield (q/ha) (%) | Per cent parasitism / disease development |
|--|-----------------------------------|---------------------------|------------------------|--|
| T. japonicum + T. chilonis @ 50,000 adults/ha/release (T1) | 7.10 (15,45) | 8.74 (17.16) | 19.80 | 28.00 |
| T. japonicum + T. chilonis @ 1,00,000 adults/ha/release (T2) | 5.78 (13,90) | 6.90 (15.22) | 290 | 37.40 |
| Bt (Delfin WG(@ 1 kg/ha (T3) | 6.00 (14.17) | 7.68 (16.08) | 22.8 | 19.62 |
| Chemical control: Two sprays of monocrotophos @ 1 lit/ha and one spray of phosphamidon @ 300 ml/ha (T4) | 5.20 (13.17) | 6.00 (14.15) | 26.4 | 00.00 |
| Untreated control T5) | 16.80 (24.19) | 12.10 (20.33) | 10.0 | 00,00 |
| C.D. (P=0.05) | (0.48) | (1.23) | 2.16 | |

Figures in parentheses are angular transformations

4.22.1.3, AAU, Jorhat

Evaluation of *Trichogramma japonicum* and *T. chilonis* against rice stem borer and leaf folder was conducted as per the technical programme in farmer's field at Borholla (Assam) during rabi, 2001. The dead heart per cent was lower (2,39%) in the 3^{rd} week after the field release of *T. japonicum* + *T. chilonis* as against in the unreleased plot (9.01%). In general there were no difference between the release rates in checking the formation of dead heart during different weeks of observation. The white ear head population was also low (4.19%) in *T. japonicum* released plot against 7.97% in the unreleased plot. The per cent dead heart and white ear head were significantly lower in all treatments than control. Insecticide spray and Bt formulation (Delfin) were on par with both doses of parasitoids (Table 69). The per cent infestation of leaf folder was lowest in the released plot (1.91%) five weeks after release against 6.11% in the unreleased plot. The same experiment was also carried out during *kharif*, 2001 in the farmer's filed at Rongamati, Dergaon (Assam). The results are presented in Table 70.

Table 69. Field evaluation of integrated use of *Trichogramma japonicum*. *Trichogramma chillonis* and *Bacillus* thuringiensis against leaf folder and rice stem borer (Rabi, 2001) Location: Borholla

| Treatment | Pre- release | Perca fo | ont leav Ider at v | es dama | Percent leaves damaged by leaf folder at weekly intervals | leaf s | Pre- release | Per | Percent dead heart at weekly intervals | ead heart intervals | t at wee | kly | WEH % | WEH Yield (kg/ |
|--|-----------------|-------------|-----------------------|---------|--|-----------|----------------------|------|--|------------------------|----------|------|----------|------------------------|
| | count | _ | ПП | П | N | > | count | - | П | Ш | IN | > | | |
| T.japonicum + T. chilonis @ 50,000/ha | 2.85 | 3.13 | 3.13 3.10 | | 3.301 | 161 | 3.37 3.301 1.91 7.69 | 6.13 | 4.09 | 2.39 | 2.39 | 3.23 | 4.44 | 2.39 3.23 4.44 4095.00 |
| T. japonicum + T. chilonis @ 100,000/ha | 2.70 | 2.58 | 3.39 | -3.84 | 2.57 | 1.47 | 8.05 | 6.36 | 4.92 | 3.93 | 3.07 | | 4.19 | 3.87 4.19 4090.20 |
| Bt | 3.07 | 3.84 | 3.36 | 4.53 | 2.17 | 1.36 | 8.53 | 5.43 | 3.79 | 4.56 | 3.34 | | 3.95 | 3.89 3.95 4009.80 |
| Insecticide | 2.79 | 3.68 | 3.61 | 4.23 | 3,04 | 2.32 | 7.11 | 6.50 | 3.52 | 4.04 | 3,13 | | 4.44 | 3.54 4.44 4021.40 |
| Untreated Check | 3.28 | | 3.58 5.13 | 81.9 | 60.9 | 6.11 | 6.09 6.11 6.93 7.48 | 7.48 | 4.96 | 9.01 | 96.6 | 7.70 | 7.97 | 7.70 7.97 3343.00 |
| CD (P=0.05) | SN | SN | 0.79 | 1.06 | 1.06 0.58 | 69.0 | NS | SN | SN | 0.92 | | 1.19 | 1.05 | 0.98 1.19 1.05 165.07 |

Table 70. Field evaluation of integrated use of Trichogramma japonicum, Trichogramma chillonis and Bacillus thuringiensis against leaf folder and rice stem borer (Kharif, 2001) Location: Rangamati

| E | | | Percent leaves damaged by leaf | es dam | aged by | leaf | Pre- | | cent de | Percent dead heart at weekly | at wee | kly | WEH | WEH Yield (kg/ |
|--|---------|------|--------------------------------|--------|-----------|------|-------------------------------|------|---------|------------------------------|--------|-------|-------|---|
| Heatment | release | IC | folder at weekly intervals | weekly | interva | S | release | | - | ntervals | 10 | | 9% | ha) |
| | count | - | П | Ш | 2 | > | count | Ι | = | Ξ | \sim | Λ | | |
| T. japonicum + T. chilonis @ 50,000/ha | 2.14 | 2.78 | 2.78 2.83 | 1.95 | 1.95 2.07 | 2.23 | 4.09 | 4.71 | 5.53 | 4.46 | 4.85 | 5.58 | 3.93 | 4.09 4.71 5.53 4.46 4.85 5.58 3.93 3179.40 |
| T. japonicum + T. chilonis @ 100,000/ha | 2.01 | 3.15 | 2.94 | 1.78 | 2,00 | 2.11 | 4.60 | 4.72 | 7.49 | 5.99 | 4.47 | 4.88 | 3.96 | 3.15 2.94 1.78 2.00 2.11 4.60 4.72 7.49 5.99 4.47 4.88 3.96 3247.20 |
| BI | 1.95 | 2.63 | 3.04 | 2.57 | 2.29 | 2.79 | 3.04 2.57 2.29 2.79 4.44 4.32 | 4.32 | 6.94 | 6.26 | 4.76 | 4.39 | 3.70 | 6.94 6.26 4.76 4.39 3.70 3115.20 |
| Insecticide | 2.33 | 2.55 | 2.55 2.75 2.61 | 2.61 | 2.59 | 2.49 | 2,49 5,71 5,74 | 5.74 | 8.81 | 6.40 | 5.14 | 4.29 | 3.62 | 6,40 5.14 4.29 3.62 3056.20 |
| Untreated Check | 2.20 | 2.67 | 2.67 3.67 | 10.9 | 5.76 | 6.72 | 6.01 5.76 6.72 5.78 5.18 | 5.18 | 6.93 | 10.83 | 10.35 | 11.55 | 12.42 | 6.93 10.83 10.35 11.55 12.42 2503,20 |
| CD (P=0.05) | NS | SN | 0.62 | 0.54 | 0.69 | 0.97 | NS 0.62 0.54 0.69 0.97 NS | SN | 1.43 | 1.48 | 1.05 | 1.59 | Ξ | NS 1.43 1.48 1.05 1.59 1.11 288.24 |

4.22.1.4. KAU, Thrissur

The experiment was laid out in two seasons during the year at the Regional Agricultural Research Station, Pattambi as per the approved technical programme.

Kharif season

There was no significant difference between treatments in leaf folder incidence in before and after parasitoid release on 60 DAT. The count of dead hearts differed significantly before the release of *Trichogramma* spp. But after II release and at the time of harvest all the treatments were on par for stem borer incidence. Total grain weight was significantly high in the *Trichogramma* released and *B. t.* treatments as compared to untreated control (Table 71).

Rabi season

There was no significant difference in the leaf folder incidence in different treatments. At the time of harvest white earheads were least in *Trichogramma* released plot (1 lakh/ha). Maximum yield was also recorded in this plot (4512 kg./ha.) and it was on par with chemical control and *B.t.* Yield in control was on par with *B.t.*, chemical control, and *Trichogramma* spp. (50,000/ha.) released plots (Table 72).

4.22.2. Evaluation of biocontrol based IPM in rice

4.22.2.1. TNAU, Coimbatore

This trial was conduced at Kallapuram in Udumalpet taluk on var. ADT-36 with the following treatments.

- T Biocontrol Six releases of *Trichogramma japonicum* @ 50,000/ha from appearance of 2-5 moths of stem borer /leaf folder at weekly intervals.
- T_s Endosulfan (0.07%) 6 sprays.
- T₃ Control (untreated check)

Plot size: 0.2 ha / treatment

Replications: 10

Per cent dead hearts was the lowest and the yield highest in *Trichogramma* release plots as against endosulfan treated plot at all crop stages. Similar results were noted with respect to per cent white ears (Table 73).

Table 71. Observations on leaf folder and stem borer incidence (percentage) during kharif

| Treatment | Pre-count | 25 DAT | 45 DAT | 60 DAT | Pre-count 25 DAT 45 DAT 60 DAT Pre-count 25 DAT (DH) (DH) | 25 DAT (DH) | 45 DAT (DH) | White | Yield (kg./ha) |
|---------------------------|-----------|--------|--------|--------|---|----------------|----------------|-------|-------------------|
| Control | 2.24 | 5.05 | 17.80 | 14.50 | 2.28 | 11.38 | 9.15 | 11.40 | 2363.75 |
| Bt | 4.59 | 2.67 | 15.56 | 7.57 | 5.41 | 7.32 | 7.86 | 5.69 | 2948.12 |
| Chemical Control | 3.36 | 4.09 | 17.92 | 13.19 | 3.47 | 10.90 | . 8.46 | 61.6 | 2765.00 |
| Trichogramma spp1 lakh/ha | 1.03 | 5.38 | 31.75 | 18.09 | 1.00 | 7.28 | 10.37 | 8.10 | 3199.75 |
| Trichogramma spp50,000/ha | 4.95 | 0.99 | 23.57 | 22.29 | 00.00 | 4,47 | 11.47 | 8.15 | 3218.75 |
| CD (P=0.05) | NS | 2.30 | 10.27 | SZ | 3.23 | 3.81 | NS | NS | 504.4 |

Table 72. Observations on leaf folder and stem borer incidence (percentage)

| Treatment | Pre-count | 25 DAT | 45 DAT | Pre-count (DH) | 25 DAT (DH) | 45 DAT (DH) | White earhead | Yield (kg./ ha) |
|---------------------------|-----------|--------|--------|-------------------|----------------|----------------|---------------|--------------------|
| Control | 0 | 0.91 | 3.58 | 1.14 | 10.35 | 8.50 | 11.62 | |
| Bt | 0 | 0.17 | 5.62 | 0.00 | 2.83 | 9.17 | 9.26 | 4137 |
| Chemical Control | 0 | 0.45 | 5.08 | 2.18 | 11.58 | 7.32 | 9.39 | 4037 |
| Trichogramma spp1 lakh/ha | 0 | 0.63 | 4.59 | 1.73 | 6.57 | 9.70 | 3.50 | 4512 |
| Trichogramma spp50,000/ha | 0 | 0.00 | 5.32 | 3.82 | 0.00 | 10.55 | 5.16 | 3500 |
| CD (P=0.05) | SN | SN | NS | NS | 5.8 | SN | 4.72 | 529.2 |

Table 73. Effect of biocontrol and insecticide application on stem borer damage and yield

| Treatments | | % dama | ige by sten | borer | | | Yield (kg/ha) |
|--|-----------|-------------------|-------------|------------------|-----------|-------------------|------------------|
| | . % | Dead hea | rts | W | hite ears | | (Kg/Ha) |
| | 30 DAS | 37 DAS | 44 DAS | 80 DAS | 87 DAS | 94 DAS | |
| 6 releases of <i>Tricho-gramma</i> @ 50,000/ ha/release | 28.4 | 11.6° | 11.8° | 3.24 | 8.24 | 11.84 | 4042" |
| Endosulfan (0.07%) | 26.2ª | 29.2 ^h | 24.2b | 4.6a | 16.2° | 14.8 ^h | 3906b |
| Untreated check | 26.1 | 29.2 ^b | 32.6° | 8.2 ^b | 26.4° | 34.2° | 3160° |

Data are means of five values; Means followed by similar letters in a column are not significantly different by DMRT, P=0.05

Leaf folder damage at 30 and 37 was higher in *Trichogramma* released plot than endosulfan sprayed plot, but was lower at 44 DAS. Per cent parasitism of stem borer eggs was highest in *Trichogramma* plot on 37, 44 and 80 DAS. It was insignificant in endosulfan treated plots and less than that in untreated check (Table 74).

Table 74. Damage by rice leaf folder and parasitism of rice stem borer eggs by *Trichogramma* spp. in biocontrol based IPM plot

| Treatment | | parasitism or by <i>Trichograi</i> | | Per co | ent damage i folder | by leaf |
|--|--------|---------------------------------------|--------|-------------------|------------------------|-------------------|
| | 37 DAS | 44 DAS | 80 DAS | 30 DAS | 37 DAS | 44 DAS |
| Six releases of Trichogramma @ 50,000 / ha / release | 29.62h | 33.42 ^b | 26.21 | 16.2 ^b | 26.8 ^b | 19.6" |
| Endosulfan (0.07%) | 0.21" | 1.024 | - | 11.6ª | 18.2ª | 21.4ª |
| Untreated check | 4.81 | 3.88ª | 6.92 | 48.2° | 52.4° | 58.2 ^b |

Values are means of five values; Means followed by same letter are not significantly different DMRT, P=0.05

4.22.2.2. PAU, Ludhiana

Large scale demonstration of IPM (seven releases of *T. chilonis* + *T. japonicum* each @1,00,000 /ha/ week, starting 30 DAT) was carried out at farmer's field at village Karni Khera (Dist. Ferozpur) and compared with chemical control.

The per cent dead hearts, and leaves folded were lower in chemical control and IPM plots than control. The yield in control was lower (50.03 q/ha) than that in chemical control (68.04 q/ha) and IPM (66.09 q/ha) (Table 75).

Table 75. Effectiveness of *T. chilonis* and *T. japonicum* for the control of leaf folder and stem borer of rice at village Karni Khera (Ferozpur) during 2001

| Treatment | Percent hearts | Percent white dead ears | Percent leaves folded | Yield (q/ha) |
|--|-------------------|-------------------------|--------------------------|-----------------|
| Release of <i>T. chilonis</i> + <i>T. japonicum</i> | | | | |
| @ 50,000 per ha (T1) | 23 (14.37) | 8.21 (16.56) | 12.73 (20.87) | 52.08 |
| Release of T. chilonis + T. japonicum | | | | |
| @ 1,00,000 per ha (T2) | 2.86 (9.69) | 3.94 (11.41) | 7.96 (16.32) | 65.98 |
| Chemical control (T3) | 2.47 (9.01) | 3.46 (10.70) | 8.86 (17.24) | 68.04 |
| Control (T4) | 9.41 (17.78) | 10.40 (18.79) | 19.60 (26.23) | 50.03 |
| CD (P=0.05) | (3.37) | (2.14) | (3.67) | 2.31 |

Note: 1. Plot size was 1.0 ha each for T₁, T₂; 2.0 ha for T₃ and 0.4 ha for control

- 2. Parasitoids released 7 times at weekly interval starting 30 DAT in T, and T,
- 3. Two sprays of monocrotophos (Nuvacron 36 SL, 1400 ml/ha) given in T₃

4.22.2.3. AAU, Jorhat

Biocontrol based IPM was evaluated in comparison with chemical control in a farmer's field at Borholla during *rabi*, 2001. Release of *Trichogramma* @ 50,000/ha checked the formation of dead hearts significantly (2.58% to 4.30%) whereas the percentage of dead heart in the unreleased plot ranged from 4.11% to 7.17%. The lowest population of dead heart was 2.58% in the 3rd week after release of *Trichogramma* against 7.51% in the unreleased plot. The white ear head population was also lower (2.94%) in the *Trichogramma* released plot than in the unreleased plot (8.45%). The lowest leaf folder infestation was recorded (2.19%) in the released plot in the 4th week after release of the parasitoid against 6.01% leaf folder

damaged leaves in the unreleased plot (Table 76). The performance of *Trichogramma* @ 50,000/ha was on par with the chemical control plot. The yield in *Trichogramma* released plot (4099.75 kg/ha) was on par with the chemical control plot (4113.88 kg/ha).

The results of a similar trial conducted at Rongamati, Dergaon, Assam during *kharif* 2001 revealed significantly better control of stem borer in the released plot (2.84%) than in the unreleased plot (7.59%) in third week after release of *Trichogramma*. The white earhead population and leaf folder population were lower in the released plot than in the unreleased plot (Table 77).

4.22.2.4. KAU, Thrissur

Biocontrol based IPM on rice was evaluated during December 2001 in a farmer's field at Avinissery panchayath. Results showed there is no significant difference among the treatments on the stem borer incidence or on grain yield.

4.22.3. Survey and quantification of natural enemy complex in rice

4.22.3.1. TNAU, Coimbatore

This survey was undertaken in three locations, viz. Malayandipattinam and Kallapuram (Udumalpet taluk) and Puthur village in Coimbatore district.

Among the predators, spiders constituted maximum numbers in Udumalpet area (28.2 and 31.4). In Coimbatore area spider population was less. Spiders, coccinellids, Odonata (Dragon flies) and *Cyrtorhinus* were the predominant predators in the 3 locations. Among the parasites, hymenopterans were seen in large numbers than dipterans. Per cent parasitism on rice YSB was 16.8-21.4 in these locations.

4.22.3.2. PAU, Ludhiana

Natural enemy complex in rice eco-system was surveyed in farmer's field at village Poehram (Distt. Nawanshahar) at weekly intervals during July-October 2001.

Three egg parasitoids, viz. Trichogramma chilonis, T. japonicum and Telenomus dignoides were recorded causing 57.6 per cent parasitism in Scirpophaga incertulas. One egg-larval parasitoid, Chelonus sp. was observed causing 2.7% parasitism in Cnaphalocrocis medinalis. Bracon sp. and Stenobracon sp. with 2.0 and 8.1 per cent parasitism, respectively, were recorded from S. incertulas larvae, Cotesia sp. (5.4 %) on C. medinalis. One pupal parasitoid, Brachymeria sp. (4.1 %) from S. incertulas and two pupal parasitoids, viz. Brachymeria sp. (6.3%) and Tetrastichus sp. (4.2%) from C. medinalis were recorded.

Table 76. Evaluation of Biocontrol based IPM in rice during rabi, 2001 Location: Borholla

| Treatment | Pre- release | Perce | Percent leaves damaged by leaf folder at weekly intervals | es dam: | aged by interval | leaf | Pre- release | | cent de, i | Percent dead heart at weekly intervals | t at week | kly | WEH % | WEH Yield (kg/ |
|------------------|-----------------|-------|--|---------|---------------------|-----------|-----------------|------|---------------|--|-----------|------|----------|----------------------------|
| | count | I | П | Ш | IV | > | count | - | п | Ш | ΛI | > | | |
| Biocontrol | 3.26 | 3.80 | 2.86 | 2.35 | 2.9 | 2.71 | 2.71 5.36 3.57 | 3.57 | 4.30 | 2.58 | 2.59 | 2.81 | 2.94 | 2.94 4099.75 |
| Chemical control | 2.80 | 3.81 | 2,93 | 2,49 | 2.28 | 2.28 2.23 | 6.26 | 3.99 | 3.95 | 2.96 | 2.77 | 3.15 | 3.13 | 3.15 3.13 4113.88 |
| Control | 3.09 | 3.4 | 4.87 | 5.59 | 6.01 | 4.94 | 3.92 | 4.11 | 5.79 | 5.79 7.51 7.10 7.17 8.45 | 7.10 | 7.17 | 8.45 | 3383.00 |
| CD (P=0.05) | NS | SN | 0.63 | 0.56 | 0.56 0.53 0.48 | 0.48 | SN | SN | 98.0 | | 0.78 | 0.83 | 0.74 | 0.83 0.78 0.83 0.74 254.54 |

Table 77. Evaluation of Biocontrol based IPM in rice during kharif, 2001 Location: Rangamati

| Treatment | Pre- | Perc | Percent leaves damaged by leaf | es dam | aged by | leaf | Pre- | Percen | t dead h | ad heart at v | veekly | Percent dead heart at weekly WEH % | Yield (kg/ |
|------------------|---------|------|--------------------------------|--------|-----------|---------|-----------|--------|----------|---------------|-----------|------------------------------------|------------|
| ALCAUTION | 1010030 | TY | MULTINE CIT | WOODLY | THEOR ACT | 10 | LC1Casc | | HILL | Vello | | | na) |
| | count | 1 | П | Ш | IV | > | count | - | П | Ш | Ν | | |
| Biocontrol | 2.46 | 2.25 | 2.45 | | 2.19 1.78 | 1.86 4. | 4.44 3.87 | 3.87 | 4.70 | 2.84 | 3.53 | 3,46 | 3117.38 |
| Chemical control | 2.26 | 2.23 | 2.54 | 2.14 | 2.14 1.51 | 1.70 | | 4.32 | 4.84 | 3.24 | 3.18 | 3.70 | 3051.00 |
| Control | 2.23 | 2.91 | 3.48 | 3.47 | 5.75 | 5.45 | 3.99 | 4.73 | 4.25 | 7.59 | 7.25 | 8.63 | 2639.13 |
| CD (P=0.05) | NS | 0.47 | 0.47 0.68 0.64 0.61 0.55 | 0.64 | 0.61 | 0.55 | SN | NS | SN | | 0.75 0.58 | 0.82 | 308.59 |

Eighteen species of spiders belonging to seven families were recorded from rice ecosystem. The spiders were available from July to October and the maximum population was during second fortnight of July and first fortnight of September *Tetragnatha javana* was the most predominant followed by *Araneus inustus* and *Oxyopes javanus*.

It can be concluded that very high egg parasitism (57.6%) in case of *Scirpophaga incertulas* was recorded and *Telenomus dignoides* was the most important parasitoid. Larval and pupal parasitism both in *S. incertulas* and *C. medinalis* was low. Eighteen species of spiders belonging to seven families were recorded from the rice eco-system. *T. javana* was next predominant followed by *A. inustus* and *O. javanus*.

4.22.3.3. AAU, Jorhat

The natural enemies of rice pests were surveyed at farmers' fields in villages of Rongamati, Borholla and ICR Farm at weekly intervals during September-November 2001. The predators recorded included coleopterans, spiders, dragonflies, damselflies, crickets, grasshoppers and praying mantids and the parasitoids comprised *Cardiochiles philippinensis*, *Aulosaphes* sp., *Bracon* spp., *Telenomus* sp., *Cotesia* sp. and *Trichogramma* sp. at Rongamati, Dergaon, Assam.

The extent of parasitism of leaf folder larval parasitoid *Cardiochiles philippensis* during *kharif* season varied from 7 to 10% and that of *Autosaples* spp. varied from 12 to 15%. During *kharif* 2001, *Cotesia flavipes* was also predominant in the Rongamati experimental plots. *Trichogramma* was recorded in the 1st week of September and the extent of parasitism was 25%. The spiders were available throughout the cropping season. *Lycosa pseudoannulata* was most common followed by *Tetragnatha* and *Oxyopes javanus*.

4.22.3.4. KAU, Thrissur

Egg parasitism due to *Trichogramma* spp., *Telenomus* sp. and *Tetrastichus* sp. in areas surveyed during October 2001- January 2002 ranged from 21 to 77 per cent. Gall fly parasitism was highest (50 %) during January.

4.23. Biological suppression of oilseed crop pests

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

Two bioagents, viz., Ischiodon scutellaris @ 15,000 first instar larvae per ha and Verticillium lecanii @ 108 conidia/ml (released/sprayed twice at 20 days interval) were evaluated for the control of mustard aphid. PAU recommendation (two sprays of Metasystox 20 EC @ 750 ml/ha) and control were compared with these.

The aphid population in chemical control was lowest on all the dates of observations (Table 78). It was significantly lower than control two and three weeks after *Verticillium lecanii* spray. The highest yield (7.00 q/ha) was obtained with insecticides and it was significantly higher than all other treatments. The yield from V. *Iecanii* treated plots (5.62 q/ha) was significantly higher than control (4.56 q/ha). *I. scutellaris* proved ineffective.

Table 78. Biosuppression of Lipaphis erysimi on mustard in Punjab

| Treatment | | Mea | n number (| of aphids/s | hoot | | Yield |
|---|--------------------------|--------------------------|---------------------------|---------------------------|---------------------------|-----------------|--------|
| | 25 th Feb. | 4 th March | 11 th March | 18 th March | 26 th March | Mean | (q/ha) |
| Ischiodon scutellaris @ 15000/ha first instar larvae (T1) | 53.3 (7.35) | 80.5 (9.02) | 19.8 (4.51) | 2.0 (1.72) | 1.1 (1.05) | 31.2 (4.73) | 2.25 |
| Verticillium lecanii @ 10 ⁸ conidia/ml (T2) | 47.6 (6.97) | 42.7 (6.59) | 12.7 (3.69) | 2.2 (1.76) | 0.0 (1.00) | 21.0 (4.00) | 5.62 |
| Metasystox 20 EC @ 750 ml/ha (T3) | 11.8 (3,53) | 21,9 (4.74) | 2.0 (1.69) | 1.05 (1.40) | 0.5 (1.02) | 7.37 (2.48) | 7.00 |
| Control (T4) | 57.1 (7.61) | 73.8 (8.64) | 23.3 (4.90) | 4.9 (2.37) | 0.5 (1.02) | 31.81 (4.91) | 4.56 |
| CD (P= 0.05) | (0.93) | (0.72) | (0.96) | NS | NS | (0.30) | (0.80) |

Note 1. Dates of spray/release of bioagents: Feb19 and March 11, 2002

4.24. Biological suppression of coconut pests

4.24.1. Field evaluation of Mycohit against coconut mite, Aceria guerreronis

4.24.1.1.Regional Station, CPCRI, Kayangulam

Mycohit was field tested as per the protocol supplied by PDBC at Mavelikkara. The results are summerised in Table 79.

^{2.} Dates of Insecticidal spray: Feb 19 and March 6, 2002

Table 79. Pre-treatment population count and damage grading

| Treatment | Live | mites/mm ² | Infestatio | n index |
|--------------|-----------|-----------------------|------------|-----------|
| | 4th bunch | 5th bunch | 4th bunch | 5th bunch |
| Mycohit | 3.5 | 8.05 | 1.76 | 2.04 |
| Azadirachtin | 8.02 | 10.55 | 1.67 | 1.67 |
| Sulphur | 10.78 | 6.45 | 1.73 | 1.86 |
| Control | 7.18 | 7.06 | 1.3 | 2.07 |

^{*} Post-treatment population counts to be recorded in June; * Post-treatment damage grading to be recorded at pre-harvest stage during November 2002.

4.24.1.2. KAU, Thrissur

The mean density of live mites was found to be reduced in all the treatments (T1, T2 and T3) whereas an increased count was recorded in untreated control. The mean reduction in live mite count over untreated control was 28.59 (Mycohit), 25.12 (neem) and 35.04 (sulphur) (Table 80).

Table 80. Comparative efficacy of mycohit with other miticides on coconut mite

| Treatment | Period | Mean live mites/mm ² | Per cent reduction over contro |
|--------------|--------|---------------------------------|--------------------------------|
| Mycohit | Pre | 7.95 | |
| | Post | 4.32 | 28.59 |
| Azadirachtin | Pre | 7.79 | |
| | Post | 4.53 | 25.12 |
| Sulphur | Pre | 6.91 | F |
| | Post | 3.93 | 35.04 |
| Control | Pre | 5.48 | - |
| | Post | 6.05 | - |

In Mycohit treated trees the post treatment population reduction ranged from 9.95 to 90.92 per cent. The percentage reduction in mite population reached up to 84.65 in the case of neem applied trees though there was no reduction in population in one tree (R8). The lowest value recorded in this treatment was 8.15%. The reduction in mite population was as high as 100 per cent, the lowest being 3.28 in the case of sulphur application. In the case of untreated control the population was increased over pre-treatment count excepting four

replications, which recorded a reduction in population. In other cases the values ranged from 2.91 to 89.08. On analysis of variance, all the three treatments were found to be statistically on par and untreated control was significantly inferior (Table 81).

Table 81. Population reduction of mites in different treatments

| Treatments | % reduction in mite population |
|------------------|--------------------------------|
| Azadirachtin 1% | 36.75° |
| Wettable sulphur | 42.45 * |
| Control | -15.36 ^b |

4.24.1.3. ANGRAU, Hyderabad

Mycohit, a formulation of *Hirsutella thompsonii*, was evaluated against coconut eriophyid mite under field conditions. A replicated trial was initiated in the month of January 2002. The treatments consisted of (i) Mycohit 1% - 3 sprays at 15 days interval (ii) Azadirachtin 1% - single spray (iii) Sulphur 50 WP (0.3%) as local check and (iv) untreated control.

Pre-treatment population count of the mite was recorded from the nuts of 4th and 5th bunches @ 1 nut per bunch. The post treatment population count of the mite was recorded on the 45th day after each of the three sprays of Mycohit from 2nd and 3nd bunches @ 1 nut per bunch. Live mite population in 4 mm² was recorded from three places on the nut surface and expressed as mean per mm². Damage grading will be made for the nuts of 2nd and 3nd bunch during pre-harvest stage. The trial is in progress.

No mycelial fragments of *H. thompsonii* on the mite colonies were seen at 45, 90 and 135 days after application (Table 82) and no significant reduction in the population of mite was observed. Azadirachtin and sulphur also were not effective.

Table 82. Effect of Mycohit against coconut mite

| Treatment | Pre count | Mite popu | lation /mm² 45 o | lays after * |
|------------------------|--------------|--------------|------------------|--------------|
| | | I spray | II spray | III spray |
| Mycohit (1%) | 4.07 (2.04) | 26.42 (4.99) | 32.65 (5.66) | 22.45 (4.54) |
| Azadirachtin* (1%) | 4.15 (1.90) | 49.22 (6.84) | 22.45 (4.67) | 22.80 (4.60) |
| Sulphur WP* (6 g/palm) | 15.20 (3.87) | 30.10 (5.35) | 21.87 (4.26) | 15.57 (3.70) |
| Control | 12.07 (3.29) | 42.22 (6.20) | 20.52 (3.81) | 25.22 (4.93) |
| CD (P=0.05) | NS | NS | NS | NS |

^{*} Single Spray

4.24.1.4. TNAU, Coimbatore

Mycohit was evaluated against coconut mite under field conditions at Perur, in Coimbatore District.

In all the post treatment counts, Mycohit 1% sprayed twice or thrice at 15 days interval was on par with control and did not reduce mite population on nut surface. Triazophos 40 EC (5 ml/l) caused maximum reduction in mite population, followed by Azadirachtin 1% 5 ml/l and wettable sulphur 80 WP 5 g/l.

Pre-harvest bunch damage scoring was done on 10.04.2002 on tagged bunches which received all rounds of treatment. Triazophos 40 EC (5 ml/l) recorded a mean damage grade of 1.51, followed by wettable sulphur (2.19) and Azadirachtin 1% (2.22). Mycohit sprayed twice (3.51) and thrice (3.53) recorded damage grades on par with untreated control (3.58) (Table 83).

Table 83. Bioefficacy of Mycohit in comparison with chemicals against coconut eriophyid mite (August 2001 onwards)

| Treatment | Population of eriophyid mite (No./4mm²) | | | | | Pre-harvest |
|--|---|--------------------|--------------------|--------------------|--------------------|--|
| | Pretreatment | 15 DAT | 30 DAT | 45 DAT | 60 DAT | damage grading on tagged bunches (240 DAT) |
| Mycohit 1% 2 sprays (15 days interval) | 34.91* | 30.65 ^b | 37.08 ⁶ | 41.92° | 42.11° | 3.51° |
| Mycohit 1% 3 sprays (15 days interval) | 39,67* | 27.92 ^b | 35.40 ^b | 42.92° | 40,03° | 3.536 |
| Wettable sulphur 80 WP 5 g/lit | 47.25" | 14.00° | 22.09 ^µ | 22.58h | 23.88b | 2.19 ^b |
| Triazophos 40 EC 5 ml/l | 32.16 ^a | 9.82ª | 14.58* | 16.25* | 17.98° | 1.51ª |
| Azadirachtin 1% 5 ml/l | 33.92 | 14.83° | 19.16ª | 20.83 ^b | 23.38 ^b | 2.22 ^b |
| Untreated control | 37.33ª | 29.58b | 30.83 ^b | 40.58° | 42.93° | 3.58° |
| CD (P=0.05) | 1.3* | 1.0* | 0.41* | 0.57* | 0.37 | |

^{*} CD for square root transformed values: ** Days after I round of Mycohit treatment Treatment 1 given on 0 and 15 DAT; Treatment 2 given on 0, 15 and 30 DAT; Treatment 3, 4 and 5 given on 0, 45 and 90 DAT

4.24.2. Studies on the seasonal incidence of *Opisina arenosella* and its natural enemies (KAU, Thrissur)

This experiment was initiated in January 2000 at four locations. Observations on the seasonal incidence are reported in Table 84.

The promising parasitoids, *Goniozus, Elasmus, Brachymeria* and *Apanteles* were present in all the locations with peak population during April - July. In location IV (Vazhappally), *Brachymeria* was high during September when the pest population had the 2nd peak of the year.

The experiment was started during January, 2002. Two locations were selected from Thrissur district (Irinjalakkuda and Ayyanthole) for studying the seasonal infestation of *Opisina* and occurrence of its natural enemies. The results are given in Table 85 and 86.

Table 84. Seasonal incidence of Opisina arenosella in four locations (Population/palm)

| Month | Locations | | | | |
|-----------|-----------|-------|-------|-------|--|
| | I | П | III | IV | |
| January | 11.1 | 24.34 | 18,49 | 6,36 | |
| February | 33.68 | 24.37 | 27.6 | 47.9 | |
| March | 43.86 | 54.43 | 27.04 | 28.3 | |
| April | 54.4 | 73.3 | 50.55 | 62.6 | |
| May | 58.37 | 61.4 | 47.6 | 67.4 | |
| June | 49.1 | 57.4 | 48.15 | 52.46 | |
| July | 37.32 | 47.27 | 37.2 | 41.9 | |
| August | 32.23 | 36.4 | 26.9 | 37.5 | |
| September | 45.91 | 23.57 | 22.4 | 51.35 | |
| October | 20.75 | 19.28 | 23.7 | 20.57 | |
| November | 7.83 | 19.28 | 9.05 | 25.8 | |
| December | 7.52 | 10.35 | 9.25 | 33.33 | |

Table 85. Opisina arenosella count and parasitism (From 100 leaflets)

| Months | Irinjalakuda | Ayyanthole |
|---------------------|--------------|------------|
| JANUARY | | |
| Adults | | 3 |
| Larvae | * | 30 |
| Pupae | 22 | 86 |
| Total | 22 | 119 |
| Per cent parasitism | 4.55 | 25.00 |
| MARCH | | |
| Adults | - | 5 |
| Larvae | 1 | 1.9 |
| Pupae | 107 | 179 |
| Total | 108 | 203 |
| Per cent parasitism | 13.89 | 26.79 |

Table 86. Infestation of Opisina arenosella at Irinjalakkuda and Ayyanthole

| Iree Number | | | Irinjalakkuda | | | Ayyaı | Ayyanthole | |
|-------------|--|--|--|--|--------------------------------------|--------------------------------|------------|--------------------------------|
| | Jan | January | Mg | March | Jani | January | | March |
| | Percent Infestation on leaves/ tree | Mean Percent Infestation on leaflets/ | Percent Infestation on leaves/ tree | Mean Percent Infestation on leaflets/ | Percent Infestation on leaves/ | Mean Percent Infestation | 2 5 5 | Mean Percent Infestation |
| | 10 CV | tree | | tree | 3 | tree | ree | on leaflets/ tree |
| | 17,000 | 10.78 | 48.00 | 34.39 | 25.00 | 24.71 | 34.48 | 29.40 |
| | 26.32 | 22.24 | 33.33 | 29.91 | 36.84 | 13.57 | 10.00 | |
| 3. | 23.81 | 7.27 | 28.57 | 32.23 | 35.48 | 20.00 | 42.00 | 34.04 |
| 4 | 34.62 | 6.70 | 29 99 | 50.73 | 01.00 | 32.30 | 36.00 | 41.95 |
| | 17 06 | 0 | | 0000 | 41.0/ | 23.38 | 48.14 | 32.49 |
| i . | 17.00 | 8.88 | 39.29 | 38.26 | 52.17 | 17.53 | 47.62 | 22 77 |
| .0 | 30.43 | 9.81 | 50.00 | 49.54 | 37.50 | 3L 9C | 0000 | 17:01 |
| 7. | 33.33 | 10.18 | 65.38 | 48.05 | 61.00 | C1.04 | 38.89 | 25.55 |
| ∞, | 26.92 | 4.59 | 80.95 | 35.69 | 31.43 | 48.33 | 61.90 | 51.59 |
| 9. | 18.18 | 11.05 | 22.22 | 00000 | 74.17 | 21.25 | 29.03 | 26.70 |
| 101 | 26.00 | 0 | 55.55 | 00.01 | 42.86 | 35.86 | 37.5 | 15.92 |
| | 70.74 | 9.10 | 67.86 | 44.20 | 00.09 | 38.92 | 52.94 | 63.70 |
| Mean | 28.13 | 90.01 | 51.34 | 37 00 | 41.40 | 1000 | | 02:10 |

4.25. Biological suppression of fruit crop pests

4.25.1. Survey for natural enemies of spiralling whitefly, Aleurodicus dispersus

4.25.1.1. IIHR, Bangalore

Surveys were carried out in five states, viz. Karnataka, Kerala, Tamil Nadu, Andhra Pradesh and Maharashtra during 2001-2002 mainly for the presence of Encarsia spp. Encarsia guadeloupae was collected in all the locations except Coimbatore, but E. ?haitiensis was collected in Kolar, Shimoga, Bangalore North, Coimbatore and Trichur. In some areas both E. ?haitiensis and E. guadeloupae occurred together. In addition to Encarsia spp., general predators, viz. Axinoscymnus puttarudriahi, Cybocephalus sp., C. montrouzieri and Chrysopa spp. were also encountered. Parasitism by Encarsia guadeloupae ranged from 24.59% to 72.96% on six-year-old guava plants with Aleurodicus dispersus infestation at Hebbal (Bangalore) in different months.

4.25.1.2. KAU, Thrissur

Whitefly infested leaves (containing last stage nymphs) of various host plants such as guava, chilli, ceara rubber, brinjal, tapioca, balsam, banana, etc. were collected from the fields in Thrissur district at fortnightly/monthly intervals and per cent parasitisation recorded. The extent of parasitism by *Encarsia* spp. was highest (73 %) from Vellanikkara during March - April 2002. In Mannuthy it was 66 per cent during November 2001, but came down to 10% during December 2001 and February 2002. In Mulayam area, it ranged from 1.41 to 18.40 per cent. On ceara rubber, parasitism was < 1% in October 2001, but reached >50% in late November and December, going up to a maximum (78.88%) in February.

4.25.1.3. TNAU, Coimbatore

Fortnightly observations were taken on three branches of 10 marked guava trees. The incidence of spiralling white fly was lowest in June-July and October and highest in November-January at Ayakkudi village in Palani taluk.

4.25.2. Colonization of Encarsia guadeloupae on spiralling whitefly (IIHR, Bangalore)

Encarsia guadeloupae has established very well on spiralling whitefly infesting cassia in and around Bangalore. Leaves containing parasitised nymphs (black) were collected in Bangalore and distributed in several locations of South India during 2001-2002. The areas covered were Gulbarga, Davangere, Belgaum, Kolar, Shimoga, Kadur, Raichur, Bellary, Madikeri, Bijapur and Gulberga in Karnataka, Hyderabad and Madanapalli in Andhra Pradesh, Coimbatore in Tamil Nadu, Trichur in Kerala and Pune in Maharashtra. E. guadeloupae was

recovered from spiralling whitefly in Hyderabad and Madanapalli, Pune and several locations in Karnataka.

4.25.3. Parasitism of oriental yellow scale *Aonidiella orientalis* on custard apple and Sapota (IIHR, Bangalore)

Aphytis sp. was found parasitizing the oriental yellow scale, A. orientalis, which appeared in severe form on the fruits of custard apple in the second week of January 2002 at IIHR Farm to the tune of 2.52 to 6.42%. Several sapota fruits were also found infested with A. orientalis during September 2001. Encarsia sp. was collected from the scale insect and per cent parasitism ranged from 5.24 to 8.56 during September-November 2001.

4.25.4. Pomegranate fruit borer and its natural enemies (YSPUH & F, Solan)

This year first incidence of pomegranate fruit borer, *Deudorix epijarbas*, was noticed in 24th standard week (24 SW, beginning on June 11) and it increased from 0.4% of bored fruits to 20.8% by 31 SW (beginning on July 30) and maximum number of bored fruits was 20.8 in SW 31. In subsequent observations, the bored fruits were 3.3 and 4.2% in 32 SW and 34 SW. Only the scelionid egg parasitoid *Telenomus* (*T. ? cyrus* Nixon) was reared from collected eggs (25-33.3%). There was no parasitism by *Trichogramma* sp.

4.25.5. Evaluation of *Trichogramma chilotraeae* against *Deudorix isocrates* on pomegranate (IIHR, Bangalore)

Trichogramma chilotraeae was collected from the eggs of D. isocrates in the field in 1998 and it was maintained on the eggs of Corcyra cephalonica in the laboratory. A total of one-lakh parasitoids was released during January-April 2002 in the field for evaluation against D. isocrates. There was not much reduction in fruit damage on the plants released with T. chilotraeae (33.91%) as compared to that in the check (40.45%).

$4.25.6.\ Storage\ of\ \textit{Trichogramma\ chilotraeae}\ (\Pi HR,\ Bangalore)$

Trichogramma chilotraeae was maintained on the eggs of rice moth. Four-day-old parasitised eggs in paper bits (1.0 cm²) were kept at 10°C for 5, 10, 15, 20, 25, 30 and 35 days of storage. Storage of eggs at 10°C for up to 10 days did not affect development period, per cent emergence and progeny production (Table 87), but further storage adversely affected these parameters.

Table 87. Effect of storage on development and progeny production of *Trichogramma* chilotraeae at 10°C.

| Duration of storage (days) | Development period (days) | Per cent emergence | Progeny numbers |
|----------------------------|---------------------------|-----------------------|-----------------|
| 5 | 14 | 75.00 | 438.50 |
| 10 | 18 | 62.73 | 348.40 |
| 15 | 23 | 22.83 | 333.00 |
| 20 | 29 | 11.32 | 223.60 |
| 25 | 32 | 5.48 | 52.80 |
| 30 | 34 | 4.04 | 12.30 |
| 36 | 44 | 1.14 | 0 |
| Check | 11 | 78.58 | 440.50 |

4.25.7. Field efficacy of *Trichogramma chilonis* against the ber fruit borer, *Meridarches scyrodes* (IIHR, Bangalore)

Releases of *T. chilonis* were initiated in July and continued up to September at weekly intervals. A total of 50,000 parasitoids was released on ber plants. At the time of harvesting fruit damage was 29.41% on the parasitoid released plants as compared to 75.83% in the check.

4.25.8. Efficacy of Cryptolaemus montrouzieri against pink mealy bug, Maconellicoccus hirsutus on ber

Severe infestation of *M. hirsutus*, a sporadic pest of ber, was observed on three-yearold ber plants in January, 2002 in IIHR Farm. The mealybug population was brought down from 62.50/plant on 01-01-2002 to 0.85/plant on 21-01-2002 by *Cryptolaemus montrouzieri*.

4.25.9. Impact of Cheilomenes sexmaculata in the suppression of Toxoptera aurantii on acid lime (IIHR, Bangalore)

The citrus aphid *T. aurantii* appeared in large numbers in January 2002 on five-year-old acid lime plants in Block No. 2 at IIHR Farm. The aphid infestation was brought down from a mean population of 301.40/plant on 03-01-2002 to zero/plant on 01-03-2002 by the activity of the predator, *Cheilomenes sexmaculata*.

4.25.10. Field evaluation of Cryptolaemus montrouzieri against mealybugs Maconellicoccus hirsutus and Ferrisia virgata on custard apple (IIHR, Bangalore)

The citrus aphid *T. aurantii* appeared in large numbers in January 2002 on five-year-old acid lime plants in Block No. 2 at IIHR Farm. The aphid infestation was brought down from a mean population of 301.40/plant on 03-01-2002 to zero/plant on 01-03-2002 by the activity of the predator, *Cheilomenes sexmaculata*.

During July 2002, severe infestation of *F. virgata* and *M. hirsutus* on custard apple fruits was noticed at IIHR Farm, Bangalore (3507.50 mealy bugs/plant (10 fruits)). Since the mealybug population was found to be very high and that of the local predator *Spalgis epius* was negligible, the coccinellid *C. montrouzieri* was released @ 30/plant to supplement the control of the mealybugs. There was marked reduction in the population of mealybugs subsequently. The fruits were completely cleared of the mealybugs on 14th September 2002. During the study period only *C. montrouzieri* and *S. epius* were observed.

4.25.11. Screening of insecticides against fruit crop pests and their natural enemies

4.25.11.1. Safety of botanicals and conventional pesticides to E. guadeloupae (IIHR, Bangalore)

Eight conventional pesticides and nine botanicals were screened for their residual toxicity to adults of *E. guadeloupae*. Carbaryl was the most persistent insecticide causing very high mortality for up to 21 days application. Fungicides showed less residual toxicity to the adults. Botanicals were safe after 7 days of application.

4.25.11.2. Efficacy of Bt formulations in controlling ber borer, Meridarches scyrodes(IIHR, Bangalore)

The comparative efficacy of the commercial Bt products (Delfin, Dipel and Halt) was evaluated against M. scyrodes on ber. Application @ 1 kg/1 at weekly intervals was started with the peanut formation of fruits till harvest. Dipel recorded the minimum per cent fruit damage of 12.89, followed by Halt (20.54) and Delfin (23.28). Application of Decis (0.025%) and fenvalerate resulted in 0.83 and 4.33 per cent fruit damage, respectively. All the treatments were found statistically significant to control (47.04%).

4,25.11.3. Screening of *Bt* products against pomegranate fruit borer *Deudorix isocrates* (IIHR, Bangalore)

The Bt products Halt, Dipel, Delfin and Biolep were evaluated against pomegranate fruit borer D. isocrates @ 1.0 kg/l against the standard check Decis (0.025%) and untreated

control. Weekly sprays were carried out from fruit formation stage to harvest. Each treatment was replicated four times. Biolep was found to be most effective (1.5% damage), followed by Delfin (4%), Dipel (6.14%), Halt (7.7%) and Decis (9.0%).

4.25.12. Field release of natural enemies against San Jose scale, *Quadraspidiotus perniciosus* (SKUA & T, Srinagar)

Field releases of *Aphytis proclia*, *Encarsia perniciosi* & *Chilocorus infernalis* were made and the numbers released were 96159, 96825 and 1035, respectively.

4.25.13. Impact of parasitoids at released sites against San Jose scale (SKUA & T, Srinagar)

In order to study the impact of parasitoids released during previous years at different locations in the valley, seven places representing 5 districts of the valley were surveyed. Both *Aphytis* sp. and *Encarsia* sp. were found to be well established, with per cent scale parasitism ranging from 28.37 to 48.00.

4.25.14. Seasonal incidence of the San Jose scale and its natural enemies in Himachal Pradesh (YSPUH & F, Solan)

The incidence of the San Jose scale is on the decline in managed apple orchards with use of the dormant spray oil and now recommendation of the use of summer-spray oil for suppression of phytophagous mites is likely to give an additive advantage. Wherever the scale insect was present, its population was low. Out of 11 twigs (each 20 cm long), live scale population was present only on three (7, 3 and 1 scales) in an orchard in Jubbal (Shimla district) in October. In Kotkhai (Shimal district), the average live scale population/20 cm twig was 104 (the three consecutive instars being 24, 55 and 21%) in November. At Bajaura (Kullu district), it was 22 scales per 20 cm twig (the three consecutive instars being 74, 6.5 and 19.5%) in December and almost similar situation was noticed in February-March on twig samples of pear. While most of the scale population was predated in Jubbal, predation was 14.2 and 17.6% in Kotkhai and Kullu area, respectively. In all these areas, though live population of the parasitoids Aphytis sp. and Encarsia perniciosi was not present, there was an indication of the presence of the former in all the three localities and of the latter in Kullu. In the apple orchard in which population of the woolly apple aphid was monitored in Solan, scanty scale population was present on two trees (10-55 per 20 cm twig) and larvae of Chilocorus infernalis were observed feeding on this population during last week of May to last week of June. The laboratory population of this predator produced progeny only once during September-March end.

4.25.15. Parasitism of wooly apple aphid by the parasitoid, $Aphelinus\ mali$ (SKUA & T, Srinagar)

Aphelinus mali was not observed during March and April, but was active from May onwards. Parasitism ranged between 10.0 and 20.0% and was highest in August.

4.25.16. Seasonal abundance of woolly apple aphid in relation to natural enemies (YSPUH & F, Solan)

Monitoring of the woolly apple aphid (*Eriosoma lanigerum*) population and its natural enemies throughout the year at weekly intervals revealed that the aphid population started building up in April 2001, when colony count, mean colony size and aphid coverage/replicate were 0-2.4, 0-0.18 cm and 0-0.54 cm, respectively. By May end, the respective values had increased to 16.6, 0.41 cm and 7.56 cm. By third week of June, coverage/replicate of 8.6 cm was the maximum for the year (mean colony number 17 and mean colony size 0.44 cm). Parasitisation of the aphid by *Aphelinus mali* ranged between 0 and 1.4 mummified bodies/replicate during April-May and increased to 8.4 -24.2 per replicate in June. During April-July, predator activity (syrphid, chrysopid and coccinellid), though very poor, also increased from 0 to 0.8/replicate.

The aphid population remained low (0-2.4 colonies, up to 0.33 cm size and aphid coverage of 2.57 cm) during July to first-third of October. The mummified aphid counts and predator activity were also negligible. The second spurt in aphid activity occurred during October end to December (with maximum colony count of 13.2, mean size 0.61 cm and coverage 7.52 cm per replicate in the first week of December) and so did the mummified aphid count (maximum value of 10.8 mummified aphids/replicate). Thereafter, the aphid count declined (from 6 to 0.2 colonies of 0.49-0.06 cm size with coverage of 2.78-0.06 cm) and remained low till March. No mummified aphid was found among these colonies.

Aphelinus mali was the only persistent and specific parasitoid. Among predators, coccinellids were encountered during April-May and November, chrysopids during May and November and syrphids during June and November.

4.25.17. Effect of insecticides on natural enemies of woolly apple aphid (YSPUH & F, Solan)

In continuation of last year's experiment, residual toxicity of malathion (0.05%), carbosulfan (0.25%) (Marshal 25 EC) and profenophos (0.05%) (Curacron 50 EC) to Chrysoperla carnea was worked out. Malathion (0.05%) continued to give mortality of larvae for up to 8 days (96.7, 83.3 and 53.3% on 0, 1 and 2-day-old deposits/residues and 46.7% on 8-day-old residues in 24 hours mortality counts) and it was safe to release the

larvae after 10 days of the spray. Carbosulfan (0.025%) provided 100 to 78.6% mortality for up to 11 days of the spray and 46.7% on 13-day-old residues and proved more toxic. However, on 15-day-old deposit, there was no mortality. Profenophos (0.05%) resulted in 100 to 76.7% mortality on for up to 22-days and it tapered to 41.7%, 8.3 and nil on 26, 29 and 30-day-old residues.

On the basis of this experiment, it can be concluded that in malathion, carbosulfan and profenphos treated orchards, *Chrysoperla* larvae can be released safety after 10, 15 and 30 days of the spray. These insecticides were also safer to overwintering population of *Aphelinus mali* when sprayed in mid-November.

4.25.18. Release of Chrysoperla carnea against woolly apple aphid (YSPUH & F, Solan)

Releases of C. carnea larvae (2-3 day old) were made @ 4 larvae/colony of the aphid on selected branches of an apple tree having aphid population on October 31, 2001, after aphids started increasing. In the pretreatment count, mean number of colonies, their mean size (in cm) and spread (in cm) was 11, 0.84 cm and 9.2 cm, respectively, on the release tree. In October end, unusually ants were found actively moving around colonies and collecting the honeydew. Some ants picked up the moving larvae of C. carnea after release. Such ants brought to the laboratory along with larvae were found dead next day but larvae survived. One and two weeks after the release, mean colony number, size and coverage on the released site were 19 and 19, 0.584 ad 0.632 cm, and 11.1 and 12 cm respectively. On the unreleased trees, the colony count increased from 5 to 9, the mean size from 0.46 to 0.55 cm and the aphid coverage from 2.44 to 4.59 cm during this period. There was definitely an increase in colony number after the release of the predator but the mean colony size shrank as compared to the pretreatment count; however, the aphid coverage also increased. The increase on the released tree was 1.3-fold as compared to 1.88-fold on the unreleased tree. In the subsequent observation, recovery of chrysopid larvae was negligible. There was no marked effect of Chrysoperla carnea, and ant activity associated with the experimental tree adversely affected the predator activity.

4.26. Biological suppression of vegetable crop pests

4,26.1. Survey of natural enemies of vegetable crop pests

4.26.1.1. IIHR, Bangalore

Parasitism by Campoletis chlorideae was 23.20% on larvae of Helicoverpa armigera infesting tomato. About 16.10%, 8.40% and 12.00% parasitism by Hemiptarsenus varicornis was obtained from serpentine leaf miner infested leaves of tomato, watermelon and French

beans, respectively. Cotesia plutellae was collected from diamond back moth, Plutella xylostella. The maximum parasitism was 72.00% during September–November 2001. Cheilomenes sexmaculata, anthocorids, chrysopids and a predatory mite were collected from thrips on chillies.

4.26.1.2. GAU, Anand

The following natural enemies of pests of vegetables were recorded in and around Anand

| Crop/pest | Natural enemy | Stage attacked | Per cent parasitism | Remarks |
|--------------------------------|-------------------|---------------------|------------------------|--------------------------------|
| Plutella xylostella on cabbage | Trichogramma sp. | Egg | 42.00 | New record |
| | Cotesia plutellae | Young larvae | 42-62 | |
| Aphids on cabbage | Xanthogramma sp. | Nymph | Abundant | = 1 |
| Helicoverpa armigera on tomato | T. chilonis | Egg | 75-80 | - |
| | Nesidiocoris sp. | Egg/young larvae | 5-30 | Always seen in abundance |

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

Moths were seen on light source by third week of March and observations on oviposition in April revealed maximum eggs (mean \pm SD per spike: 9.4 ± 6.7) on snap dragon (*Antirrhinum majus*), followed by calendula (0.83 \pm 0.15/head) and oviposition was poor on paperflower (0.07+0.25/head). In first week of May, egg laying declined on these plants. There was no egg parasitisation.

In first half of May, 30% plants of snapdragon (egg density 1.22 ± 0.44 eggs/spike), 15% plants of carnation (1.3 ± 0.58) and 5% plants each of godesia and California poppy (0.1 and 0.05 egg/plant) had eggs, while 25.5% tomato plants were infested with mean egg density of 1.54 ± 1.17 /plant. Egg parasitisation was 30% on tomato and 25% on carnation. In another field, 10% tomato plants had egg density of 1.2 ± 0.4 /plant and egg parasitisation of 41.7%. In second half of May, oviposition was confined to tomato crop. In two locations, 56 and 30% plants were infested with 2.6 ± 2.3 and 1.3 ± 0.5 eggs/plant and larval count of 0.26 and nil per plant. Egg parasitisation was 85.7% and 62.5% and only $Trichogramma\ chilonis$ was reared.

Bracon on H. armigera was collected from floral head of carnation in May 14, 2001. Bigger larvae of H. armigera (fourth instar and older) were aggressive and even ate away the parasitoid. H. armigera larva was less preferred than Corcyra cephalonica larva and rate of oviposition was just half (5.6 eggs/day). Bigger larvae of H. armigera were unsuitable for development of the parasitoid.

4.26.1.4. Serpentine leaf miner on tomato (Dr.YSPUH & F., Solan)

This year, incidence of the serpentine leaf-miner on tomato was low. During II-fortnight of May and I and II fortnight of June, 24.8, 45.2 and 37.7% leaflets were infested with larval density of 1, 0.5 and 0.75/leaflet, respectively. On these leaflets, 1.1, 0.8 and 0.5 larvae had already completed development. The live, dead and parasitized larval population was 8.3, 75 and 16.6% in second half of May, 15.4, 84.6 and nil in the I half of June and 33.3, 40 and 26.7% in II half of June.

4.26.1.5. Green house whitefly and its natural enemies(Dr.YSPUH & F., Solan)

At Solan, French bean crop in some fields was severely attacked by whitefly, *Trialeurodes vaporariorum* during June-September. This year also, its pupae were parasitized by the aphelinid endoparasitoid, *Encarsia transvena*, while grubs and adults of the predatory coccinellid *Serangium montazerii* were found feeding upon developing stages of the whitefly. In August, on an average as many as 369 pupae/leaflet were counted and amongst these 58.8% were parasitized by *E. transvena*. Besides, these leaflets had 789 pupae from which either adult of the whitefly or that of the parasitoid had emerged; counts of the pupae revealed the old parasitisation of 2.4%. The overall parasitisation was 20.4%.

4.26.1.6. Spiralling whitefly on chilli and brinjal (KAU, Thrissur)

In the case of chilli, parasitism was found to be highest in Vellanikkara area during November (56.70), January (68.56) and February (61.22). In the other two locations, maximum parasitism recorded was 39.75% (Mannuthy) during February first fortnight and 41.40% (Ollukkara) during December second fortnight.

On brinjal, parasitism up to 57 per cent was recorded during November 2001. On other host plants like banana, balsam and poinsettia, moderate parasitism was recorded. However, it was relatively low in tapioca and wild tapioca.

On ceara rubber, brinjal and chilli, *E. guadeloupae* was the predominant parasitoid during October-December. However, on guava, *Encarsia* sp. nr. *meritoria* was more (117). During January-April, emergence of *Encarsia* sp. nr. *meritoria* was high from brinjal and *E. guadeloupae* was more from chilli. In general the adult emergence was higher during October-December as compared to January-April.

4.26.2. Evaluation of Trichogrammatoidea bactrae against P. xylostella on cabbage

4.26.2.1. IIHR, Bangalore

Cabbage var. Maharani was planted in 500 m² area. A total of 25 plots were made each with 20-m² area. The entire area was subjected parasitoid release. A separate 100 m² area was held at an isolated distance for both chemical (endosulfan 3 sprays at weekly interval) and control treatments. Egg parasitoid, *Trichogrammatoidea bactrae* was released @ 2.5 lakh adults per hectare right before primordial formation (10 days from transplanting) 5 times at weekly intervals.

The larval population was 0.56 - 3.24/plant (mean=1.53/plant) in release plot as against 2.20-4.04 larvae per plant (mean=2.88 larvae/plant) in control. In endosulfan treated plot the reduction was 1.60 per plant, which was lower than the control. A reduction of 53.13% and 55.55% larval population with parasitoid release and endosulfan, respectively over control was observed. Release of egg parasitoid was on par with insecticide treated plot during this period. There was not much larval population in the field to assess the efficacy of egg parasitoid.

4.26.2.2. MPKV, Pune

Five releases of *Trichogrammatoidea bactrae* @ 50,000 adults/ha/release at weekly interval commencing from 25 days after planting were found significantly superior to untreated control for the suppression of DBM on cabbage. This treatment recorded 7.0 larvae/10 plants as against 11.2 surviving larvae/10 plants in untreated control, and the yield was 363.7 q/ha cabbage heads as against 239.8 q/ha in control.

4.26.3. Effect of Bt products against Plutella xyllostella

4.26.3.1. Cauliflower (IIHR, Bangalore)

Dipel, Delfin, Biolep and Halt were evaluated against DBM on cauliflower. Spraying was initiated at weekly intervals @ 1 kg/1 from primodium initiation stage and compared with endosulfan (2 ml/l) and untreated control. Biolep recorded the minimum larval count (4.8), followed by Delfin (5.7), Halt (5.9) and Dipel (6.2). Endosulfan (6.5) was on par with control (6.7).

4.26.3.2. Cabbage (MPKV, Pune)

Delfin WG, Dipel 8L, Halt WP, Biolep and Biobit WP all at @ 1 kg/ha, were evaluated against DBM on cabbage with endosulfan (0.07%) and a control for comparison. Spraying of Delfin WG @ 1 kg/ha recorded minimum of 2.67 larvae/10 plants and maximum yield of marketable cabbage heads (372.8 q/ha) (Table 88).

Table 88. Efficacy of different Bt formulations against Plutella xylostella

| Treatment | Larval population /10 plants | | | | |
|---------------------|------------------------------|--------------------------|--------------|--|--|
| | Pre count | Av. surviving population | Yield (q/ha) | | |
| Delfin WG 1kg/ha | 9.67 (3.18_ | 2.67 (1.77) | 372.8 | | |
| Dipel 8L @ 1 lit/ha | 10.00 (3.23) | 3.07 (1.88) | 360.2 | | |
| Halt WP @ 1 kg/ha | 10.33 (3.29) | 3.47 (1.99) | 351.8 | | |
| Biolep @ 1 kg/ha | 10.66 (3.34) | 3.53 (2.00) | 304.2 | | |
| Biobit @ 1 kg/ha | 9.33 (3.13) | 3,33 (1.95) | 290.5 | | |
| Endosulfan 0.07% | 10.33 (3.26) | 3.87 (2.14) | 257.3 | | |
| Untreated control | 9.67 (3.18) | 16.93 (4.17) | 207.6 | | |
| CD (P=0.05) | (NS) | (0.27) | 30.99 | | |

Figures in parentheses are $\sqrt{n+0.5}$ transformations: Surviving larval populations are averages of five post-counts; NS = Non-significant

4.26.3.3. Cabbage (GAU, Anand)

Dipel, BTT, BTK I, BTK II, Biobit, and Agree (all at 1.0 kg/ha) were evaluated against DBM and compared with endosulfan (0.07%) treated plot and control. Btk- I (3.20 larvae/10 plants) was found superior to the rest, but was on par with Biobit (3.58 larvae / 10 plants) and endosulfan (3.00 larvae/10 plants) (Table 89).

Table 89. Effect of Bt formulations on P. xylostella in cabbage

| Treatment | | Mean larval population / 10 plants | Yield (kg/ha) |
|-------------|----------|------------------------------------|---------------|
| Dipel | 1 kg/ha | 2.45 (5.00) | 29713 |
| BTT | 1 kg/ha | 2.17 (3.71) | 30286 |
| ВТК- І | I kg/ha | 2.05 (3.20) | 31027 |
| BTK-II | 1 kg/ha | 2.50 (5.25) | 29545 |
| Biobit | l kg/ha | 2.14 (3.58) | 30454 |
| Agree | 1 kg/ha | 2.41 (4.81) | 30039 |
| Endosulfan | (0.07 %) | 2.00 (3.00) | 30864 |
| Control | | 3.27 (9.69) | 20740 |
| CD (P=0.05) | | 0.204 | 3999 |

4.26.4. Field evaluation of T. chilonis against P. xylostella on cabbage (GAU, Anand)

Efficacy of *Trichogramma chilonis* against *P. xylostella* was evaluated on cabbage (var. Suttan Express). Observations were recorded on the larval population and larval parasitism on randomly selected plants. The overall population of *P. xylostella* was quite low. The population of *P. xylostella* was significantly lower in *Trichogramma* released plots (1.04/10 plants) and insecticide treated plot (2.81/10 plants) and the yield was higher than control (Table 90).

Table 90. Evaluation of Trichogramma chilonis against Plutella xylostella in cabbage

| Treatment | Mean Larval Population / 10 plants | Yield (kg/ha) |
|-------------|------------------------------------|---------------|
| T. chilonis | 1.43 (1.04) | 30716 |
| Insecticide | 1.91 (2.65) | 29086 |
| Control | 2.41 (4.81) | 24196 |
| CD (P=0.05) | 0.17 | 1987 |

4.26.5. Evaluation of *Bacillus thuringiensis* var. *kurstaki* against *Pieris brassicae* (Dr.YSPUH & F, Solan)

Five formulations of *Bacillus thuringiensis* var. *kurstaki*, viz., Biobit DF (32000 IU/mg), Biolep (16000 IU/mg), Delfin (17600 IU/mg), Halt (55000 IU/mg) and Hill-BTK (32000 IU/mg) each @ 1.0 kg/ha (taking 32000 IU/mg potency as base) with endosulfan (0.05%) as standard, were evaluated against cabbage butterfly, *Pieris brassicae*. The leaves from the sprayed field were brought to the laboratory after the deposits had dried as 0-day old deposits and also at one-day intervals. Larvae of *P. brassicae* (III and IV instar) reared in the laboratory from field collected eggs were released on treated leaves and mortality data collected after 48 and 120 hours of the release.

On fresh endosulfan deposits, there was cent per cent mortality within 24 hours of release. Biobit, Biolep, Delfin, Halt and Hill BTK provided 20, 40, 10, 90 and 20% mortality in 48 hours; it increased to 80, 80, 60, 80 and 100% in 120 hour count. On one-day old deposits, mortality was 40, 0, 20, 0 and 10% at 48 hour on leaves with Biobit, Biolep, Delfin, Halt and Hill BTK deposits which increased to 100, 90, 90, 30 and 70% at 120 hours count. On two-day-old deposits, mortality was negligible as compared to the untreated control.

4.26.6. Field evaluation of *Steinernema carpocapsae* against brinjal fruit and shoot borer, *Leucinodes orbonalis* (IIHR, Bangalore)

The efficacy of *S. carpocapsae* (culture obtained from PDBC) was evaluated under field conditions against *L. orbonalis*. The nematodes (at the rate of 1 billion/hectare) were sprayed at 10, 20 and 30 days interval. All the EPN treated plots recorded less per cent infestation than cypermethrin and control plots (Table 91).

Table 91. Effect of S. carpocapsae against L. orbonalis

| Treatments | Percent fruits infested |
|--------------------------|-------------------------|
| EPN at 10 days intervals | 21.92 |
| EPN at 20 days intervals | 18.79 |
| EPN at 30 days interval | 26.95 |
| Cypermethrin 0.5 ml/l | 42.30 |
| Control | 45.93 |

4.26.7. Evaluation of Trichogramma chilonis and Bt formulations for the control of Leucinodes orbonalis in brinjal

4.26.7.1. ANGRAU, Hyderabad

Two Bt formulations, viz. Dipel (1 lit/ha) and Delfin (1 kg/ha) in combination with T. chilonis release, were tested in comparison with control and an insecticide check (endosulfan 0.07%) against L. orbonalis in brinjal (var. Pusa Purple Long). The performance of Bt formulations was not very encouraging as compared to insecticidal check (Table 92), though they fared better than control.

Table 92. Effect of *Trichogramma chilonis* and different *Bt* formulations against *Leucinodes orbonalis* on brinjal

| Treatments | Pre count | e count Per cent fruit damage | | | | |
|--------------------|----------------|-------------------------------|-----------------|----------------|----------------|----------------|
| | | First spray | Second spray | Third spray | Fourth spray | Fifth spray |
| Dipel (1 lt./ha) | 15.5 (23.2) | 31,0 (33,8) | 36.8 (37.3) | 29.5 (32.8) | 46.5 (43.0) | 37.3 (37.6) |
| Delfin (1 kg/ha) | 14.6 | 38.8 | 39.0 | 34.0 | 46.3 | 48.3 |
| | (22.5) | (38.5) | (38.6) | (35.6) | (42.8) | (44.0) |
| Endosulfan (0.07%) | 13.8 (21.6) | 25.3 (30.1) | 30.0 (33.2) | 29.3 (32.7) | 35.9 (36.8) | 35.0 (36.2) |
| Control | 13.2 (21.6) | 43.9 (41.5) | 44.2 (41.8) | 44.2 (41.6) | 55,4 (48,1) | 57.5 (49.3) |
| CD (P=0.05) | NS | 3.81 | 2.59 | 2.97 | 3.28 | 3.94 |

4.26.7.2. College of Agriculture, MPKV, Pune

Trichogramma chilonis @ 2.5 lakhs adults/ha, Dipel 8L @ 1 lit/ha, and Delfin WG @ 1 kg/ha and endosulfan 0.07% were evaluated in comparison with untreated control. Five sprays of Delfin WG @ 1kg/ha given at 10 days interval starting from initiation of flowering were found to be the most effective recording minimum fruit infestation (10.78%) and maximum marketable fruit yield (120.4 q/ha). Though release of T. chilonis @ 50,000 adults/ha/release/ week was significantly better than control, it was least effective for the control of L. orbonalis (Table 93).

Table 93. Efficacy of *T. chilonis* and different *B. thuringiensis* formulations for the control of *L. orbonalis* on brinjal

| Treatment | Average fruit infestation (%) | Yield (q/ha) |
|---|-------------------------------|--------------|
| Trichogramma chilonis @ 50,000 adults/ha/ releases – 5 releases | 19.67 (26.32) | 95.5 |
| Dipel 8L @ 1 lit/ha | 13.46 (21.51) | 109.6 |
| Delfin WG @ 1 kg/ha | 10.78 (19.16) | 120.4 |
| Endosulfan 0.07% | 16.30 (23.81) | 102.4 |
| Untreated control | 36.46 (37.14) | 78.4 |
| CD (P=0.05) | (0.94) | 4.29 |

Figures in parentheses are angular transformations

4.26.8. Management of tomato fruit borer, Helicoverpa armigera

4.26.8.1. MPKV, Pune

The following treatments were evaluated for fruit borer management on tomato.

- T1: Trichogramma pretiosum alone @ 50,000 adults/ha/release five times with observations of eggs in the field (release 'Trichobits' 2 m apart).
- T2: HaNPV alone @ 250 LE/ha (1.5x1012 POBs/ha) 5 sprays at weekly interval.
- T3: T. pretiosum @ 50,000 adults/ha/release 5 times at weekly interval + HaNPV @ 250 Le/ha (1.5x10¹² POBS/ha) 3sprays- first spray 5 days after release of parasitoids and subsequent sprays at weekly intervals

T4: T. pretiosum @50,000 adults/ha/rlease five tiems at weekly interval+ HaNPV @ 250 Le/ha (1.5x10¹² POBS/ha) 2 sprays-first spray 5 days after release of parasitoids and subsequent spray at 10 days interval.

T5: Untreated control

Five sprays of *HaNPV* @ 250 LE/ha and five releases of *T. chilonis* + 3 sprays of *HaNPV* @ 250LE/ha were the most effective, recording minimum larval population and fruit infestation and maximum yield (Table 94).

Table 94. Efficacy of T. pretiosum and HaNPV against H. armigera on tomato

| Treatment | No. of I | arvae/5 plants* | Average fruit | Yield (q/ha) |
|---|------------------|-----------------|------------------|--------------|
| | Pre-count | Post-count | infestation** | |
| T. pretiosum @ 50,000 adults/ha/release – 5 releases | 10.25 (3.26) | 3.46 (1.99) | 17.30 (24.58) | 262.2 |
| HaNPV @ 250 LE/ha – 5 sprays | 11.50 (3.46) | 1.54 (1.42) | 9.74 (18.07) | 299.2 |
| T. pretiosum @ 50,000 adults/ha/rel, – 5 releases + HaNPV @ 250 LE/ha-3 sprays | 11.25 (93.42) | 2.20 (1.640) | 8.93 (17.19) | 297.9 |
| T. pretiosum @ 50,000 adults/ha/rel. – 5 releases + HaNPV @ 250 LE/ha-2 sprays | 10.75 (3.34) | 2.84 (1.83) | 9.87 (18.30) | 276.7 |
| Untreated control | 11.50 (3.46) | 7.58 (2.84) | 24.95 (29.96) | 208.6 |
| CD (P=0.05) | (NS) | (0.18) | (3.18) | 50.25 |

Figures in parentheses are $\sqrt[*]{n+0.5}$ and \sqrt

4.26.8.2. GAU, Anand

For the management of tomato fruit borer, H. armigera, five schedules of treatments (same as above) were evaluated.

Though the population of H. armigera was very low, T. p. + HaNPV 3 sprays, found to be superior to control, was on par with the other treatments (Table 95).

Table 95. Efficacy of different treatments against H. armigera on tomato

| Treatments | Egg/ 5 Plants | Larvae/ 5 plants | Percent damage | Mean percent parasitism | Yield kg/ha |
|-----------------|------------------|---------------------|----------------|----------------------------|-------------|
| TP+NPV 3 sprays | 1.40 (0.96) | 1.20 (0.44) | 9.25 (2.60) | 20.25 | 1510 |
| TP+2 sprays | 1.65 (1.72) | 1.40 (0.96) | 12.12 (4.41) | 19.25 | 1470 |
| TP alone | 1.80 (2.24) | 1.48 (1.19) | 15.28 (6.95) | 19.00 | 1425 |
| NPV alone | 2.20 (3.84) | 1.60 (1.56) | 15.00 (6.70) | 7.70 | 1335 |
| Control | 2.52 (5.35) | 1.85 (2.42) | 17.50 (9.04) | 7.85 | 1250 |
| CD5% | 0.18 | 0.11 | 3.32 | - | 152,25 |

4.26.8.3. PAU, Ludhiana

The parasitoids, *Trichogramma brasiliense* and *T. pretiosum, HaNPV* and endosulfan were evaluated alone and in combination for the management of *H. armigera* on tomato.

When *T. pretiosum*, *Ha*NPV and endosulfan were used in different combinations, the mean egg population was highest in the control (8.0/5 plants) and there was no significant difference among the treatments. The larval population in the control (2.4/5 plants) was significantly higher than all other treatments. The lowest larval population (0.3/5 plants) was recorded in *T. pretiosum* + HaNPV + endosulfan and it was significantly lower than 3 sprays of *Ha* NPV and control and was on par with all other treatments (Table 96). The mean egg parasitization was very high in *T. pretiosum* and *T. brasiliense* released plot (36.32% & 33.75%) (Table 97).

Table 96. Integrated Pest Management of H. armigera on tomato (egg and larval population)

| Treatment | Number of releases / sprays | Mean population of H. armigera/5 plants | | |
|-------------------------------------|-----------------------------|--|------------|--|
| | | Eggs | Larvae | |
| Trichogramma pretiosum (T1) | 5 | 4.9 (2.33) | 0.7 (1.29) | |
| T. pretiosum + Endosulfan (T2) | 5+3 | 5.9 (2.51) | 0.6 (1.23) | |
| T. pretiosum + NPV (T3) | 5+2 | 4.1 (2.08) | 0.9 (1.35) | |
| T. pretiosum + NPV (T4) | 5+3 | 4.8 (2.36) | 0.9 (1.35) | |
| T. pretiosum + NPV+ Endosulfan (T5) | 5+3+3 | 3.9 (2.14) | 0.3 (1.14 | |
| NPV (T6) | 5 | 5.4 (2.48) | 0.9 (1.35 | |
| NPV (T7) | 3 | 5.1 (2.42) | 1.2 (1.45 | |
| NPV + Endosulfan (T8) | 3+3 | 5.9 (2.55) | 0.6 (1.24 | |
| T _a Endosulfan (T9) | 3 | 6.2 (2.58) | 0.6 (1.24 | |
| Control (T10) | - | 8.0 (2.94) | 2.4 (1.83 | |
| CD (P=0.05) | - | (0.43) | (0.22 | |

Figure in brackets are transformed means after $\sqrt{n+1}$ transformation

Table 97. Integrated Pest Management of H. armigera on tomato (egg parasitization)

| Treatment | Number of releases/ sprays | Mean per cent parasitization o H. armigera eggs by | | |
|-------------------------------------|-------------------------------|---|----------------|--|
| | | T. pretiosum | T. brasiliense | |
| Trichogramma pretiosum (T1) | 5 | 36.32 | 33.75 | |
| T. pretiosum + Endosulfan (T2) | 5+3 | 12.57 | 9,59 | |
| T. pretiosum + NPV (T3) | 5+2 | 33.26 | 23.52 | |
| T. pretiosum + NPV (T4) | 5+3 | 36.60 | 34.74 | |
| T. pretiosum + NPV+ Endosulfan (T5) | 5+3+3 | 18.28 | 12.49 | |
| NPV (T6) | 5 | 6.96 | 16.96 | |
| NPV (T7) | 3 . | 5.57 | 5.57 | |
| NPV + Endosulfan (T8) | 3+3 | 3.10 | 3.10 | |
| T. Endosulfan (T9) | . 3 | 0.86 | 0.86 | |
| Control (T10) | - | 5.15 | 5.15 | |

When *T. brasiliense*, *Ha*NPV and endosulfan were used in combination, there was no significant difference in mean population of *H. armigera* eggs. However, the mean larval population in the control was significantly higher than all other treatments (Table 98).

Table 98. Integrated Pest Management of H. armigera on tomato (egg and larval population)

| Treatment | Number of releases / sprays | Mean population of H. armigera/5 plants | | |
|---------------------------------------|--------------------------------|--|------------|--|
| | | Eggs | Larvae | |
| Trichogramma brasiliense (T1) | 5 | 4.9 (2.39) | 0.7 (1.29) | |
| T. brasiliense + Endosulfan (T2) | 5+3 | 5.0 (2.35) | 0.6 (1.23 | |
| T. brasiliense + NPV (T3) | 5+2 | 5.8 (2.57) | 0.9 (1.35 | |
| T. brasiliense + NPV (T4) | 5+3 | 5.3 (2.39) | 0.9 (1.35 | |
| T. brasiliense + NPV+ Endosulfan (T5) | 5+3+3 | 5,17 (2.37) | 0.3 (1.14) | |
| NPV (T6) | 5 | 5,42 (2.48) | 0.9 (1.35 | |
| NPV (T7) | 3 | 5.1 (2.42) | 1.2 (1.45 | |
| NPV + Endosulfan (T8) | 3+3 | 5.9 (2.55) | 0.6 (1.24) | |
| T ₉ Endosulfan (T9) | 3 | 6.3 (2.58) | 0.6 (1.24) | |
| Control (T10) | * | 8.0 (2.94) | 2.4 (1.83) | |
| CD (P=0.05) | | NS | (0.21) | |

Figure in brackets are transformed means after $\sqrt{n+1}$ transformation

The lowest fruit damage (9.11 %) was given by T. brasiliense + HaNPV + endosulfan and it was significantly better than all other treatments except five sprays of HaNPV. All the treatments gave significantly higher yield than control (Table 99). Highest yield (348.53 q/ha)was given by T. brasiliense + HaNPV + endosulfan (T_5) and it was significantly higher than all other treatments except five sprays of HaNPV (Table 99).

Table 99. Integrated Pest Management of tomato fruit borers (fruit damage and marketable yield)

| Treatments | Number of releases / spray | Per cent fruit damage | Marketable yield (q/ha) |
|----------------------------------|----------------------------------|--------------------------|----------------------------|
| Trichogramma pretiosum | 5 | 14.10 (22.04) | 296.20 |
| T. pretiosum + Endosulfan | 5+3 | 12.78 (20.88) | 321.66 |
| T. pretiosum + NPV | 5+2 | 13.69 (21.70) | 304.27 |
| T. pretiosum + NPV | 5+3 | 12.65 (20.77) | 325.87 |
| T. pretiosum + NPV + Endosulfan | 5+3+3 | 7.60 (15.99) | 364.40 |
| Trichogramma brasiliense | 5 | 14.53 (22.36) | 287.93 |
| T. brasiliense + Endosulfan | 5+3 | 13.11 (21.21) | 299,33 |
| T. brasiliense + NPV | 5+2 | 14.96 (22.73) | 283.67 |
| T. brasiliense + NPV | 5+3 | 13.20 (21.27) | 309.67 |
| T. brasiliense + NPV+ Endosulfan | 5+3+3 | 9.11 (17.55) | 348.53 |
| NPV | 5 | 10.13 (18.54) | 341.33 |
| NPV | 3 | 14.62 (22.46) | 281.33 |
| NPV + Endosulfan | 3+3 | 11.53 (19.82) | 333.13 |
| Endosulfan | 3 | 14.21 (22.12) | 286.46 |
| Control | | 22.51 (28.29) | 240.33 |

Figures in brackets are arc sine transformations

4.26.8.4. GAU, Anand

The following module was evaluated against tomato fruit borer, H. armigera with a control.

- 1. Interspersing marigold with tomato.
- Inundative release of Trichogramma chilonis @ 50,000/week synchronizing with Helicoverpa oviposition in tomato
- Hand picking of H. armigera at weekly interval and placing them in cages installed in the field which will facilitate escape of parasitoids

- 4. Perching sites for insectivorous birds (50 perches/h).
- 5. Need based application of HaNPV @ 1.5 X 10 12 /h.

Egg and larval population of *H. armigera* and percentage damage were lower and yield and percentage parasitism higher in IPM plots that control (Table 100).

Table 100. Effectiveness of different treatments against H. armigera on tomato

| Treatments | IPM | Control | STD | Error | T |
|--------------------|-------|---------|------|-------|-------|
| Eggs/20 Plants | 5.2 | 19.35 | 3.80 | 1.32 | 9.47 |
| Larvae/20 plants | 2.25 | 8.45 | 1.82 | 0.64 | 8.58 |
| Percent damage | 1.51 | 10.80 | 1.60 | 0.71 | 12.05 |
| Percent parasitism | 24.12 | 7.28 | ş | 621 | - |
| Yield (kg/ha) | 1615 | 1185 | * | | - |

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

4.27.1. Evaluation of release methods of parasitoids *Copidosoma koehleri* and *Chelonus blackburni* and microbial agents against PTM on potato in country stores (*Arnies*)

An experiment was conducted at Entomology Section, College of Agriculture, Pune to evaluate release methods of *Copidosoma koehleri* and *Chelonus blackburni* and microbial agents (granulosis virus (GV) & *Bacillus thuringiensis* (Bt)) against PTM on potato in country stores (*Arnies*) house.

Release of *C. koehleri* @ 1 mummy/4 kg tubers and *C. blackburni* @ 2 adults/kg tubers at fortnightly interval was found to be the most effective at 30 and 75 days after initiation of treatments resulting in 10.83 and 19.20% tuber infestation, respectively. Application of *Bt* @ 1 g/kg of tubers at monthly interval was on par with these treatments. Maximum parasitism (52.33%) due to release of *C. blackburni* adults and infection up to 62.66% due to GV @ 1 LE/kg tubers (62.66%) were recorded (Table 101).

Table 101. Efficacy of release method of parasitoids and microbial agents against PTM in country stores (Arnies)

| Treatment | Mean tuber infestation (%)* after | | Parasitism / disease development |
|--|---|------------------|--|
| | 30 DAT | 75 DAT | (%) |
| C. koelileri @ 5 pairs of adult/kg tubers at 15 days | 13.45 (21.44) | 20.72 (27.05) | 47.33 |
| C. koehleri 1 mummy/4 kg tubers at fortnight interval | 10.83 (19.19) | 20.58 (26.92) | 50.66 |
| C. blackburni @ 2 adults/kg tubers at fortnight interval | 14.83 (22.62) | 19.20 (25.98) | 52.33 |
| C. blackburni @ 2 pupae/kg tubers at fortnight interval | 11.70 (19.98) | 24.18 (29.39) | 40.82 |
| GV @ 1 LE/kg tubers at monthly interval | 18.16 (25.20) | 28.73 (32.39) | 62.66 |
| B. thuringiensis @ 1.0g/kg tubers at monthly interval | 12.42 (20.61) | 22.70 (28.39) | 17.45 |
| Untreated control | 28.86 (32.47) | 38.87 (38.56) | - |
| C.D. (P=0.05) | (3,20) | (4.16) | |

Figures in parentheses are angular transformations; DAT: Days after treatment

4.27.2. Standardization of mass release technology for parasitoids *Copidosoma koehleri* and *Chelonus blackburni* against PTM under field conditions

An experiment was conducted in a farmer's field to standardize mass release technology for parasitoids *Copidosoma koehleri* and *Chelonus blackburni* against PTM under field conditions at Peth village in Pune district during *rabi* 2001-2002, on potato variety 'Kufri Jyoti' in 20 x 10 m² plots with spacing of 45 x 30 cm.

Among three methods of release tested for each parasitoid, release of *C. koehleri* @ 5,000 mummies/ha in four equal doses at weekly interval in perforated plastic vials (2 x 1.5 cm size) hung at 5 m distance in potato fields 45 days after planting (DAP) recorded minimum PTM leaf mines (0.47 mines/m row), least tuber infestation (6.27%), maximum recovery (19.33%) and highest tuber yield (227.8 q/ha). Release of *C. blackburni* @ 60,000 pupae/ha by the same method was also found effective (Table 102).

Table 102. Efficacy of different methods of release of parasitoids against PTM on potato under field conditions

| | | | Leaf mines/m row* | s/m row* | | Percent | Per cent managing | Magn tuhas | |
|---|-------------|-------------|--------------------|---|-------------|--------------------|-------------------|------------------|-------|
| Treatment | Pre-count. | | Post-count inil | Post-count, after weeks from initial release | s from | infestation ** (%) | nu ** (%) | (q/ha) | Yield |
| | | I | n | m | IV | oneggs | on larvae | | |
| C. koehleri @ 5000 mummies An in plastic vials | 3.57 (2.01) | 3.67 | 2.47 (1.72) | 1.47 | 0.47 | 64.50 | 227.8 | 19.33 (14.49) | 6.27 |
| C. koehleri @ 5000 munmies //ha in gelatinous capsules | 3.53 (2.00) | 3.93 (2.10) | 2.73 (1.80) | 2.00 (1.58) | 1.07 | 56.83 | 12.50 | 8.00 (16.43) | 213.1 |
| C. koehleri @ 21akh adults/ha | 3.73 (2.04) | 3.80 (2.07) | 3.33 (1.95) | 1.67 | 1.07 (1.25) | 65.17 | 214.8 | 15.67 (15.30) | 6.97 |
| C. blackburni @ 60000 pupac An in plastic vials | 3.43 | 3.80 (2.07) | 2.13 (1.62) | 1.20 (1.30) | 0.60 | 29.69 | 225.7 | 18.00 (14.80) | 6.53 |
| C. blackburni @ 60000 pupae Ana in gelatinous capsules | 3.20 (1.92) | 3.87 (2.09) | 2.93 (1.84) | 1.73 (1.49) | (1.40) | 59.33 | 194.8 | 10.83 (20.03) | 11.73 |
| C. blackburni @60000 adultha | 3.33 | 3.60 (2.02) | 2.67 (1.78) | 1.53 (1.42) | 0.53 (1.02) | 65.33 | 15.17 | 7.03 (15.38) | 3.20 |
| Untreated control | 4.07 | 6.73 | 6.93 | 3.87 (2.72) | (2.09) | ż | ili. | 27.40 (31.56) | 161.4 |
| C.D. (P=0.05) | (NS) | (NS) | (0.14) | (0.17) | (0.19) | | | (0.84) | 7.65 |

Figures in parentheses are * 7n+0.5 and ** angular transformed values

NS = Non-significant

4.27.3. Large scale evaluation, recovery and carryover of parasitism of *Copidosoma* koehleri and *Chelonus blackburni* against PTM from field to storage

The experiment was conducted in a farmers' field at Malegaon village (Pune district) during *kharif* 2001 on variety 'Kufri Jyoti'.

Large scale release of *C. koehleri* and *C. blackburni* was found significantly more effective than untreated control in reducing PTM leaf mines and tuber infestation and increased parasitoid recovery (14 to 16%) and yield of marketable tubers. Further, the parasitoids were also carried over from field to storage to the extent of 6-9% (Table 103).

4.27.4. Effect of plant products on parasitoids of PTM

Adults of *C. koehleri* and *C. blackburni* were exposed to finely ground foliage powders of 7 plants, *viz.*, nirgundi (*Vitex negundo* Linn), lantana (*Lantana camara* Linn.), basil (*Ocimum sanctum* Linn.), custard apple (*Annona squamosa* Linn.), neem (*Azardirachta indica* Linn.), eucalyptus (*Eucalyptus globulus* Lab.) and paddy straw (*Oryza sativa*). Per cent parasitism, adult emergence and survival were studied.

Paddy straw followed by custard apple, nirgundi and neem products recorded better survival of adult parasitoids (Table 104). Paddy straw also gave maximum parasitisation of *C. koehleri* (16.33%) and *C. blackburni* (23.33%).

4.27.5. Evaluation of different entomopathogens for the control of Spodoptera litura on potato

An experiment was conducted in a farmer's field at Malegaon village (Pune district) on potato variety 'Kufri Jyoti' in plots of 10 x 5m² size and 45 x 30 cm spacing during *kharif* 2001. The trial was laid out in RBD with three replications. The treatments consisted of one spray each of *Sl*NPV, *Bt. Beauveria bassiana, Nomuraea rileyi*, endosulfan and untreated control (given at 52 DAP when 2 larvae/plant were recorded).

Spraying of SINPV @ 500 LE/ha (3x10¹² POBs/ha) was most effective against S. litura and gave lowest larval population (0.20 larvae/plant) and tuber infestation (11.90%) and maximum larval mortality (80%) and yield of marketable tubers (217.3. q/ha). However, Bt. @ 0.5 kg/ha (Delfin WG) was on par with it in respect of larval mortality and yield of tubers (Table 105).

Table 103. Large scale evaluation, recovery and carryover of parasitism of C. koekleri and C. blackburni against PTM from field to storage

| Tratment | | ı, | Leaf mines/m row* | m row* | | Per cent | Per cent parasitism | | | |
|--|-----------|--------|-------------------|---|---------|----------|---------------------|----------------------------------|-----------------|---------|
| | Pre-count | | Post-cour | Post-count, after weeks from initial release | ks from | | | Mean tuber infestation ** (%) | Yield (q/ha) | Регоепт |
| | | 1 | п | Ħ | 2 | On seed | An Innie | | | over |
| C. koehleri @ 2 lakhs adults/ha | 2.11 | 2.51 | 2.00 | 1.60 | 100 | 000 | | | | |
| | (1.61) | (1.73) | (1.62) | (1.45) | (1.12) | 64.07 | 16,50 | 6.24 | 223.2 | 6.80 |
| C. blackburni @ 60,000 adulis/ha | | 242 | 2 . 0 | | | | | (14.39) | | |
| | (1.64) | (171) | (1.63) | (1.50) | 0.89 | 63.50 | 14.36 | 7.17 | 217.5 | 0.37 |
| Untreated control | 000 | | | | (17.7) | | | (15.36) | SON 100 | 2 |
| | (1.64) | (1.77) | (1.86) | 3.20 | 3.06 | 1 | E | 28.18 | 146.7 | |
| CD (P=0.05) | /Mox | 100000 | | | 11100) | | | (32.04) | | |
| And the second s | (Car) | (ex) | (0.12) | (0.19) | (0.21) | | , | 2000 | | |

Figures in parentheses are * \(\sigma_{n+0.5}\) and ** angular transformations; NS = Non-significant

Table 104. Effect of different foliage powders on parasitism, emergence and adult survival of parasitoids of PTM

| | | Per cei | Per cent survival after exposure | after expx | Sure | | Parasitism due to C. koelderi (%) | PTM emergence (%) | Parasitism due to) C. blackburni (%) | PTM emergence (%) |
|-------------------------------------|-------|-------------|----------------------------------|--------------|---------------|-------|-----------------------------------|-------------------------|--|-------------------------|
| | C. | C. koehleri | | C. blax | C. błackburni | | | | | |
| | 24 h | 48 h | 72 h | 24 h | 48 h | 72 h | | | | |
| Nirgundi (Vitex negundo) | 20.00 | 26.67 | 13.33 | 79.96 | 86.67 | 46.67 | 14.00 | 37.00 | 16.67 | 38.00 |
| Lantana (Lantana camara) | 40.00 | 13.33 | 3.33 | 70.99 | 36.67 | 16.67 | 11.33 | 38.67 | 17.33 | 33.00 |
| Basil (Ocimum sanctum) | 6.67 | 0.00 | 0.00 | 10,00 | 3.33 | 00.0 | 3.33 | 22.33 | 3.33 | 28.67 |
| Custard apple (Annona squamosa) | 70.00 | 33.33 | 16.67 | 96.67 | 83.33 | 63.33 | 9.67 | 34.00 | 16.00 | 34.33 |
| Neem (Azardirachta indica) | 56.67 | 23.33 | 3.33 | 90.00 | 63,33 | 30.00 | 12.00 | 36.33 | 18.33 | 34.00 |
| Eucalyptus (Eucalyptus globulus) | 46.67 | 26.67 | 6.67 | 76.67 | 19.99 | 16.67 | 10.33 | 37.33 | 18.00 | 35.00 |
| Paddy straw (Oryzu sativa) | 86.67 | 40.00 | 26.67 | 100.00 90.00 | | 76.67 | 16.33 | 41.33 | 23.33 | 31.33 |

Table 105. Efficacy of different entomopathogens against S. litura on potato

| Treatment | por | Larval pulation / plant* | Larval mortality (%)** | Average tuber (%)** | Yield (q/ha) infestation |
|--|----------------|--------------------------------|------------------------------|---------------------------|-----------------------------|
| | Pre-count | Post-count | | | |
| S/NPV @ 500 LE/ha (3x10 ¹² POBs/ha) | 0.67 (1.08) | 0.20 (0.84) | 80.00 (63.81) | 11.90 (20.15) | 217.3 |
| B. thuringiensis (Delfin WG) @ 0.5 kg/ha | 0.60 (1.05) | 0.32 (0.92) | 72.50 (58.61) | 14.41 (22.30) | 207.5 |
| B. bassiana @ 250 LE/ha (1 x 10 ¹² conidia/ha) | 0.69 (1.09) | 0.42 (0.96) | 45.00 (42.12) | 24,40 (29,60) | 189.1 |
| N. rileyi @ 10º conidia/ml (1 x 1012 conidia/ha) | 0.66 (1.08 | 0.39 (0.94) | 57.50 (49.39) | 22.00 (27.96) | 182.8 |
| Endosulfan 0.07% | 0.59 (1.04) | 0.27 (088) | 67.50 (55.28) | 19.06 (25.88) | 186,4 |
| Untreated control | 0.68 (1.09) | 0.80 (1.14) | 17.50 (24.53) | 35.30 (36.44) | 143,1 |
| C.D. (P=0.05) | (NS) | (0.036) | (7.93) | (1,23) | 17.24 |

Figures in parentheses are * \(n + 0.5 \) and ** angular transformations;

NS = Non-significant

4.28. Biological suppression of weeds

 $4.28.1. Monitoring \ and \ evaluation \ of \ \textit{Neochetina eichhorniae}, \ \textit{N. bruchi} \ and \ \textit{Orthogalumna terebrantis} \ on \ water \ hyacinth$

4.28.1.1. ANGRAU, Hyderabad

Two thousand weevils (*Neochetina* spp.) and 2000 mites (*O. terebrantis*) supplied by Project Directorate of Biological Control, Bangalore, were released in four different ponds in two villages, *viz.* Hassan Nagar and Talabkatta near Hyderabad @ 500/pond separately. Assessment of impact is to be carried out after three months of release.

4.28.1.2. MPKV, Pune

Two fresh ponds with water hyacinth were selected and 2000 adults of *Neochetina* spp., and 40 leaves containing *O. terebrantis* were released in the first week of August 2001. The average damage by feeding of *Neochetina* spp. increased from 12.10% to35.35% from October 2001 to April 2002 and the average weevil population was 1.23/plant in October 2001 and 3.10/plant in April 2002. Mite population also increased from 15.77 during October 2001to 27.01/leaf in April 2002.

4.28.1.3. AAU, Jorhat

Successful control of water hyacinth has been achieved by the exotic weevils *N. eichhorniae* and *N. bruchi*. The dispersal of the weevils has taken place in eight districts of Assam, *viz.*, Sonitpur, Lakhimpur, Dibrugarh, Sibsagar, Jorhat, Golaghat, Nagaon and Kamrup through aerial migration and Brahmaputra river and its tributaries. In Alengmora district, more than 700 ha of water body has been cleared by the action of this exotic weevil and control achieved is about 90%. The weevils were well adapted to the new environment very successfully as evidenced by the presence of larvae and adult weevils on the leaves. The adult count varied from 0.2 to 2.28 and damage scars from 57.32 to 127.40.

4.28.1.4. PAU, Ludhiana

Neochetina eichhorniae and N. bruchi, which were earlier released at Ladowal (Ludhiana district), were collected and released in four new ponds in Ludhiana, Jalandhar, Kapurthala and Nawanshehar districts during February- March 2002. Their breeding and feeding potential is being monitored.

4.28.1.5. KAU, Thrissur

Sampling of water hyacinth plants was done from Ernakulam, Kottayam, Alappuzha and Trichur districts during May 2001-March 2002. Population of adults and grubs of *Neochetina* spp. varied from 2.2 to 6.2 and from 0.1 to 2.9 per cent, respectively. Scars/leaf ranged from 1.9 to 3.8. Population of *O. terebrantis* was 33.96–161.30/leaf during this period and the leaf damage score was 2.28–3.52.

4.28.1.6. GAU, Anand

The weevils have adapted to the new environment very well as evidenced by the presence of the larvae and adults in the bulbs as well as fresh damage observed on the leaves. The adult count of *N. eichhorniae* and *N. bruchi* varied from 1.3 to 3.6 and 1.5 to 4.5 per plant, respectively during different periods. The number of scars varied from 50 to 250 per leaf during 2001.

4.28.2. Monitoring and evaluation of Cyrtobagous salviniae (KAU, Thrissur)

Cyrtobagous weevils were present in all the locations except Thrissur (Vellanchirakkulam) during the sampling period (June-March). The weevil population varied from one to 11 per square foot in different locations.

4.28.3. Parthenium control with Zygogramma bicolorata, under mid-hill conditions (YSPUH & F, Solan)

The field activity of the beetle commenced in mid hills of Solan at 1250m altitude in the second week of June 2001 when scattered egg laying was observed. The activity continued till September, at low levels (0-0.8 beetle, 0-0.4 egg and 0-0.13 larva/plant).

In August, a survey was carried out in five districts of Himachal Pradesh, viz. Solan, Bilaspur, Hamirpur, Kangra and Una, representing subtropical, submontane to sub-temperate and sub-humid mid hill regions of the state. In all, 22 locations were surveyed at an altitude range of 200-1200m msl and in only two locations there was no indication of the beetle (Subathu at 1180m and Dhundhan at 1140 m, both in Solan district). However, the beetle was present in all the five districts. It had well established in Kangra district (200-500 m altitude) where on an average 72.8% (43.5-100%) plants were attacked by it and population per infested plant was also high (mean 8.5, range 1.3-18.3). Similar was the situation at Nadaun in Hamirpur district. Impact of defoliation on growth of the plant was evident at Nadaun (Hamirpur) and Jwalaji (Kangra), where 89-100% plants were attacked and population of larvae and adults was high (73.5 and 56.6%, respectively) and attacked plants had almost dried up. At Nadaun, grubs of *Z. bicolorata* were observed to be predated by the nymphs of a pentatomid bug. Although at Pong Dam (Kangra) population per plant and percentage of damaging stages (74.8%) was high, defoliation was not sufficient to take toll of the attacked plants.

Continuous monitoring of *Z. bicolorata* since its recovery at Solan (Nauni) in 1996 revealed that at altitudes above 1100m, its spread is very slow and at the most the beetle was recorded at 1500m altitude. However, its dispersal and coverage is best at altitudes below 500m.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1. Technology assessed

5.1.1. Mass production of Verticillium chlamydosporium and Paecilomyces lilacinus

Technology for mass production of *Verticillium chlamydosporium* and *Paecilomyces lilacinus* for the control of root knot and reniform nematodes was assessed and standardized.

5.1.2. Standardization of mass release technology for parasitoids *Copidosoma koehleri* and *Chelonus blackburni* against potato tuber moth under field conditions

Technology for release of *Copidosoma koehleri* and *Chelonus blackburni* by placing their mummies/pupae in perforated plastic vials (2 x 1.5 cm size) and gelatinous capsules with holes in potato fields against PTM was assessed and standardized.

5.2. Technology transferred

5.2.1. Large scale evaluation of *Copidosoma koehleri* and *Chelonus blackburni* against potato tuber moth under field conditions

Field demonstrations by releasing *Copidosoma koehleri* and *Chelonus blackburni* against PTM on potato were conducted over 5 ha area on farmer's field at villages Peth and Malegon, Dist-Pune during *kharif* and *rabi* seasons.

6. EDUCATION AND TRAINING

6.1. Education

Ms.A.Sujatha, Technical Officer, CPCRI, Kasargod submitted Ph.D. thesis entitled, "Investigations on natural enemy complex of coconut leaf eating caterpillar, *Opisina arenosella* Walker (Lepidoptera: Oecophoridae) with special reference to egg and early larval parasitoids and predators" to Mysore University, Mysore, in October, 2001.

Miss Tincilley Abraham from the Department of Microbiology, Sri Ramakrishna College of Arts and Science, submitted M.Sc. thesis entitled "Studies on the mass production and pathogenicity of *Beauveria bassiana* and *Nomuraea rileyi*" and Miss. Daisy Leena from the Department of Microbiology, Dr.G.R.Damodaran College of Science, submitted M. Sc. thesis entitled "Studies on mass production and pathogenicity of *Paecilomyces farinosus* and *Paecilomyces lilacinus*."

6.2 Training

Dr.S.K.Jalali, Scientist SS, attended a training programme, "Alternate strategies for insect pest management in major crops" from 11th June to 2nd July, 2001 at Division of Entomology, Indian Agricultural Research Institute, New Delhi.

Dr.(Ms.) J.Poorani, Scientist SS attended a training programme on "Identification and management of mite pests of crops" from 24th June to 14th July 2001 at Department of Entomology, University of Agricultural Sciences, Bangalore.

Dr.T.Venkatesan, Scientist SS attended a training programme "New vistas in biological control of insect pests and weeds" from 4th - 24th September, 2001 at Division of Entomology, Indian Agricultural Research Institute, New Delhi.

Dr.T.Venkatesan, Scientist SS attended a training programme on "Statistical package for social sciences" from 24th - 29th September 2001 at Division of Computer Application, Indian Agricultural Statistical Research Institute, New Delhi.

Dr.(Ms.)K. Veena Kumari, Senior Scientist attended a training on "Recent advances in Baculovirus Research" from 18th January to 7th February, 2002 at the Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore.

Dr. S. J. Rahman, Senior Scientist, attended a training programme on Biological Control of Crop Pests in different cropping systems from 13.8.2001 to 12.10.2001 at Project Directorate of Biological Control, Bangalore.

Ms.I.M.Dautie, Assistant Administrative Officer, attended the training programme on "Vigilance Awareness" from 01-02-2002 to 04-02-2002 at Central Institute of Fisheries Education, Mumbai.

7. AWARDS AND RECOGNITIONS

Dr. S.P. Singh received the following recognitions

Member, Editorial Board of Biocontrol News and Information (BNI), London.

Invited to deliver the prestigious C.P. Alaxender Memorial Lecture by Delhi University.

Dr.M.Mani was declared as Fellow of Plant Protection Association of India, Hyderabad.

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

- 8.1. NATP funded project entitled "Team of Excellence for Human Resource Development in Biological Control" with a total budget of Rs.86.17 lakh for a period of four years from 1999-2000 to 2002-2003. The project is operative at Project Directorate of Biological Control, Bangalore, and the clients are scientists from various State Agricultural Universities, traditional universities and ICAR Institutes. This project will have linkage with all the institutes interested in biocontrol of crop pests and weeds.
- 8.2. NATP funded project entitled "Development of bio-intensive IPM modules in chickpea against *Helicoverpa armigera*, wilt and dry root rot" with a budget of Rs.24.60 lakh for a period of four years from 2000-01 to 2002-2003. The project is operative at Indian Institute of Pulses Research, Kanpur, and Project Directorate of Biological Control, Bangalore, is one of the co-operating centres.
- 8.3. NATP funded project entitled "Control of leaf curl viral disease in cotton and development of protocols for mass multiplication of predators, parasites and insect pathogens" with a budget of Rs.6.44 lakh for a period of three years from 1999-2000 to 2002-2003. The project is operative at Central Institute for Cotton Research, Nagpur, and Project Directorate of Biological Control, Bangalore, is one of the cooperating centres.
- 8.4. NATP funded project entitled "Development of an integrated pest management package for the eriophyid mite, Aceria guerreronis (Keifer) of coconut in the southern states" with a budget of Rs.12.34 lakh for a period of three years from 2000-01 to 2002-2003. The project is operative at Tamil Nadu Agricultural University, Coimbatore, and Project Directorate of Biological Control, Bangalore, is one of the co-operating centres.
- 8.5 NATP funded project entitled "Development of IPM modules for oilseeds and nutritious cereals based production system" with a budget of Rs.15.31 lakh for a period of three years from 2000-01 to 2002-2003. The project is operative at National Centre for Integrated Pest Management, New Delhi, and Project Directorate of Biological Control, Bangalore, is one of the co-operating centres.
- 8.6. NATP funded project entitled "Validation and promotion of IPM Technology in selected crops in different agro-ecological regions" with a total budget of Rs.33.94 lakh for a period of two years and nine months (up to 31-12-2003). The project is operative at National Centre for Integrated Pest Management, New Delhi, and Project Directorate

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of Biological Control, Bangalore, is one of the co-operating centers. The clients are the staff from various co-operating centers of the project and Plant Protection Officers from KVKs. This project will have linkage with all the institutes interested in biocontrol of pests of cotton, pigeon pea, chickpea, groundnut, tomato, cabbage, mango and

- Based on the linkage developed, Coconut Board gave a further financial assistance of 8.7. Rs.13.31 lakh in the second phase for bioefficacy and biosafety tests and generation of data for registration of "Mycohit".
- A linkage has been developed with Ministry of Agriculture, DARE, for mass production 8.8. of quality biocontrol agents/ biopesticides with a financial assistance of 483.00 lakh with five centers, with PDBC as the lead center.
- A linkage has been developed with Ministry of Agriculture, DAC, under Technology 8.9 Mission for Cotton for development and evaluation of location specific IPM modules and for development of efficient strains with a financial assistance of 20.10 lakhs. The project is operative at Central Institute for Cotton Research, Nagpur and Project Directorate of Biological Control, Bangalore, is one of the co-operating centers.

AICRP / COORDINATION UNIT / NATIONAL CENTRES 9.

With a view to fulfil the mandate given, the Project Directorate has divided the workload among six ICAR Institute based and ten State Agricultural University (SAUs) based co-ordinating centres based on infra-structural facilities and expertise available as follows:

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

ICAR Institute based centres

Central Plantation Crops Research Institute, Regional Station, Coconut

Kayangulam (Kerala)

Tobacco Central Tobacco Research Institute, Rajahmundry

(Andhra Pradesh)

Basic Research Indian Agricultural Research Institute,

New Delhi

Fruits & Indian Institute of Horticultural Research, Bangalore vegetables

(Karnataka)

Indian Institute of Sugarcane Research, Lucknow (Uttar Pradesh)
Sugarcane Breeding Institute, Coimbatore (Tamil Nadu)

State Agricultural University based centres

Assam Agricultural University, Jorhat (Assam) Acharya N.G.Ranga Agricultural University, Hyderabad (Andhra Pradesh)

Govind Ballabh Pant University of Agricultural Sciences and Technology, Pantnagar (Uttaranchal) Gujarat Agricultural University, Anand (Gujarat)

Kerala Agricultural University, Thrissur (Kerala)

Mahatma Phule Krishi Vidyapeeth, Pune (Maharashtra)

Punjab Agricultural University, Ludhiana (Punjab)

Sher-E-Kashmir University of Agricultural Sciences & Technology, Srinagar (Jammu and Kashmir) Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu) Dr.Y.S.Parmar University of Horticulture & Forestry, Solan (Himachal Pradesh)

- Sugarcane
- Sugarcane
- Rice and weeds
- Pulses, cotton, vegetables, coconut & weeds
- Basic research & weeds
- Cotton, pulses,
 vegetables & weeds
- Weeds, rice, fruits & coconut
- Potato, weeds, rice, vegetables, sugarcane and cotton
- Sugarcane, cotton, weeds, oilseeds, rice & vegetables
- Temperate fruits & vegetables
- Rice, cotton, pulses, oilseeds & coconut
- Fruits & vegetables

GENERAL / MISCELLANEOUS

10. LIST OF PUBLICATIONS

10.1 Publications in scientific journals

Project Directorate of Biological Control, Bangalore

- Hussaini, S.S., Kavitha J. Satya and Abid Hussain, M. 2001. Tolerance of some entomopathogenic nematode isolates to pesticides, and their effect on survival and progeny production. *Current Nematology*, 12: 29-34.
- Hussaini, S.S., Singh, S.P. and Shakeela, V. 2001. Compatibility of entomopathogenic nematodes (Steinernematidae, Heterorhabditidae: Rhabditida) with selected pesticides and their influence on some biological traits. *Entomon*, 26: 37-44.
- Hussaini, S.S., Singh, S.P., Parthasarathy, R., Shakeela, V. 2001. Comparison of bioassays to measure the infectivity of some isolates of entomopathogenic nematodes against *Agrotis* ipsilon and A. segetum. Current Nematology, 12: 63-68
- Hussaini, S.S., Singh., S.P., Parthasarathy, R. and Shakeela, V. 2001. Determination of dosage levels of *Steinernema bicornutum* and *Heterorhabditis indica* (Rhabditida) for *in vitro* use against *Agrotis ipsilon* (Hufnagel) (Noctuidae: Lepidoptera). *Entomon*, 26(1): 37-44.
- Jalali, S.K. and Singh, S.P. 2001. Distribution of *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) on fodder maize in different seasons in Bangalore. *Journal of entomological Research*, 25: 27–30.
- Jalali, S.K. and Singh, S.P. 2001. Life table studies on the natural enemies of *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae). *Journal of Biological Control*, 15: 113-118.
- Jalali, S.K. and Singh, S.P. 2001. Studies on monitoring of *Chilo partellus* (Swinhoe) population during different seasons through pheromone traps on fodder maize. *Indian Journal of Ecology*, 28: 131–138.
- Jalali, S.K. and Singh, S.P. 2001. Studies on the thermal requirements for estimating the number of generations of *Chilo partellus* (Swinhoe) and its natural enemies in the field. *Annals of Plant Protection Sciences*, 9: 213–138.

- Jalali, S. K., Singh, S. P. and Venkatesan, T. 2001. Choice of suitable trichogrammatid species for suppression of diamondback moth *Plutella xylostella* (Linnaeus) (Lepidoptera: Yponomeutidae) on cabbage. *Shashpa*, 8: 161 – 166.
- Joshi, S., Poorani, J. and Singh, S. P. 2001. Bioecology of Sticholotis cribellata Sicard (Coleoptera: Coccinellidae), a potential predator of Melanaspis glomerata (Green) (Homoptera: Diaspididae). Journal of Biological Control, 15: 21-26.
- Kumar, P. S., Singh, S. P. and Anuroop, C. P. 2001. First report of Sporothrix fungorum de Hoog & de Vries as a pathogen of Aceria guerreronis Keifer, the coconut eriophyid mite. Insect Environment, 7: 106-107.
- Kumar, P. S., Singh, S. P. and Gopal, T. S. 2001. Natural incidence of *Hirsutella thompsonii* Fisher on the coconut eriophyid mite, *Aceria guerreronis* Keifer in certain districts of Karnataka and Tamil Nadu in India. *Journal of Biological Control*, 15(2): 151-156.
- Kumar, P. S. and Singh, S. P. 2002. Wettable sulphur is toxic to *Hirsutella thompsonii*, the most important natural enemy of the coconut mite. *Indian Coconut Journal*, 33(1): 1-2.
- Kumar, P. S. and Singh, S. P. 2001. Coconut mite in India: Biopesticide breakthrough. Biocontrol News and Information, 22 (4): 76N-78N.
- Narayanan, K. and B.L. Tandi 2001. Occurrence of entomopoxvirus on whitegrub, *Holotrichia consanguinea* Blanch. (Coleoptera: Scarabaeidae). *Insect Environment*, 7: 104-106.
- Poorani, J. 2002. An annotated checklist of the Coccinellidae (Coleoptera) (excluding Epilachninae) of the Indian subregion. *Oriental Insects*, 36: 307-383.
- Poorani, J. 2002. A review of the genus *Oenopia* Mulsant (Coleoptera: Coccinellidae) from the Indian subcontinent, with description of a new species. *Oriental Insects*, 36: 97-116.
- Prasada Rao, G.M.V., Ramani, S. and Singh, S.P. 2001. Field parasitisation of the maize stem borer *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) in Bangalore. *Journal* of *Biological Control*, 15: 193-195.
- Prasada Rao, G.M.V., Ramani, S. and Singh, S.P. 2001. Studies on *Cotesia flavipes* and *Tetrastichus howardi* parasitoids of the maize stem borer *Chilo partellus* (Swinhoe). *Insect Environment*, 7 (3): 112-113.
- Rai, A. K., Ballal, C. R. and Srinivasan, R. 2001. Effect of continuous and selective laboratory rearing of Helicoverpa armigera (Huebner). Nature Conservators, 13 (1): 57-60.

- Ramani, S., Poorani, J. and Bhumannavar, B.S. 2002. Spiralling whitefly, Aleurodicus dispersus Russell (Homoptera: Aleyrodidae) in India. Biocontrol News and Information, 23 (in press).
- Singh, S. P., Jalali, S. K. and Venkatesan, T. 2000. Susceptibility of diamondback moth and its egg parasitoid to a new *Bt* formulation. *Pest management in Horticultural Ecosystems*, 6: 114 117.
- Venkatesan, T., Singh, S.P. and Jalali, S.K. 2001. Development of Cryptolaemus montrouzieri Mulsant (Coleoptera: Coccinellidae), a predator of mealybugs on freeze-dried artificial diet. Journal of Biological Control, 15: 139-142.
- Yadav, R. C., Singh, S. P., Jalali, S. K. and Rao, N. S. 2001. Effect of host density on parasitism and adult emergence in *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) in two systems. *Journal of Biological Control*, 15: 11–14.

Central Tobacco Research Institute, Rajahmundry

Gunneswararao, S. and Sitaramaiah, S. 2001. Application strategies for microbial pesticides against *Spodoptera litura* and *Helicoverpa armigera* in tobacco. *Tobacco research*, 27(1): 1-6.

Indian Institute of Horticultural Research, Bangalore

- Ganga Visalakshy, P.N. 2001. Artificial diet for mass multiplication of Bactra venosana Zeller (Lepidoptera: Tortricidae), a potential natural enemy of Cyperus rotundus Linn. Pest management in Horticultural Ecosystems, 7: 134-136.
- Ganga Visalakshy, P. N. and Krishnan, S. 2001. Propagation of Ceutorhynchus portulacae, a potential biocontrol agent of Portulaca oleracea. Entomon, 26: 79-85.
- Ganga Visalakshy, P.N and Gopalakrishnan, C. 2001. *Encarsia* sp. a natural enemy of *Bemisia tabaci* infesting gerbera under polyhouse conditions. *Insect Environment*, 7:
- Ganga Visalakshy, P.N. and Krishnan, S. 2001. Quiescence behaviour in Ceutorhynchus portulacae Marshall, a potential biocontrol agent of the purslane weed Portulaca oleracea. Journal of Biological Control, 15: 27-30
- Krishnamoorthy, A., Mani, M. and Rama, N. 2001. Sex ratio and longevity of *Hemiptarsenus varicornis* (Girault) (Eulophidae: Hymenoptera), a parasitoid of serpentine leaf miner, *Liriomyza trifolii* (Burgess) (Agromyzidae: Diptera). *Insect Environment*, 7(2): 61

- Krishnamoorthy, A., Rama, N. and Mani, M. 2001. Laboratory evaluation of the potential of Hemiptarsenus varicornis (Girault) (Eulophidae: Hymenoptera) in controlling serpentine leaf miner, Liriomyza trifolii (Burgess) (Agromyzidae: Diptera). Pest management in Horticultural Ecosystems, 7(2): 130–133.
- Mani, M. and Krishnamoorthy, A. 2000. Safety of plant products and conventional pesticides to *Distatrix papilionis* (Viereck) (Hymenoptera: Broconidae), a parasitoid of citrus butterfly. *Indian Journal of Plant Protection*, 28(1): 19-24.
- Mani, M. and Krishnamoorthy, A. 2000. Biological suppression of mealybugs *Planococcus citri* (Risso) and *Planococcus lilacinus* (Ckll.) on pomegranate in India. *Indian Journal of Plant Protection*, 28(2): 187-189.
- Mani, M., Raghunatha, R. and Krishnamoorthy, A. 2001. Spiralling whitefly Aleurodicus dispersus Russell in Hyderabad. Insect Environment, 7(2): 82.
- Mani, M. and Krishnamoorthy, A. 2001. Managing scale insects on fruit crops. *Indian Horticulture*, 46(3): 4-7.

Sugarcane Breeding Institute, Coimbatore

- Easwaramoorthy, S., Nirmala, R. and Santhalakshmi, G. 2001. Occurrence of Metarhizium anisopliae (Metschnikov) Sorokin var. anisopliae on sugarcane internode borer Chilo sacchariphagus indicus (Kapur). Journal of Biological Control, 15: 81-84.
- Easwaramoorthy, S., Nirmala, R. and Santhalakshmi, G. 2001. Biology and predatory potential of Micraspis univitata (Hope), a coccinellid predator recorded in sugarcane ecosystem. Journal of Biological Control, 15: 97-100.
- Karunakar, G., Easwaramoorthy, S. and David, H. 2001. Influence of storage temperature, population density and duration of storage on the survival of three species of entomopathogenic nematodes. *Journal of Biological Control*, 15: 183-188.
- Srikanth, J., Easwaramoorthy, S. and Kurup, N. K. 2001. Camponotus compressus F. interferes with Cryptolaemus montrouzieri Mulsant activity in sugarcane. Insect Environment, 7: 51-52.

Assam Agricultural University, Jorhat

Basit, A. and Bhattacharya, B. 2001. Biocontrol potential and its exploitation in sustainable agriculture. *Insect Pests*, 2: 113-130.

- Basit, A., Saikia, K. and Bhattacharya, B. 2001. Varietal responses of *Trichogramma chilonis* Ishii in laboratory. *Insect Environment*, 7(1): 22-23.
- Bhattacharya, B., Basit, A. and Saikia, K. 2001. Orientation response of *Bracon hispae* to different coloured stimuli. *Insect Environment*, 7(1): 21-22.
- Borah, M., Basit, A. and Nath, R. K. 2001. Effect of certain insecticides on the parasitisation and emergence of the egg parasitoid, *Trichogramma japonicum*. Crop Research, 22(1): 138-140.

Gujarat Agricultural University, Anand

Jha, A., Yadav, D. N. and Komala Devi, P. 2001. Evaluation of toxicity of some insecticides against Geocoris ochropterus Fieber (Hemiptera: Lygaeidae) Pestology, 25 (7): 12

Kerala Agricultural University, Thrissur

- Lyla, K.R., Abraham, C.C and Joy, P.J. 2001. Metabolic changes in Siam weed. Chromolaena odorata induced by feeding of weed killer, Pareuchaetes pseudoinsulata (Arctiidae: Lepidoptera). Journal of Tropical Agriculture, 39: 35-37.
- Sajithakumari and Lyla, K.R. 2001. A survey of the pests of orchids. *Journal of Tropical Agriculture*, **39**: 32.
- Sajithakumari and Lyla, K.R. 2001. Management of *Limax* sp. (Limacidae: Stylomatophora), a pest of orchids in Kerala. *Journal of Tropical Agriculture*, **39**: 80-81.

College of Agriculture (Mahatma Phule Krishi Vidyapeeth), Pune

- Pokharkar, D. S., Charati, S. N., Bade, B. A. and Ghorpade, S. A. 2001. Evaluation of biocontrol agents for managing Spodoptera litura damaging potato (Solanum tuberosum). Indian Journal of Agricultural Sciences, 71(12): 52-54.
- Pokharkar, D. S., Hadapad, A. B. and Puranik, T. R. 2002. Bioassay and persistence of Bacillus thuringiensis Berliner against Plutella xylostella (Linn.) on cabbage. Annals of Plant Protection Sciences, 10(1): 1-4.

Punjab Agricultural University, Ludhiana

Ashwani Kumar, S. and Shenhmar, M. 2001. Utilization of different cereal grains for mass production of Corcyra cephalonica (Stainton) (Lepidoptera: Pyralidae). Journal of Biological Control, 15(2): 147-150.

- Brar, K. S., Khosa, S. S. and Sekhon, B. S. 2000. Host searching capacity of laboratory reared and field collected population of *Trichogramma chilonis Ishii*. *Journal of Biological Control*, 14(2): 29-33.
- Brar, K. S., Shenhmar, M. and Singh, J. 2001. Integrated pest management in sugarcane. *Progressive Farming*, **38**(6): 13-16.
- Brar, K. S., Shenhmar, M. and Singh, J. 2001. Kamad De Hanikarak Kirhian Dee Sarvpakhi Roktham. Changi Kheti, 37(6): 15-18.
- Joshi, N., Brar, K. S. and Shenhmar, M. 2001. Comparative efficacy of HaNPV Bathinda isolate and Helicide HaNPV against Helicoverpa armigera (Hubner). Insect Environment, 7(2): 90-91.
- Joshi, N., Shenhmar, M. and Brar, K. S. 2001. Fungal isolates of carrot weed, Parthenium hysterophorus L. from Punjab. Journal of Biological Control, 15(1): 101-102.
- Kaur S., Shenhmar, M. and Brar, K. S. 2001. Spider fauna of paddy in Punjab. Insect Environment, 7(1): 24-25.
- Khosa, S. S. and Brar, K. S. 2000. Effect of storage on the emergence and parasitisation efficiency of laboratory reared and field collected population of *Trichogramma chilonis*. *Journal of Biological Control*, 14(2): 71-74.
- Shenhmar, M. and Brar, K. S. 2001. Tricho-baloon: A new technique for release of adult trichogrammatids. *Insect Environment*, 7(2): 88-89.
- Singh, J., Brar, K. S., Shenhmar, M. and Bakhetia, D. R. C. 2000. Effect of cold storage on the emergence, sex-ratio and parasitisation efficiency of *Trichogramma japonicum* Ashmead. *Journal of Insect Science*, 13(1): 55-56.

Sher-e-Kashmir University of Agricultural Science & Technology, Srinagar

Zaz, G.M. 2001. Biology of *Hyalopterus pruni* (Geoffroy) in Kashmir. *SKUAST Journal of Research*, **3**: 89-95.

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

Dayal, K. and Gupta, P.R. 2001. Predatory potential of the larvae of the hover fly, *Betasyrphus serarius* (Wiedemann) on *Aphis fabae solanella* (Theobald). *Insect Environment*, 6(4): 150-151.

Dayal, K. and Gupta, P.R. 2001. Biology and feeding potential of *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae), a predator of cabbage aphid, *Brevicoryne brassicae* L. (Homoptera: Aphididae). *Journal of Aphidology*, 15: 191-194.

Papers presented in Seminars/Symposia/Workshops/Meetings/Training

Project Directorate of Biological Control, Bangalore

- Bajpai, N. K., Ballal, C. R. and Singh, S. P. 2001. Preference of Telenomus remus Nixon for Spodoptera litura (Fabricius) eggs on different soyabean varieties, pp. 46-47. In Biological Control-Contributed papers-Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19, 2001) at PAU, Ludhiana (Eds. Darshan Singh et al., 224 pp.
- Ballal, C. R. and Singh, S. P. 2001. Comparative studies on pheromone trap catches of Helicoverpa armigera (Hubner) in sunflower and pigeonpea ecosystems, pp. 177-179. In Biological Control-Contributed papers-Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19, 2001) at PAU, Ludhiana (Eds. Darshan Singh et al., 224 pp.
- Ballal, C. R., Jalali, S. K., Sunil Joshi and Rao, N. S. 2001. Variations in populations of Campoletis chlorideae Uchida and Helicoverpa armigera (Hubner) from different crop ecosystems, pp. 11-12. In Biological Control – Contributed papers – Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19, 2001) at PAU, Ludhiana (Eds. Darshan Singh et al., 224 pp.
- Ballal, C. R., Sunil Joshi and Rao, N. S. 2001. Bio-deterioration of laboratory cultures of Campoletis chlorideae Uchida, pp. 210-213. In IPM in Horticultural Crops: Emerging Trends in the New Millennium; Proceedings of the Second National Symposium on Integrated Pest Management (IPM): New molecules, Bio-Pesticides and Environment. October 17 - 19, 2001, Bangalore. (Eds. A. Verghese and P. P. Reddy), 257 pp.
- Baktavatsalam, N., Singh, S.P., Tandon, P.L., Hanumantharaya Rao, L. and Vellaikumar, S. 2001. Influence of different cultivars of sunflower on the electroantennogram response and behaviour of Chrysoperla carnea (Stephens) (Neuroptera: Chrysopidae), pp. 52-53. In: Biological Control (Contributed Papers), Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19), D. Singh et al., (Eds.).

- Bhumannavar, B. S. and Ramani, S. 2001. A laboratory mass culturing technique for the American serpentine leaf-miner, *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) for rearing its natural enemies, p. 9 (abstract.) In: Symposium on Biocontrol Based Pest management for Quality Crop Protection in the Current Millennium, 17-18 July, 2001, PAU, Ludhiana.
- Hussaini, S.S. 2001. Mass production and use of entomopathogenic nematodes for insect control. Lead paper presented at National Congress on Centenary of Nematology in India-Appraisal and future plans, Dec. 5-7, 2001, IARI, New Delhi, p. 40.
- Hussaini, S.S. and Sankaranarayanan, C. 2001. Effect of soil type and depth on pathogenicity of indigenous isolates of entomopathogenic nematodes. In: National Seminar on Emerging Trends in Pests and Diseases and Their Management, October 11-13.2001, pp.57-58
- Hussaini, S.S., Singh, S.P. and Shakeela, V. 2001. Effect of different host plants on infectivity and progeny production of entomopathogenic nematodes, (Steinernematidae, Heterorhabditidae: Rhabditida) in Agrotis ipsilon, pp. 223-225. In: IPM in Horticultural Crops: Emerging Trends in the New Millennium: Proceedings of Second National Symposium on IPM in Horticultural Crops, New Molecules, Biopesticides and Environment, A. Verghese and P. P. Reddy (Eds.). October 17-19, 2001. IIHR, Bangalore, India, 257 pp.
- Hussaini, S.S., Singh, S.P. and Shakeela, V. 2001. Influence of temperature on infectivity of entomopathogenic nematodes to black cutworm, Agrotis ipsilon larvae. In: National Congress on Centenary of Nematology in India-Appraisal and Future Plan. Indian Agricultural Research Institute, New Delhi, 5-7 Dec., 2001.
- Hussaini, S.S., Singh, S.P. Parthasarathy, R. and Shakeela, V. 2001. Encapsulated entomopathogenic nematode, Steinernema bicornutum PDBC EN 3.2 as a bait for control of black cutworm, Agrotis ipsilon. Proceedings of Symposium on Biocontrol based Banagement for Quality Crop Protection in the Current Millennium, Punjab Agricultural University, Ludhiana, July 18-19, 2001, p. 104.
- Hussaini, S.S., Kavita J. Satya and Abid Hussain, M. 2001. Survival and pathogenicity of indigenous entomopathogenic nematodes in different UV protectants. In: National Congress on Centenary of Nematology in India-Appraisal and Future Plans. Dec. 5-7, 2001, IARI, New Delhi – 12, p.120.

- Hussaini, S.S., Singh, S.P., Parthasarathy, R. and Shakeela, V. 2001. Effect of different host plants on infectivity and progeny production of entomopathogenic nematodes (Steinernematidae, Heterorhabditidae: Rhabditida) in Agrotis ipsilon. In: Proceedings of the Second National Symposium Integrated Pest management in Horticultural Crops New molecules, Biopesticides and Environment, Institution of Agricultural Technologists, Bangalore, October 17-19, 2001, pp. 204-206.
- Hussaini, S.S., Kavita J. Satya and Abid Hussain, M. 2001. Effect of metal ion on activity of EPN. In: Proceedings of the Second National Symposium—Integrated Pest management in Horticultural Crops-New molecules, Biopesticides and Environment, Institution of Agricultural Technologists, Bangalore, 17-19, October, 2001.
- Jalali, S. K. and Ramani, S. 2001. Toxicity of Spinosad to natural enemies of cabbage diamondback moth *Plutella xylostella* (Linnaeus) (Lepidoptera: Yponomeutidae). In: *IPM in Horticultural Crops: Emerging Trends in the New Millennium* (Eds. A. Verghese and P. P. Reddy). Proceedings of Second National Symposium on IPM in Horticultural Crops: New Molecules, Biopesticides & Environment, October 17 – 19, 2001, Bangalore.
- Jalali, S.K. and Singh, S.P. 2001. Effect of abiotic and biotic factors on population dynamics of Chilo partellus (Swinhoe), p. 73. In: Biological Control (Contributed Papers), Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19), D. Singh et al. (Eds.). Punjab Agricultural University, Ludhiana, India, 224+4 pp.
- Jalali, S.K., Singh, S.P. and Venkatesan, T. 2001. Natural enemies of cotton bollworms in sprayed farmers' fields in different states of India, p. 157. In: Biological Control (Contributed Papers), Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19), D. Singh et al. (Eds.). Punjab Agricultural University, Ludhiana, India, 224+4 pp.
- Kumar, P. S. and Singh, S. P. 2001. Mycoacaricides: The emerging class of biopesticides. In: Proceedings of the III Asia Pacific Crop Protection Conference-2001, Pesticide Manufacturers and Formulators Association of India, Habitat Centre, New Delhi, 6-7 September 2001, pp. 60-67.
- Kumar, P. S. and Singh, S. P. 2001. Mycohit: The mycoacaricide based on the fungus Hirsutella thompsonii for the biological control of the coconut mite. Paper distributed at the Meeting convened by the Hon'ble Minister for Social Welfare and Horticulture, Government of Karnataka, to discuss the action to be taken to mitigate the problem of the coconut mite and black-headed caterpillar pests in Karnataka, 26 September 2001, 2 pp.

- Kumar, P. S., Singh, S. P., Anuroop, C. P. and Ramachandra, C. G. 2001. Acaropathogenic fungi associated with the coconut eriophyid mite (*Aceria guerreronis*) in south India. In: Abstracts of Papers, National Seminar on Emerging Trends in Pests and Diseases and Their Management, Tamil Nadu Agricultural University, Coimbatore, 11-13 October 2001, pp. 99-100.
- Kumar, P. S., Singh, S. P. and Anuroop, C. P. 2002. Microbial control of the coconut mite with 'Mycohit', the first Indian mycoacaricide based on *Hirsutella thompsonii*. Abstracts of Papers, Fifty-fourth Annual Meeting and National Symposium on Crop Protection and WTO-An Indian Perspective, Central Plantation Crops Research Institute, Kasaragod, 22-25 January 2002, pp. 103-104.
- Kumar, P. S. and Singh, S. P. 2002. Development of 'Mycohit', the first mycoacaricide based exclusively on *Hirsutella thompsonii*, for suppressing the coconut mite in India. pp. 209-213. In: *Bioinoculants for Sustainable Agriculture and Forestry* (S. M. Reddy, S. Ram Reddy, M. A. Singarachary and G. Girisham, Eds.), Scientific Publishers (India), Jodhpur, India.
- Kumar, P. S., Singh, S. P., Marulasiddesha, K. N. and Anuroop, C. P. 2002. Role of the acaropathogenic fungus, *Hirsutella thompsonii* Fisher, in the natural suppression of the coconut eriophyid mite, *Aceria guerreronis* Keifer, in Andhra Pradesh, India. pp. 215-221. In: *Bioinoculants for Sustainable Agriculture and Forestry* (S. M. Reddy, S. Ram Reddy, M. A. Singarachary and G. Girisham, Eds.), Scientific Publishers (India), Jodhpur, India.
- Nagesh, M. and Hussaini, S. S. 2001. Efficacy of some antagonistic fungi against Meloidogyne incognita and Rotylenchulus reniformis infecting cowpea. National Symposium on "Biocotrol Based Pest Management for Quality Crop Protection in the Current Millennium". 18-19 July, 2001, SBA & ISASC, 122-123, PAU, Ludhiana.
- Nagesh, M., Hussaini S. S. and Singh, S. P. 2001. An easy and rapid technique for screening antagonistic fungi against nematodes on host plant. National Seminar on "Emerging Trends in Pests and Diseases and their Management" 11-13 October, 2001, Centre for Plant Protection Studies and TNAU, Coimbatore. pp. 178.
- Nagesh, M., Hussaini, S. S., Singh, S. P. and Gopinatha, K. V. 2001. Management of root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood in chrysanthemum using formulations of *Paecilomyces lilacimus* in combination with neem cake. Second National Symposium on "IPM in Horticultural Crops: New Molecules, Biopesticides and Environment". 17-19 October, 2001, AAPMHE, IIHR, Bangalore, pp. 149.

- Nagesh, M. and Hussaini, S. S. 2001. Dose optimization of antagonistic fungi against root-knot and reniform nematodes in tomato under microplot conditions. National Congress on Centenary of Nematology in India-Appraisal and Future Plans. 5-7 December, 2001. Nematological Society of India, IARI, New Delhi, pp. 146.
- Narayanan, K. 2001. Studies on the occurrence, gross pathology, histopathology and safety of entomopoxvirus of gram pod borer, *Helicoverpa armigera*. Paper presented during Symposium on "Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium" at Punjab Agricultural University, Ludhiana, July 18-19, (Abstract) pp. 138-139.
- Narayanan, K. and Sharma, K. K. 2001. Investigations on the dose-mortality relationship of nuclear polyhedrosis virus of potato cutworm, *Agrotis segetum*. Paper presented during Symposium on "Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium" at Punjab Agricultural University, Ludhiana, July 18-19,2001 (Abstract), pp 137-138.
- Narayanan, K. and Sharma, K. K. 2001. Effect of Agrotis segetum nuclear polyhedrosis virus on its food consumption and its safety towards mulberry silkworm, Bombyx mori and common predator, Chrysoperla carnea. Paper presented during Symposium on "Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium" at Punjab Agricultural University, Ludhiana, July 18-19,2001 (Abstract), pp 136-137.
- Narayanan, K. and Veenakumari, K. 2001. Entomopoxvirus: A new insect virus for the control of maize stem borer, *Chilo partellus* Swinhoe (Pyralidae: Lepidoptera). National symposium on Biological control of insect pests, Feb. 7-8, 2002, at Loyola College, Chennai, Abstract. p 24.
- Narayanan, K. and Veenakumari, K. 2001. Observations on the new NPV of the coconut skipper, *Gangara thyrsis* (Fab). National Symposium on Biological control of Insect Pests, Feb. 7-8, 2002, at Loyola College, Chennai, (Abstract.) pp. 48-49.
- Narayanan, K. and Veenakumari, K. 2001. Occurrence of nucleopolyhedrosis virus on the mottled emigrant white butterfly, *Catopsilia pyranthe* (Linn.). Proceedings of the second National symposium on Integrated Pest Management (IPM) in Horticultural Crops: New Molecules, Biopesticides and Environment. Oct. 17-19th 2001, Bangalore, India. (Abstract.), pp. 233-234.

- Narayanan, K. and Gopalakrishnan, C. 2001. Field efficacy of Steinernema feltiae (Rhabditida: Steinernmetidae) (DD-136) against the larval population of Athalia lugens proxima on radish. Proceedings of the Second National Symposium on Integrated Pest Management (IPM) in Horticultural Crops: New Molecules, Biopesticides and Environment. Oct. 17-19th 2001, Bangalore, India. Abstract. pp. 199-200.
- Padmanabhan, B., Sundararaju, P., Cannayane, I. and Hussaini, S.S. 2001. Effect of entomopathogenic nematode, Heterorhabditis indica against banana stem weevil, Odoiporus longicollis. In: National Congress on Centenary of Nematology in India Appraisal and Future Plans. Dec. 5-7, 2001, IARI, New Delhi p.121.
- Ramani, S. and Bhumannavar, B. S. 2001. Introduction of an aphelinid parasitoid of the spiralling whitefly, *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae) into India. Presented in the poster session I: Symposium on "Biocontrol Based Pest management for Quality Crop Protection in the Current Millennium" held at PAU, Ludhiana, 17-18 July, 2001.
- Ramani, S. and Bhumannavar, B. S. 2001. Spiralling whitefly, Aleurodicus dispersus Russell (Homoptera: Aleyrodidae) in India and options for management of the pest. Proceedings of "Emerging Trends in Pests and Diseases and their Management", TNAU, CPPS, Coimbatore, 11-12 October, 2001 Ab. No. 76 pp. 72-73 PP.
- Ramani, S., Poorani, J. and Singh, S.P. 2001. Biological control and insect biodiversity an Indian Perspective, p. 13 (abstract). In: Proceedings, National Symposium on Biodiversity vis-à-vis resource exploitation: An Introspection, held during April 23-24, 2001, Andaman Science Association, CARI, Port Blair, Andamans.
- Ramani, S., Poorani, J. and Singh, S.P. 2001. Insect Biodiversity and Biological Control, pp. 214-216. In: IPM in Horticultural Crops: Emerging trends in the New Millennium (Eds. A. Verghese & P. Parvatha Reddy). Proceedings of the Second National Symposium on Integrated Pest Management (IPM) in Horticultural Crops: New Molecules, Biopesticides & Environment, October 17-19, AAPMHE, Bangalore, India.
- Ramani, S. and Singh, S.P. 2002. Alien Invasive Pests and Classical Biological Control in India, p. 4-5 (abstract) In: National Symposium on Biological Control of Insect Pests, held during February 7-8, 2002 at Entomology Research Institute, Loyola College, Chennai.

- Tandon, P. L. and Bakthavatsalam, N. 2001. Influence of chickpea genotypes on the parasitizing efficiency of *Trichogramma chilonis* Ishii on *Helicoverpa armigera* (Hubner) eggs. Biocontrol-Contributed Papers. Proceedings of the Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium, July18-19, 2001, PAU, Ludhiana.
- Singh, S.P. 2001. Advances in biological control in India, pp. 12-30. In: Souvenir Advances in Biological Control, Indian Society for the Advancement of Insect Science and Society for Biocontrol Advancement, Punjab Agricultural University, Ludhaina, 71 pp.
- Singh, S.P. 2001. Biological control of invasive weeds in India–Key Note Address, pp. 11-19.
 In: Alien Weeds in Moist Tropical Zones: Banes and Benefits, K.V. Sankaran, S.T. Murphy and H.C. Evans (Eds.). Kerala Forestry Research Institute, India and CABI Bioscience Centre, Ascot, U.K., 172 pp.
- Singh, S.P. 2001. Biological control of pests and diseases. Presented at the Foundation Day of National Academy of Agricultural Sciences, New Delhi on 5th June, 2001.
- Singh, S.P. 2001. Current status of biocontrol agents in insect management with special emphasis on application value. In: Two-day workshop organised by Biotechnology Unit, Hyderabad, for implementing the Andhra Pradesh-Netherlands Biotechnology Programme on 5th November, 2001 at Directorate of Oilseeds Research, Hyderabad.
- Singh, S.P. 2001. Essentials in mass production of biological control agents. In: Training Programme on Mass Production Technology of Biological Control Agents, NCIPM, New Delhi on 9th April, 2001.
- Singh, S.P. 2001. Predators and parasitoids and their role in BIPM as biocontrol agents.

 Presented at Seminar entitled, Biopesticides: Emerging Trends (BEG 2001) held at Chandigarh, India.
- Singh, S.P. 2001. Progress of Biological Control in India. Workshop on Integrated Pest Management in Indian Agriculture at National Centre for Agricultural Economics and Policy Research, IASRI campus, Pusa, New Delhi on 2nd August, 2001.
- Singh, S.P. 2001. Prospects of biological control of important pests associated with soil, pp. 177-210. In: *Indian Phytophagous Scarabs and Their Management: Present Status and Future Strategy*, G. Sharma (Ed.). September 27, 2001. Jaipur, India, 216 pp.

- Singh, S.P. 2001. Role of biological control agents in relation to IPM in horticultural crops, pp. 181-184. In: IPM in Horticultural Crops: Emerging Trends in the New Millennium: Proceedings of Second National Symposium on IPM in Horticultural Crops, New Molecules, Biopesticides and Environment, A. Verghese and P. P. Reddy (Eds.). October 17-19, 2001. IIHR, Bangalore, India, 257 pp.
- Singh, S.P. 2001. Status of biological control of insect pests and weeds in India An overview' to the participants of winter school at IARI, New Delhi, on 6th August, 2001.
- Singh, S.P. 2001. World scenario of biological control with special reference to commercialization, pp. 46-77. In: ICAR-IARI Summer School on Alternate Strategies for Insect Pest Management in Major Crops, June 18, 2001. Division of Entomology, IARI, New Delhi, 346+iv pp.
- Singh, S.P. 2002. Progress and potential of biological control in India. Thirteenth Dr. C.P. Alexander Memorial Lecture-2001. 25th February, 2002, Department of Zoology, University of Delhi, Delhi, 32 pp.
- Singh, D., Dilawari, V.K., Mahal, M.S., Brar, K.S., Sohi, A.S. and Singh, S.P. 2001. Biological Control (Contributed papers), Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19), Punjab Agricultural University, Ludhiana, India, 224+4 pp.
- Singh, S.P. and Ramanujam, B. 2002. Entomopathogenic fungi and their scope for utilization in pest control. Paper presented at 54th Annual Meeting and National symposium on "Crop Protection and WTO-An Indian Prospective". Organized by Indian Phytopathological Society at Central Plantation Crops Research Institute, Kasaragod, Kerala during 22-25, January 2002.
- Singh, S. P., Sunil Joshi and Ballal, C. R. 2001. Innovations in mass rearing technology and techniques for mass releases, transportation and storage of natural enemies. Pp. 1-33.
 In: Biological Control Lead Papers, Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19, 2001) at PAU, Ludhiana (Eds. S. P. Singh et al.), 181 pp.
- Sithanantham, S., Singh, S.P. and Romeis, J. 2001. Natural enemies in *Helicoverpa* management—the potential and bottlenecks. Presented at *Workshop on Helicoverpa Management: The Journey Ahead,* ICRISAT, Hyderabad, on 22nd December, 2001.

- Srivastava, R.K., Prasad, R.D., Rangeshwaran, R., Wasnikar, A.R., Singh, S.P. and Rao, N.S. 2001. A rapid in vivo bioassay method for testing and selection of fungal antagonists of plant pathogens, pp. 95-97. In: Biological Control (Contributed Papers), Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19), D. Singh et al. (Eds.). Punjab Agricultural University, Ludhiana, India, 224+4 pp.
- Srivastava, R.K., Prasad, R.D., Rangeshwaran, R., Wasnikar, A.R., Singh, S.P. and Rao, N.S. 2001. Screening and selection of potential *Trichoderma* species for the control of phytophthora root/crown rot and blight of bell pepper, pp. 135-136. In: *Biological Control (Contributed Papers)*, *Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium* (July 18-19), D. Singh et al. (Eds.). Punjab Agricultural University, Ludhiana, India, 224+4 pp.
- Venkatesan, T., Singh, S. P. and Jalali, S. K. 2001. Toxicity of Spinosad 48 SC to natural enemies present in cotton ecosystem. In: *International Conference on Pesticides*, *Environment, and Food Security* held at IARI, New Delhi, 19 - 23, November 2001, pp. 202-203.
- Venkatesan, T., Singh, S.P. and Jalali, S.K. 2001. An oligidic diet for rearing of Chrysoperla carnea (Stephens) (Neuroptera: Chrysopidae), pp. 61-62. In: Biological Control (Contributed Papers), Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19),
 D. Singh et al. (Eds.). Punjab Agricultural University, Ludhiana, India, 224+4 pp.
- Wasnikar, A.R., Rangeshwaran, R., Prasad, R.D., Srivastava, R.K., Singh, S.P. and Rao, N.S. 2001. Isolation of endophytic bacteria for biological control of wilt pathogens, pp. 99-100. In: Biological Control (Contributed Papers), Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19), D. Singh et al. (Eds.). Punjab Agricultural University, Ludhiana, India, 224+4 pp.

Central Tobacco Research Institute, Rajahmundry

Gunneswararao, S., Singh S.P. and Sivaraju, K. 2001. Implication of tritrophic interactions in the integrated management of *Spodoptera linura* in tobacco and associated vegetation systems. In Darshan singh *et al*(Eds.) Proceedings of the Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the current Millennium, PAU, Ludhiana. 224 pp.

- Gunneswara Rao, G., Singh, S.P. and Siva Raju, K. 2001. Management of Spodoptera litura F. in tobacco and associated vegetation system, pp. 186-187. In: Biological Control (Contributed Papers), Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19), D. Singh et al. (Eds.). Punjab Agricultural University, Ludhiana, India, 224+4 pp.
- Gunneswararao, S., Sitaramaiah, S., Sreedhar, U., Jagadish Chandra, I., Naik, P.K. and Ramaprasad G. 2001. Management of Helicoverpa armigera in non-traditional cotton growing tracts of north coastal Andhra Pradesh. In Darshan Singh et al.(Eds.). Proceedings of the Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium, PAU, Ludhiana. 224 pp.
- Sreedhar, U., Sitaramaiah, S., Gunneswararao, S., Ramaprasad, G. and Nageswararao S. 2001. Management of Spodoptera litura F. in groundnut in Andhra pradesh. In Darshan Singh et al.(Eds.). Proceedings of the Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium, PAU, Ludhiana. 224 pp
- Sreedhar, U., Sitaramaiah, S., Gunneswarao, S., Ramaprasad, G. and Nageswararao, S. 2001. Management of *Helicoverpa armigera* on pigeon pea in Andhra Pradesh. In: Darshan Singh *et al.* (Eds.). Proceedings of the Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium, PAU, Ludhiana. 224 pp

Indian Agricultural Research Institute, New Delhi

Srivastava, K.L. and Prasad, T.V. 2001. Testing of "Pusa Bi" – A new water dispersible powder formulation of Bacillus thuringiensis against last instar larvae of Spodoptera litura. In: Third Indian Agricultural Scientists and Farmer's Congress. Organized by Bioved Research Society, 3-5 Feb. 2001, p.52.

Indian Institute of Horticultural Research, Bangalore

Ganga Visalakshy, P.N. and Jayanth, K. P. 2001. Anatomical and physiological changes in relation to diapause in Zygogramma bicolorata, a biological control agent of Parthenium hystereophorus In: Proc., Symposium on Biocontrol Based Pest management for quality Crop Protection in the Current Millennium, PAU, Ludhiana. 217pp.

- Ganga Visalakshy, P. N. and Krishnan, S. 2001. Natural suppression of the purslane weed Portulaca oleracea in a crop field-need for conservation of the biological agent Ceutorhynchus portulacae. In Proceeding of the Second National Symposium – Integrated Pest mangemnt (IPM) In Horticultural Crops: New Molecules, Biopesticides and Environment, October 17-19, 2001, IIHR, Bangalore, 217pp.
- Gopalakrishnan, C. and Ganga Visalakshy.P.N. 2000. Laboratory evaluation of Spic-Bio against certain lepidopteran pests of cabbage. In Proceedings of the Second National Symposium Integrated Pest mangemnt (IPM) In Horticultural Crops: New Molecules, Biopesticides and Environment, October 17-19, 2001, IIHR, Bangalore, 217pp.
- Mani, M. and Krishnamoorthy, A. 2002. Biological control of Horticultural Crop Pests in India. Lead Paper presented in the National Symposium on Biological Control of Insect Pests at Loyola College, Chennai, Feb. 7-8, 2002.
- Mani, M. and Krishnamoorthy, A. 2001. Role of the aphelinid parasitoid Encarsia azimi. Hayat in regulating ash whitefly Siphoninus phyllireae Haliday on pomegranate. Paper presented in Second National Symposium on IPM in Horticultural Crops: New molecules, Biopesticides and Environment, IIHR, Bangalore, Oct. 17-19, 2001.
- Mani, M. 2002. Recent trends in biological control of fruit crop pests in India. In: Strategies in Integrated Pest Management (Eds. Ignacimuthu and Alok Sen). Phoenix Publishing House Pvt. Ltd., New Delhi, pp. 41-57.
- Krishnamoorthy, A., Rama, N. and Mani, M. 2001. The age specific fertility table of Hemiptarsenus varicornis, an endo-larval parasitoid of serpentine leaf miner Liriomyza trifolii. Proc. Second Natl.sym. IPM in Hort. Crops. New molecules, Biopesticides and Environment (Ed.) A. Verghese and P. P. Reddy. Pp. 226

Sugarcane Breeding Institute, Coimbatore

- Ehlers, R. U., Niemann, I., Hollmer, S., Strauch, O., Jende, D., Shanmugasundaram, M., Mehta, U.K., Easwaramoorthy, S. and Burnell, A. M. 2001. Mass production potential of *Heterorhabditis indica* in liquid culture. In: Development of entomopathogenic nematode/bacterial research (Eds. I. Friffin, C. T., Burnell, A., Downess, M. J. and Mulder, R.). Directorate General of Research, EEC, Luxembourg, pp. 264–270.
- Easwaramoorthy, S. and Padmanaban, P. 2001. Plant Protection for Co 86032. Sugarcane Breeding Institute Extension Publication No.52.

- Srikanth, J., Easwaramoorthy, S. and Santhalakshmi, G. 2002. Seasonal fluctuations of natural enemies of sugarcane shoot borer Chilo infuscatellus Snellen. Proceedings of ENTOMOCONGRESS 2000: Perspectives for the New Millennium, Association for Advancement of Entomology, University of Kerala.
- Srikanth, J. and Salin, K. P. 2002. Effect of group size on movement pattern of Cotesia flavipes Cameron (Hymenoptera: Braconidae) adults. Proceedings of the National Symposium on Vistas of Entomological Research for the New Millennium, G. S. Gill Research Institute, Chennai.
- Srikanth, J. and Salin, K. P. 2002. Sequential sampling plan for sugarcane shoot borer Chilo infuscatellus Snellen. Proceedings of the National Symposium on Vistas of Entomological Research for the New Millennium, G. S. Gill Research Institute, Chennai.
- Srikanth, J., Geetha, N., Kurup, N. K. and Santhalakshmi, G. 2002. Density-dependent natural control of sugarcane shoot borer *Chilo infuscatellus* Snellen (Lepidoptera: Crambidae) *Proceedings of the National Symposium on Vistas of Entomological Research for the New Millennium*, G. S. Gill Research Institute, Chennai.
- Srikanth, J., Easwaramoorthy, S., Shanmugasundaram, M. and Kumar, R. 2002. Comparative economics of two laboratory rearing methods of Cotesia flavipes Cameron (Hymenoptera: Braconidae). Abstracts of the National Symposium on Biological Control of Insect Pests, Entomology Research Institute, Loyola College, Chennai, February 7-8, 2002.
- Srikanth, J. and Salin, K. P. 2002. Ecological adaptability in augmentative biological control: case studies from sugarcane parasitoids. Abstracts of the National Symposium on Biological Control of Insect Pests. Entomology Research Institute, Loyola College, Chennai, February 7-8, 2002.

Acharya N.G.Ranga Agricultural University, Hyderabad

Ganeswara Rao A, Rahman. S. J, Swarna Sree. P., Saxena, R. 2001. Evaluation of sequential applications of biopesticides for the management of *Helicoverpa armigera* (Hubner) in pigeonpea. In: Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium. 18 - 19 July, 2001. PAU, Ludhiana.

- Ganeswara Rao, A., Rahman, S. J., Reddy, P. S. and Vasudeva Rao, V. 2002. Role of birds as a component in Biointensive Insect Pest Management (BIPM) under cotton ecosystem. In: Symposium on Avian Bio-Diversity-Issues and conservation strategies, 28th Feb. 2002, ANGRAU, Hyderabad.
- Rahman, S. J., Ganeswara Rao, A., Swarna Sree, P. and Saxena, R. 2001. Combination studies on the effectiveness of *Trichogramma pretiosum* and HaNPV against *Helicoverpa armigera* (Hubner) in tomato. In: Symposium on Bio-control based pest management for quality crop protection in the current millennium. 18 - 19 July, 2001. PAU, Ludhiana.
- Rahman, S. J., Ganeswara Rao, A. and Vasudeva Rao, V. 2002 Importance of birds in Biointensive Insect Pest Management (BIPM) of Gram pod borer, *Helicoverpa armigera* (Hubner). In: Symposium on Avian diversity – issues and conservation strategies. 7 & 8 Feb. 2002, ANGRAU, Hyderabad.

Gujarat Agricultural University, Anand

Yadav, D.N., Mathew, K.L. and Jha, A. 2001. In situ conservation of entomophaga in cotton ecosystem. Paper presented in the Seminar on "Sustainable cotton production to meet the future requirement of industries" organized by Director of Cotton Development, Government of India, October, 3-4, Mumbai.

Kerala Agricultural University, Thrissur

- Beevi, S.P., Kurien, S., Lyla, K.R and Krishnan, S. 2001. Field screening for the selection of cashew genotypes susceptible to tea mosquito bug *Helopeltis antonii* Sign. (Hemiptera: Miridae) In: Proceedings of Second National Symposium on Integrated Pest Management in Horticultural Crops, New Molecules, Biopesticides & Environment. Oct. 17-19, 2001, Bangalore, pp. 127-128.
- Beevi, S.P. and Lyla, K.R. 2001. Host plant mediated natural parasitism by *Encarsia* spp. (Aphelinidae: Hymenoptera) on spiralling whitefly *Aleurodicus dispersus* Russel (Aleyrodidae: Homoptera). In: Proceedings of Second National Symposium on IPM in Horticultural Crops, New Molecules, Biopesticides and Environment Oct. 17-19, 2001, Bangalore, pp. 208-210.
- Beevi, S.P., Parvathy Meera and Lyla, K.R. 2002. Diversity and relative abundance of pests and natural enemies in the rice ecosystem. In: Abstracts of National Symposium on Biological Control of Insect Pests. Loyola College, Chennai, Feb. 7-8, 2002.

College of Agriculture (MPKV), Pune

- Pokharkar, D.S. and Hadapad, A.B. 2001. Biological activity of trichogrammatids and their field evaluation against Plutella xylostella (Linn.) on cabbage. pp69. National Symposium on Biocontrol based Pest Management for Quality Crop Protection in the Current Millennium, PAU, Ludhiana, July 18th & 19th, 2001.
- Hadapad, A.B., Puranik, T. R. and Pokharkar, D.S. 2001. Evaluation of different Bacillus thuringiensis formulations for the management of DBM, Plutella xylostella (L.) on cabbage, pp.123-124. Symposium on Biocontrol based Pest Management for Quality Crop Protection in the Current Millennium, PAU, Ludhiana on July 18th & 19th 2001.
- Puranik, T.R., Hadapad, A. B., Salunkhe, G. N. and Pokharkar, D.S. 2001. Laboratory evaluation of *Bacillus thuringiensis* formulations against shoot and fruit borer, *Leucinodes orbonalis* G. on brinjal, pp.125. *Proceedings of Symposium on Biocontrol* based Pest Management for Quality Crop Protection in the Current Millennium, PAU, Ludhiana on July 18th & 19th 2001.
- Puranik, T.R., Hadapad, A.B., Salunkhe, G.N. and Pokharkar, D.S. (2001) Management of shoot and fruit borer, Leucinodes orbonalis G. on brinjal by different Bacillus thuringiensis B. formulations, pp.124-125. Proceedings of Symposium on Biocontrol based Pest Management for Quality Crop Protection in the Current Millennium, PAU, Ludhiana, July 18th & 19th 2001.

Punjab Agricultural University, Ludhiana

- Brar, K. S., Shenhmar, M., Singh, J. and Singla, M. L. 2002. Comparative efficacy of Trichogramma chilonis Ishii and insecticides against Chilo infuscatellus Snellen on sugarcane in Punjab, p.448-449. Proceedings of National Symposium on Agriculture in changing Global Scenario, IARI, New Delhi, Feb 21-23, 2002.
- Brar, K. S., Singh, D., Shenhmar, M. and Singh, J. 2001. Demonstration of the effectiveness of *Trichogramma chilonis* Ishii for the control of *Chilo auricilius* Dudgeon on sugarcane in the Punjab, pp.160-161. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium July 18-19, 2001, Ludhiana.
- Brar, K. S., Singh, J. and Shenhmar, M. 2001. Field evaluation and demonstration of egg parasitoids for the control of leaf folder and stem borer of rice, pp.33-34. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium. July 18-19, 2001, PAU, Ludhiana.

- Brar, K. S., Singh, J., Shenhmar, M., Singh, J. and Singh, J. 2002. Management of cotton bollworm with egg parasitoid *Trichogramma chilonis* Ishii in Punjab, p.27. *Proceedings* of National Symposium on Biological Control of Insect Pests, Loyola College, Chennai, Feb 7-8, 2002.
- Shenhmar, M. and Brar, K. S. 2002. Role of augmentation releases of *Trichogramma japonicum* Ashmead in the control of *Scirpophaga excerptalis* (Walker) on sugarcane, p.9. Proceedings of National Symposium on Biological Control of Insect Pests. Loyola College, Chennai Feb 7-8, 2002.
- Shenhmar, M., Brar, K. S., Kaur, S. and Singh, J. 2001. Parasitoids of sugarcane borer in the Punjab, p.20-22. Proceedings of Symposium on Biological Based Pest Management for Quality Crop Protection in the Current Millennium, July 18-19, 2001, PAU, Ludhiana.
- Shenhmar, M., Brar, K. S., Singla, M. L. and Singh, J. 2001. Field evaluation of *Trichogramma chilonis* Ishii for the control of *Chilo auricilius* Dudgeon on sugarcane in the Punjab, p.24-25. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium, July 18-19, 2001 PAU, Ludhiana.
- Shenhmar, M., Brar, K. S. and Singh, J. 2001. Parasitoids of yellow stem borer, Scirpophaga incertulas Walker and rice leaf folder, Cnaphalocrosis medinalis (Guenee), p.25-26. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium, July 18-19, 2001, PAU, Ludhiana.
- Shenhmar, M., Kaur, S. and Brar, K. S. 2001. Spiders associated with the rice ecosystem in Punjab, p.27-28. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium July 18-19, 2001 PAU, Ludhiana.
- Shenhmar, M., Brar, K. S and Singh, J. 2002. Field evaluation of *Trichogramma chilonis* Ishii against early shoot borer, *Chilo infuscatellus* Snellen of sugarcane, p.10. Proceedings of National Symposium on Biological Control of Insect Pests. Loyola College, Chennai. Feb 7-8, 2002.
- Singh, D. and Brar, K. S. 2001. Role of natural enemies in the management of sugarcane pests, pp.31-35. Souvenir, Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium July 18-19, 2001, PAU, Ludhiana.

- Singh, G. and Brar, K. S. 2001. Spider fauna of sugarcane fields around Ludhiana, p.23. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium July 18-19, 2001, PAU, Ludhiana.
- Singh, J. P., Singh, J. and Brar, K. S. 2001. Effect of storage on the emergence, parasitisation and longevity of *Trichogramma chilonis* (Bathinda strain), pp.15-16. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium July 18-19, 2001. PAU, Ludhiana.
- Singh, J. P., Singh, J. and Brar, K. S. 2001. Host preferences by Trichogramma chilonis (Bathinda strain) under laboratory conditions, pp.35-36. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium. July 18-19, 2001 PAU, Ludhiana.
- Singh, J. P., Singh, J. and Brar, K. S. 2001. Progeny production and parasitism as influenced by sex-ratio of *Trichogramma chilonis* Ishii, pp.39-40. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium. July 18-19, 2001, PAU, Ludhiana.
- Singh, J., Brar, K. S., Shenhmar, M., Kaur, S. and Kaur, S. 2001. Biocontrol based management of tomato fruit borer, Helicoverpa armigera (Hubner.), pp.165-166. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium. July 18-19, 2001, PAU, Ludhiana.
- Singh, J., Sohi, A. S., Shenhmar, M. and Brar, K. S. 2001. Natural enemies of insect pests recorded from Punjab, p. 12. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium. July 18-19, 2001, PAU, Ludhiana.
- Singh, J., Brar, K. S. and Singh, J. P. 2001. Development and use of heat and insecticide tolerant strains of natural enemies in IPM, pp.133-140. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium. July 18-19, 2001, PAU, Ludhiana.
- Singh, J., Sohi, A. S., Brar, K. S., Singh, G., Brar, D. S. and Sandhu, S. S. 2001. Status of natural enemy complex in cotton agroecosystem in Punjab, pp. 8-9. Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium. July 18-19, 2001, PAU, Ludhiana.

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

- Gupta, P.R. and Anil Sood. 2001. Role of egg parasitoids for the control of pomegranate fruit borer in mid hills of Himachal Pradesh. p. 57. In: Biological Control (Contributed Papers), Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19), D. Singh et al. (Eds.). Punjab Agricultural University, Ludhiana, India, 224+4 pp.
- Gupta, P.R. and Bhardwaj. 2001. Storage conditions favourable for holding the egg parasitoid, Trichogrammatoidea bactrae Nagaraja, p. 19. In: Biological Control (Contributed Papers), Proceedings of Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium (July 18-19), D. Singh et al. (Eds.). Punjab Agricultural University, Ludhiana, India, 224+4 pp.

Popular articles/Books/Bulletins/Book chapters/Reviews

Project Directorate of Biological Control, Bangalore

- Kumar, P. S. and Singh, S. P. 2001. Mycohit: A mycoacaricide for the management of the coconut mite (*Aceria guerreronis* Keifer). Project Directorate of Biological Control, Bangalore, 4 pp.
- Kumar, P. S. and Singh, S. P. 2002. Mycoacaricides: The emerging class of biopesticides. Agriculture Today (February 2002), pp. 43-45.
- Narayanan, K. 2002. Microbial control of insect pests: Role of genetic engineering and tissue culture, pp.117-180. In: Microbial biopesticides (Eds. By O.Koul and G.S. Dhaliwal). Taylor and Francis, London.
- Singh, S.P., Bhumannavar, B.S., Poorani, J. and Singh, D. (Eds.). 2001. Biological Control-Compendium of lead papers presented at the Symposium on Biocontrol based Pest Management for Quality Crop Protection in the current millennium held at PAU, Ludhiana, during July 18-19, 2001.
- Singh, S.P. and Srinivasa Murthy, K. 2002. Annotated bibliography on biological control of rice pests in India. *Technical Bulletin* No. 29. Project Directorate of Biological Control, India, 280 pp.
- Singh, S.P., Bakthavatsalam, N. and Pushpalatha, N.A. 2002. Annotated bibliography of biological control of plantation and spice crop pests in India. *Technical Bulletin* No. 30, Project Directorate of Biological Control, Bangalore, India, 286 pp.

Central Tobacco Research Institute, Rajahmundry

- Sitaramaiah S., Gunneswararao, S., Rama Prasad G. and Sreedhar U. 2001. Role of Biological agents in tobacco insect pest management. In: Biocontrol potential in sustainable Agriculture (Ed. Rajeev K. Upadyay), Kluwer/Academic press Inc. New York. pp.215-231.
- Gunneswararao, S., Sreedhar U. and Sitaramaiah, S. 2002. Biological control of tobacco pests in India. CTRI, Rajahmundry, 61pp.

Indian Institute of Horticultural Research, Bangalore

- Krishnamoorthy, A., and Mani, M. 2001. Parasitoids and predators as components in IPM of vegetable crops. In Integrated Pest Management in Horticultural Ecosystems (Eds. P. P. Reddy, A. Verghese and N. K. Krishna Kumar), Capital Publishing Company, New Delhi, pp.108-121.
- Mani, M. 2001. Biological control of fruit crops. In: Integrated Pest Management in Horticultural Ecosystems (Eds. P. P. Reddy, A. Verghese and N. K. Krishna Kumar), Capital Publishing Company, New Delhi, pp. 93-107.

Sugarcane Breeding Institute, Coimbatore

- Singh, S. G., Rao, G. P. and Easwaramoorthy, S. (Eds), 2002. Sugarcane Crop Management. Sci. Tech. Pub. USA.
- Easwaramoorthy, S. 2001. Genetic manipulation in granulosis virus, pp. 161-168. In: Microbial Control of Crop Pests. (Eds. Rabindra, R. J., Kennedy, J.S., Sathiah, N., Rajasekaran, B. and Srinivasan, M.R.). Tamil Nadu Agricultural University, Coimbatore.
- Easwaramoorthy, S. 2001. Pest management using granulosis viruses, pp. 148-160. In: Microbial Control of Crop Pests (Rabindra, R. J., Kennedy, J.S., Sathiah, N., Rajasekaran, B. and Srinivasan, M.R.). Tamil Nadu Agricultural University, Coimbatore.
- Easwaramoorthy, S. and Mukunthan, N. 2001. Management of sugarcane mites. In: Biodiversity and management of phytophagous mites, pp. 210-213. (Rabindra, R. J., Karuppuchamy, P., Umapathy, G., Chinniah, C. and Balasubramani, V., eds.)
 Tamil Nadu Agricultural University, Coimbatore.
- Easwaramoorthy, S. and Salin, K. P. 2002. Hundred years of Sugarcane Entomology in India. In: Sugarcane Crop Management (Singh, S. B., Rao, G. P. and Easwaramoorthy, S. eds.). Sci. Tech. Pub. USA, pp. 410-492.

11. LIST OF APPROVED ONGOING PROJECTS

Basic Research

Project Directorate of Biological Control, Bangalore

- Introduction and studies on the exotic natural enemies of some lepidopterous, dipterous and homopterous insect pests
- Biosystematic studies on predatory coccinellids and Indian Tachinida:
- Development of viable mass production techniques for parasitoids and predators
- Development of mass production techniques for cecidomyiid and acarine predators for use in biological control programmes
- Biocontrol of insect pests using baculoviruses, entomopathogenic bacteria, entomopathogenic nematodes, entomopathogenic fungi and development of suitable formulations
- Biological control of plant parasitic nematodes with fungi and bacteria with special reference to Paecilomyces lilacinus and Pasteuria penetrans
- Biological control of soilborne and other plant pathogenic fungi by antagonistic fungi and bacteria and development of suitable formulations.
- Survey, identification and utilization of plant pathogens for the biological control of weeds with particular reference to parthenium and water hyacinth
- Study of behaviour ecology of the potential predators and parasitoids to enhance their efficiency in biological suppression of key crop pests
- Evaluation of improved and selected species / strains of egg parasitoids and evaluation of artificial diet for important natural enemies and for host insects
- Development of NIS system on biological suppression of crop pests

NATP Funded projects at PDBC, Bangalore

- Team of Excellence for Human Resource Development in Biological Control
- Development of bio-intensive IPM modules in chickpea against Helicoverpa armigera, wilt and dry root rot
- Control of leaf curl viral disease in cotton and development of protocols for mass multiplication of predators, parasites and insect pathogens

- Development of an integrated pest management package for the eriophyid mite (Aceria guerreronis Keifer) of coconut in the southern states
- Development of IPM modules for oilseeds and nutritious cereals based production system
- Validation and promotion of IPM Technology in selected crops in different agroecological regions

Other sources

- 7. Bioefficacy, biosafety and generation of data for registration of "Mycohit".
- 8. Mass production of quality biocontrol agents/ biopesticides
- 9 Technology Mission on cotton for development and evaluation of location specific IPM modules and development of efficient strains

Indian Agricultural Research Institute, New Delhi

- 1. Basic studies and maintenance of Bacillus thuringiensis strains
- Studies on formulations of microbial pesticides based on baculoviruses and Bacillus thuringiensis

G.B.Pant University of Agriculture and Technology, Pantnagar

- Development of mixed formulation of Pseudomonas fluorescens and Trichoderma hazzianum
- 2. Biodiversity in antagonistic Trichoderma and Pseudomonas
- 3. Studies on methods for bio-priming of seeds of different crops

At Co-ordinating centres

Biological suppression of crop pests and weeds

Sugarcane

- Survey of and seasonal fluctuation studies on natural enemies of borers (PAU, SBI)
- Large scale studies on Trichogramma chilonis against early shoot borer (PAU, SBI, MPKV)
- 3. Field studies on Cotesia flavipes against early shoot and stalk borers (PAU)
- Evaluation of Beauveria brongniartii against white grubs (SBI)

Cotton

- Biointensive integrated pest management of cotton pests (GAU, MPKV, ANGRAU, TNAU, PAU)
- Field evaluation of inundative releases of T. chilonis in combination with Chrysoperla carnea against cotton pest complex (GAU)
- 3. Impact of inundative releases of Chrysoperla carnea against pest complex (GAU)
- 4. Identification of host plants harbouring arthropod natural enemies (ANGRAU, TNAU)
- Evaluation of different Bt products for efficacy against cotton bollworm complex (TNAU)
- 6 Colonization and establishment of Chelonus blackburni in cotton (GAU, ANGRAU)
- 7. Testing efficacy of Heterorhabditis indica and Steinernema carpocapsae against Helicoverpa armigera in cotton (GAU)

Tobacco

- Biointensive integrated pest management of Helicoverpa armigera in irrigated FCV (NLS) tobacco (CTRI)
- Performance of tobacco aphid on various host plants and natural enemy (Cheilomenes sexmaculata) interactions (CTRI)
- Identification and utilization of biocontrol agents of Spodoptera exigua, an emerging pest of solanaceous crops (CTRI)

Pulses

- Large-scale demonstration of Bt-HaNPV-Bt-HaNPV in pigeonpea for the management of pod borer complex in farmers' field in 1 ha area (ANGRAU, GAU)
- 2. NPV based management of H. armigera (TNAU)
- Effect of entomopathogenic nematode Heterorhabditis sp. against Mylabris pustulata and Helicoverpa armigera in pigeonpea (ANGRAU, TNAU, GAU)
- BIPM of pigeonpea with special reference to pod borer complex (ANGRAU, GAU, TNAU)

Rice

- Survey and quantification of natural enemy complex in rice (AAU, KAU, PAU, TNAU)
- Field evaluation of integrated use of Trichogramma japonicum, T. chilonis and Bacillus thuringiensis against rice stem borer and leaf folder (AAU, KAU, PAU, MPKV, TNAU)
- 3. Evaluation of biocontrol based IPM in rice (TNAU, KAU, AAU, PAU)
- Development of rearing techniques for key natural enemies of rice hispa and screening insecticides against them (AAU)

Oilseeds

- 1. Biological control of mustard aphid, Lipaphis erysimi (PAU)
- 2. Evaluation of Nomuraea rileyi against Spodoptera litura on groundnut (TNAU)
- 3. Biointensive IPM of Spodoptera litura in irrigated groundnut (TNAU).

Coconut

- Field testing of Hirsutella thompsonii formulations supplied by PDBC against coconut mite (CPCRI, KAU, PDBC, ANGRAU, TNAU)
- 2. Studies on seasonal incidence of Opisina and its natural enemies (CPCRI, KAU)

Fruit crops (Tropical and subtropical)

- Survey for the natural enemies of spiralling whitefly (IIHR, KAU)
- 2. Colonization of Encarsia sp. against spiralling whitefly (IIHR)
- 3. Evaluation of Trichogramma chilotraeae against pomegranate fruit borer (IIHR)
- Evaluation of Bt formulations against ber and pomegranate fruit borers (IIHR)
- Evaluation of fungal pathogens against spiralling whitefly (IIHR)
- Evaluation of fungal pathogens for the control of mango leafhoppers (IIHR)
- 7. Development of culture media for Entomophthora sp. (IIHR)

Fruit crops (Temperate)

- Seasonal incidence of San Jose scale and woolly apple aphid and their natural enemies at different altitudes (SKUAS & T, Dr. YSPUH & F)
- 2. Biocontrol based IPM in apple orchards (SKUAS & T, Dr.YSPUH & F)
- Persistent toxicity of insecticidal deposits of Chrysoperla carnea, Aphelinus mali and Aphytis sp. (proclia group) (Dr.YSPUH & F)
- 4. Ground flora as reservoir of natural enemies in apple orchards (Dr.YSPUH & F)
- Studies on the distribution and emergence pattern of egg parasitoids of Lymantria spp. (SKUAS & T)

Vegetables

- Survey for natural enemies of vegetable crop pests (IIHR, ANGRAU, MPKV, SKUAS & T, GAU, Dr. YSPUH & F)
- Evaluation of Trichogrammatoidea bactrae against Plutella xylostella on cabbage (IIHR, ANGRAU, MPKV, GAU, Dr.YSPUH & F)
- Evaluation of different formulations of Bacillus thuringiensis against Plutella xylostella on cabbage (IIHR, ANGRAU, MPKV, GAU, Dr.YSPUH & F)
- Control of Leucinodes orbonalis using Bacillus thuringiensis on brinjal (IIHR, ANGRAU and MPKV)
- Control of Helicoverpa armigera using Nomuraea rileyi (MPKV)
- Integrated pest management of tomato fruit borer (GAU)
- 7. Management of tomato fruit borer (GAU, PAU, Dr.YSPUH & F)

Potato

- Standardization of mass release technology for parasitoids Copidosoma koehleri and Chelonus blackburni against PTM under field conditions (MPKV)
- Evaluation of release methods of parasitoids Copidosoma koehleri and Chelonus blackburni and microbial agents against PTM on potato in country stores (MPKV)
- 3. Effect of plant products on parasitoids of PTM (MPKV)
- Evaluation of different entomopathogens for the control of Spodoptera litura on potato (MPKV)

Weeds

- Assessment of impact of Neochetina eichhorniae, N. bruchi and Orthogalumna terebrantis in suppressing water hyacinth (AAU, ANGRAU, GAU, GBPAU & T, KAU, PAU, TNAU, SKUAS & T, MPKV, Dr.YSPUH & F, IARI, CPCRI, CTRI, IIHR & SBI)
- Assessment of impact of Cyrtobagous salviniae in suppressing Salvinia molesta (KAU)
- Parthenium control with Zygogramma bicolorata, a case study under mid hill conditions (Dr.YSPUH&F)
- Survey and quantification of natural enemies of Mimosa rubicaulis subsp. himalayana (AAU)

CONSULTANCY, PATENTS, COMMERCIALIZATION OF TECHNOLOGY Consultancy service was arranged for

- EAG and GC-MS analysis for samples received form various organizations.
- testing the susceptibility of Helicoverpa armigera from 14 locations to Bacillus thuringiensis proteins.

Biocontrol agents were supplied to different research and development Departments of Centre and State Governments. Multicellular tray units were supplied to various State Agricultural Universities for rearing *Helicoverpa armigera*.

13. MEETINGS HELD AND SIGNIFICANT DECISIONS MADE

13.1 Significant decisions and recommendations made in the Sixth Research Advisory Committee Meeting held on 25-05-2001

Recommendations

- The use of fungal and bacterial antagonists may be directed against those crops or cultivars where resistant varieties are lacking.
- Feedback to be obtained from the institutions to which biocontrol agents were supplied by PDBC, for impact assessment.
- Cheap and easily available ingredients may be used for mass production of natural enemies and host insects.

- Effective weed pathogens to be identified for a mixture of weeds in field crops to reduce herbicide application.
- Use of powdered cow dung cake as a medium for production of *Trichoderma* spp. may be evaluated.
- 6. A scientist should be deputed for training in Biosystematics on priority basis.
- A status report on the spiralling whitefly and coffee berry borer parasitoids may be prepared.
- Identification of biocontrol agents for the newly emerging pests such as pod wasp, *Tanaostigmodes cajani* on pigeon pea.
- Strain identification work in case of Trichogramma and Pseudomonas may be further strengthened.
- 10. Quality control parameters may be evolved for biocontrol agents.

General remarks

- Duration of the projects needs to be kept for 3-5 years with clear-cut objectives and activity. The final technical reports may be prepared for projects which have completed 5 years.
- Encouraging the establishment of cost-effective biocontrol units, joining hands with private insectaries for producing biocontrol agents and large scale demonstrations with the help of NGOs may be attempted.
- 3. Strengthening of the existing programmes through networking with willing partners.
- Success stories in biointensive pest management practices need to be given wide publicity.
- The RAC meeting needs to be held for two days instead of one day for better interaction.

13.2 Significant decisions made in Management Committee Meetings

Meeting held on 25-01-2002

 Due to ban on creation of posts, the management committee approved the re-deployment of three scientific, ten technical and four administrative posts approved in the ninth plan on priority basis.

- The Committee approved the proposal for appointing two private doctors (Dr. (Ms.) P.V.Mahalakshmi and Dr. Vishwanath M.Patil) as AMAs for a period of one year from 01-04-2002.
- The committee recommended to include the civil works (construction of quarantine
 with glass house and net house; 12 residential quarters; administrative block, library
 unit, TOT centre, extension to the existing pathology laboratory and canteen/space
 for indoor games) land, equipment in the proposal and two vehicles in the tenth plan
 document.
- Approval given to condemn the three old motor cycles and replace them with latest models, subject to availability of funds under non-plan during 2001-02.
- The Management Committee considered and approved for importing foreign equipments and opening LC for the equipments proposed during the year 2002-03
- The four consultancy services rendered were approved with post-facto effect and also approved disbursement of consultancy fee to scientists and other staff who rendered the consultancy services as per guidelines prescribed by the Council.
- Approval given for upgradation of five computers subject to availability of funds under non-plan, upgradation of Pentium 166 Mhz to Workstation Pentium IV, 2 GHz with Flat bed scanner – Printer - cum - copier and CD Writer and upgradation of the existing software like MS-Windows 98, MS-Office 2000 and Norton Anti Virus.

13.3. Monthly Staff Research Council Meeting

Monthly scientific, technical and administrative staff meetings were held separately on every third Friday of the month and the detailed proceedings were sent to the Council for information. During the meetings discussions were held on the work done, in different projects, general difficulties faced and solutions for the same.

14. PARTICIPATION OF SCIENTISTS IN CONFERENCES, MEETINGS, WORKSHOPS, SYMPOSIA, etc. IN INDIA AND ABROAD

Project Directorate of Biological Control, Bangalore

Dr.S.P.Singh participated in the follwoing:

Management Development Programme on Harnessing Intellectual Property for Strategic Competitive Advantage at Indian Institute of Management, Ahmedabad, from 6th to 8th April, 2001

Launching-cum-Orientation workshop of NATP on 10th April, 2001, organised by NCIPM at IARI Library, New Delhi.

Committee Meeting to devise broad guidelines and terms of reference for central review of All India Co-ordinated Research Projects chaired by DDG (CS), ICAR, New Delhi at NBPGR, Pusa, New Delhi on 9th May, 2001.

ICAR-CABI meeting chaired by DDG (CS), ICAR at New Delhi on 10th May, 2001.

Mid term evaluation and monitoring meeting of the project entitled 'Development of ecofriendly sex pheromone based technologies for integrated pest management (IPM) having focus on sorghum and groundnut in Mahboobnagar and Nalgonda districts of Andhra Pradesh at IICT, Hyderabad on 28th May, 2001.

Meeting of the X Plan Sub-working Group on Plant Protection, Sanitary and Phytosanitary Measures under the Chairmanship of Prof. Anupam Verma, National Professor at NCIPM, IARI campus, New Delhi on 4^{th} and 5^{th} July, 2001.

Seminar on Arthropod Taxonomy - Status and Challenges on 15th July, 2001 held at Bangalore, India.

Directors' Meeting of ICAR institutes at Krishi Anusandhan Bhawan, Pusa, New Delhi on $23^{\rm rd}$ and $24^{\rm th}$ July, 2001.

Crop Division Directors' Meeting chaired by DDG (CS), ICAR on 25th July, 2001 at NBPGR, Pusa, New Delhi.

Workshop on Integrated Pest Management in Indian Agriculture at National Centre for Agricultural Economics and Policy Research, IASRI campus, Pusa, New Delhi on 2nd August, 2001.

Research Programme Committee Meeting of National Agricultural Technology Project at, IARI campus, New Delhi on 6th August, 2001.

Sectional Committee Meeting on Plant Protection for scrutiny of nominations for election of Fellows of National Academy of Agricultural Sciences, New Delhi on 7th August, 2001.

Brain Storming Session on 'Implication of Sanitary and Phytosanitary Measures of World Trade Organiation Agreement' held at IARI, New Delhi on 7th September, 2001.

National Symposium on Soil Arthropods and their Management at Jaipur on 27th September, 2001

Two - day workshop organized by Bio-technology Unit, Hyderabad, for implementing the Andhra Pradesh - Netherlands Biotechnology Programme under the overall guidance and supervision of the Biotechnology Programme committee, on 5th November, 2001 at Directorate of Oilseeds Research, Hyderabad.

VII National Symposium of Soil Biology and Ecology (7-9 November, 2001). Inaugurated the Symposium and Silver Jubilee Celebration.

Project Screening Committee Meeting of various A.P. Cess Fund Schemes of the Crop Science Division under the Chairmanship of DDG (CS) at NCIPM, New Delhi, on 19th November, 2001

12th Meeting of the ICAR-CABI Workplan Committee (ICWC) under the chairmanship of Dr. A. Alam, Deputy Director General (Agril. Engineering) at ICAR, Krishi Bhavan, New Delhi, on 7th December, 2001 (FN).

Second Meeting of Bioscience Group of ICAR-CABI Workplan Committee under the Chairmanship of Dr. Mangala Rai, DDG (CS), ICAR at Krishi Bhavan, New Delhi, on 7th December, 2001 (AN).

Deliberations of National Workshop on Coffee Berry Borer held at NIAS, Bangalore, on 11-12 December, 2001.

XVIII Meeting of ICAR Regional Committee No. VIII held at CTCRI, Trivandrum, on $14^{\rm th}$ and $15^{\rm th}$ December, 2001.

Directors' Meeting of ICAR Institutes held on 27th and 28th December, 2001 at NBPGR, New Delhi, chaired by the Secretary, DARE and Director General, ICAR.

Divisional Meeting on 28th December 2001, chaired by Deputy Director General (CS), ICAR.

Dr.P.L.Tandon attended the

Tenth Biocontrol Workers Group Meeting held at Punjab Agricultural University, during July20-21, 2001.

Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium, July18-19, 2001, PAU, Ludhiana.

Dr.K.Narayanan attended the

Tenth Biocontrol Workers Group Meeting at Punjab Agricultural University, Ludhiana on July 20-21, 2001.

Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium at Punjab Agricultural University, Ludhiana, July 18-19

National Symposium on Biological Control of Insect Pests, February 7-8, 2002, at Loyola College, Chennai

Second National Symposium on Integrated Pest Management (IPM) in Horticultural Crops: New Molecules, Biopesticides and Environment. Oct. 17-19th 2001, Bangalore

Dr.N.S.Rao attended the

Launching-cum-Orientation Workshop of the NATP funded project entitled, "Validation and Promotion of IPM Technology in Selected Crops in Different Agro-ecological Regions" at IARI, New Delhi, on 10th and 11th April 2001

Symposium on "Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium" at Punjab Agricultural University, Ludhiana on 18th and 19th July 2001

Tenth Biocontrol Workers Group Meeting at Punjab Agricultural University, Ludhiana on 20^{th} and 21^{st} July 2001.

Meeting to review the progress of the NATP funded project entitled, "Validation and promotion of IPM technology in selected crops in different agro-ecological regions" at NCIPM, New Delhi, on 5th November 2001

Workshop on "Developing IPM package of practices for different crops" at Directorate of Plant Protection, Quarantine and Storage, Faridabad, on 20th and 21st February 2001

Seminar on Industrialist entrepreneurs engaged in production of biocontrol agents at PDBC, Bangalore on 27th February.

Dr.S.S.Hussaini attended the

National Congress on Centenary of Nematology in India-Appraisal and future plans, Dec. 5-7, 2001, IARI, New Delhi

National Seminar on Emerging trends in pests and diseases and their management, October 11-13, 2001

Tenth Biocontrol Workers Group Meeting held at Punjab Agricultural University, during July 20-21, 2001.

Symposium on Biocontrol based Management for Quality Crop Protection in the Current Millennium, Punjab Agricultural University, Ludhiana, July 18-19, 2001

Second National Symposium – Integrated Pest management in Horticultural Crops - New molecules, Biopesticides and Environment, Institution of Agricultural Technologists, Bangalore, October 17-19, 2001

Dr.B.Ramanujam attended the

National symposium on Crop Protection and WTO-An Indian Perspective. Organized by Indian phytopathlogical Society at Central Plantation Crops Research Institute, Kasaragod, Kerala, during 22-25, January 2002.

Dr.N.Bakthavatsalam attended the

Tenth Biocontrol Workers Group Meeting held at Punjab Agricultural University, during July 20-21, 2001.

Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the urrent millennium, July18-19, 2001, PAU, Ludhiana.

Dr.M.Nagesh attended the

National Symposium on "Biocotrol Based Pest Management for Quality Crop Production in the Current Millennium". 18-19 July, 2001, PAU, Ludhiana.

National Seminar on "Emerging Trends in Pests and Diseases and their Management", 11-13 October, 2001, Centre for Plant Protection Studies, TNAU, Coimbatore.

Second National Symposium on IPM in Horticultural Crops: New Molecules, Biopesticides and Environment. 17-19 October, 2001, AAPMHE, IIHR, Bangalore.

National Congress on Centenary of Nematology in India-Appraisal and Future Plans. 5-7 December, 2001. Nematological Society of India, I.A.R.I., New Delhi.

Dr.S.Ramani attended the

36th Annual Rice Group Meeting at GB Pant University of Agriculture and Technology, Pantnagar, April 9 -13, 2001.

One-day workshop on "Arthropod Taxonomy: Current status and Challenges" organised by UAS, Bangalore, on 15th July, 2001 at Hotel Ashoka, Bangalore.

Tenth Biocontrol workers meet held at PAU, Ludhiana from 20-21 July, 2001, and arranged exhibition at PAU, Ludhiana, from 18-21 July 2001 depicting biocontrol of crop pests.

Symposium on "Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium" held at PAU, Ludhiana from 18-19 July, 2001.

Attended the National Conference on Coffee Berry Borer from December 11 - 12, 2001 held at JRD Tata memorial Auditorium, NIAS, Bangalore.

Dr.(Ms.)Chandish R.Ballal attended the

Tenth Biocontrol Workers Group Meeting at PAU, Ludhiana, between 20th to 21st July 2001.

Symposium on "Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium" (July 18-19, 2001) at PAU, Ludhiana.

Second National Symposium on Integrated Pest Management (IPM): New molecules, Bio-Pesticides and Environment, October 17 to 19, 2001 at Institute of Agricultural Technologists, Bangalore.

Annual workshop of the NATP Project on "Development of Biointensive IPM modules in chickpea against *Helicoverpa armigera*, wilt and dry root rot" at UAS, Gulbarga between 25th to 26th September, 2001.

The Seminar "Helicoverpa Management, the Journey ahead" held at ICRISAT, Hyderabad, on 20^{th} and 21^{st} December, 2001.

The seminar on "Agricultural Bio-technology: New Dimensions" at Monsanto Research Centre, Bangalore on 1st March, 2002.

Dr.S.K.Jalali attended the

Mananiya sansadiya rajbhasha samithi ki prashnavali bharne ke liye dhusri ek divasiya karyashala ke ayojan ke bhare mein at National Institute of Public Administration, Bangalore on 19-05-2001.

NATP launch workshop-cum-meeting on "Validation of IPM technology in Selected Crops in Different Agro-Ecological Regions" at NCIPM, New Delhi on 10–11 April 2001.

"Cotton Workshop-cum-Symposium" at HAU, Hissar during 13-14 April 2001 and participated in discussion and formulation of technical programme in entomological session.

Tenth Biocontrol Workers Group Meeting, July 20 -21, at PAU, Ludhiana and presented sugarcane report for the year.

Symposium on Biocontrol based Pest management for Quality Crop Protection in the Current Millennium, July $18-19,\,2001$

Second National Symposium on IPM in Horticultural Crops: New Molecules, Bio-pesticides and Environment from October 17-19, 2001, AAPMHE, Bangalore and IIHR, Bangalore

Dr.P.Sreerama Kumar attended the

Seminar for Industrialist Entrepreneurs in Production of Biocontrol Agents on 27th February, 2002 at PDBC, Bangalore

Sensitization Workshop-cum-Scientific Advisory Panel Meeting on Coastal Agro-ecosystem (NATP) organized by the University of Agricultural Sciences and the ICAR, New Delhi, at the Veterinary College, Hebbal, Bangalore, 30 July – 1 August 2001.

Sixth Steering Committee Meeting on the Coconut Eriophyid Mite organized by the Coconut Development Board at Lalbagh, Bangalore, on I September 2001.

Third Asia-Pacific Crop Protection Conference, organized by the Pesticide Manufacturers and Formulators Association of India at the Habitat Centre, New Delhi from 6-7 September 2001.

Thirty-Eighth Asian and Pacific Coconut Community Session (5-9 October 2001) organized by the Coconut Development Board, Government of India at Hotel Atria, Bangalore, on 5 October 2001.

National Seminar on Emerging Trends in Pests and Diseases and Their Management, organized by the Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore, 11-13 October 2001.

State-Level Coconut Farmers Knowledge Meeting (About Neera and Coconut By-products)], organized by the Karnataka Rajya Raitha Sangha (KRRS) faction headed by Mr K. S. Puttannaiah (President) at Mandya on 24 November 2001.

Fifty-fourth Annual Meeting and National Symposium on Crop Protection and WTO- An Indian Perspective organized by the Indian Phytopathological Society at the Central Plantation Crops Research Institute, Kasaragod, from 22-24 January 2002.

Dr.T. Venkatesan participated in

Symposium on Biocontrol Based Pest management for Quality Crop Protection in the Current Millennium. July 18-19, 2001, Punjab Agricultural University, Ludhiana.

Tenth Biocontrol Workers Group Meeting on Biological Control of Crop Pests and Weeds held at Punjab Agricultural University, Ludhiana, during July 19-20, 2001.

Dr.(Ms.)J.Poorani attended the

One-day workshop on "Arthropod Taxonomy: Current status and Challenges" organised by UAS, Bangalore, on 15th July, 2001 at Hotel Ashoka, Bangalore.

Ms.I.M.Dautie attended

Twelfth 12th All India Seminar on Implementation of the guidelines and norms laid down by the Hon'ble Supreme Court of India regarding sexual harassment and gender justice conducted by National Institute of Public Administration, Bangalore.

Central Tobacco Research Station, Rajahmundry

Mr. S. Gunneswararao, Scientist (SS), attended X Biocontrol Workers Group Meeting at PAU, Ludhiana and the symposium on "Biological based pest management for quality crop protection in the current millennium" July 18-19 at PAU, Ludhiana.

Mr S. Sitaramaiah, Principal Scientist & Head, Division of Crop Protection, attended DBT project meeting on IPM/INM at Calicut during Jan 28-30, 2002

Indian Agricultural Research Institute, New Delhi

Dr.K.L.Srivastava, Principal Scientist, attended the

Tenth Biocontrol Workers Group Meeting" from July 20 -21 at PAU, Ludhiana and

Symposium on "Biocontrol based Pest management for Quality Crop Protection in the Current Millennium" from July 18 – 19, 2001 and presented two papers in Poster session at PAU, Ludbiana

Indian Institute of Horticultural Research, Bangalore

Dr.M.Mani, Dr.A.Krishnamoorthy & Dr.(Ms.)P.N.Ganga Visalakshy attended

The National Seminar on Biocontrol based Pest Management for Quality Crop Protection in the Current Millenium held at PAU, Ludhiana, July 18-19, 2001.

Tenth Biocontrol Workers Group Meeting of AICRP on Biological control of Crop Pests and Weeds at PAU, Ludhiana, July 20-21, 2001.

The second National Symposium on IPM in Horticultural Crops: New molecules, Biopesticides and Environment, IIHR, Bangalore, Oct. 17-19, 2001.

The National Consultation seminar on Biological Control of Pests and Diseases of Horticultural Crops at IIHR, Bangalore, January, 27-29, 2002.

The National Symposium on Biological Control of Insect Pests at Loyola College, Chennai, Feb. 7-8, 2002.

Sugarcane Breeding Institute, Coimbatore

Dr. S. Easwaramoorthy attended

National symposium on Biological Control of insect pests organised by Entomological Research Institute, Loyola College, Chennai, Feb 7-8, 2001.

Workshop on blueprint for success, Feb. 22-24, 2001, organised by K.G.Hospital and Post Graduate Medical Institute, Coimbatore, at Hotel Sohan Regency, Avinashi Road, Coimbatore.

Mr. J. Srikanth participated in the National Symposium on Biological Control of insect pests organised by Entomological Research Institute, Loyola College, Chennai, during Feb. 7-8, 2001.

Dr. N. Geetha attended a training for three months on Characterization of entomogenous fungi (under HRD programme) from Nov 19., 2001 to Feb. 18, 2002 at Indian Agricultural Research Institute, New Delhi

Assam Agricultural University, Jorhat

Dr. A Basit, Principal Entomologist, attended the Tenth Bio-control workers group meeting held on 20th & 21st at PAU, Ludhiana.

Acharya N.G.Ranga Agricultural University, Hyderabad

Dr. A Ganeswara Rao, Principal Scientist and Dr. S. J. Rahman, Senior Scientist, participated in

Symposium on Bio-control Based Pest Management for Quality Crop Protection in the Current Millennium held on 18^{th} & 19^{th} , July 2001 at PAU, Ludhiana.

Tenth Bio-control workers' group meeting held on 20th & 21st at PAU, Ludhiana.

Symposium on Avian–Bio-diversity issues and conservation strategies at Hyderabad on 7th & 8th February, 2002.

Dr. S. J. Rahman, Senior Scientist, participated in National Workshop on castor production technology for drylands held at Hyderabad on 25^{th} & 26^{th} February, 2002.

Gujarat Agricultural University, Anand

Dr.D.N. Yadav attended the

Review meeting as member of RAC at Central Tobacco Research Institute, Rajahmundry.

Tenth Biocontrol Workers Group Meeting" from July 20-21 at PAU, Ludhiana.

Symposium on "Biocontrol based Pest management for Quality Crop Protection in the Current Millennium" from July $18-19,\,2001$.

Kerala Agricultural University, Trichur

Dr.(Ms.) Pathummal Beevi and Dr.(Ms.) K.R.Lyla participated in "Tenth Biocontrol Workers Group Meeting" from July 20 -21 at PAU, Ludhiana.

Dr.(Ms.)Pathummal Beevi attended

Second National Symposium on IPM in Horticultural Crops: New Molecules, Bio-pesticides and Environment from October 17-19, 2001 organized by AAPMHC, Bangalore and IIHR, Bangalore.

National symposium on Biological control of insect pests, Feb. 7-8, 2002, at Loyola College, Chennai

Mahatma Phule Krishi Vidyapeeth, College of Agriculture, Pune

Dr. D. S. Pokharkar, Asstt. Entomologist, participated in the Tenth Biocontrol Workers' Group Meeting held at PAU, Ludhiana during July 20-21, 2001.

Punjab Agricultural University, Ludhiana

Dr. Maninder and Sh. Jagmohan Singh participated in state level workshop on Awareness campaign regarding Schemes/ Programmes of Dept. of Agriculture and Cooperation, Ministry of Agric., Govt. of India on Aug. 17,2001. At PAU, Ludhiana.

Dr. K.S. Brar, Dr. Maninder, Sh. Jagmohan Singh and Sh. Inderpal Singh participated in National Symposium on Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium on 18-19 July and Tenth Biocontrol Workers Group meeting on 20-21 July 2001 at PAU, Ludhiana

Dr. K.S. Brar, Dr. Maninder and Sh. Jagmohan Singh participated in Agricultural Officers Workshop for Rabi Crops on 20-21 Aug. 2001 at PAU, Ludhiana

Dr K.S. Brar and Dr. Maninder participated in National Symposium on Biological Control of Insect Pests on Feb 7 & 8, 2002 at Loyola College, Chennai.

Dr K.S. Brar, Dr. Maninder and Sh. Jagmohan Singh participated in the National Symposium on Agriculture in Changing Global Scenario" on 21-23 Feb, 2002 at IARI, New Delhi

Dr K.S. Brar, Dr. Maninder, Sh. Jagmohan Singh, Sh. Inderpal Singh and Neelam Joshi participated in Agricultural Officers Workshop for Kharif Crops from Feb. 27-March 1, 2002 at P.A.U., Ludhiana.

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

Dr.P.R.Gupta participated in the

Tenth Biocontrol Workers' Group Meeting" from July 20 -21 at PAU, Ludhiana and the Symposium on Biocontrol based Pest management for Quality Crop Protection in the Current Millennium from July 18-19,2001.

WORKSHOPS, SEMINARS, SUMMER INSTITUTES, FARMERS' DAY, etc., ORGANIZED BY THE PROJECT DIRECTORATE

15.1. Organized

Symposium on Biological Control Based Pest Management for Quality Crop Protection in the Current Millennium on 19th and 29th July 2001.

Tenth Biocontrol Workers Group Meeting on Biocontrol of Crop Pests and Weeds at PAU, Ludhiana, on $20^{\rm th}$ and $21^{\rm st}$ July 2001

Seminar on Industrialist entrepreneurs engaged in production of biocontrol agents at PDBC, Bangalore, on $27^{\rm th}$ February 2002.

15.2. Celebrated

ICAR Foundation Day on 17th July 2001 and awards were presented to staff (Administration, Technical and Supporting), who excelled in their work.

16. DISTINGUISHED VISITORS

Project Directorate of Biological Control, Bangalore

Dr.Nadyakta Vladimir, Director; Dr.Ismailov Vladimir, Deputy Director, All Russian Biological Control Institute, Russia from 18-25th April 2001

Dr. Graham, P. Head - Monsanto, St.Louis, USA, on 14-05-2001

An Ethiopian delegation on 21-11-2001

Shri S.R.Gill, Cane Advisor, Punjab State Federation of State Cooperative Sugar Mills Limited, Chandigarh on 12-12-2001

Dr.J.G.S.Hamilton, Keele University, Keele, United Kingdom, on 16-01-2002

Members of the Board of Management of the Acharya N.G.Ranga Agricultural University, Hyderabad on 28-01-2002

Dr.F.A.Fattah, Dean, College of Agriculture, University of Baghdad, Baghdad, Iraq from 29 to $31^{\rm st}$ January 2002

Dr.Ebrahim Haji-Zadeh, First Secretary & Director, Science and Education Section, Embassy of the Islamic Republic of Iran, New Delhi, on 30-01-2002

17. PERSONNEL

Project Directorate of Biological Control, Bangalore

Dr.S.P.Singh Project Director (Retired w.e.f.27-02-2002) Dr.R.J.Rabindra Project Director (w.e.f.28-02-2002) Dr.P.L.Tandon Principal Scientist Dr.K.Narayanan Principal Scientist Dr.N.S.Rao Principal Scientist Mr.S.R.Biswas Principal Scientist Dr.S.S.Hussaini Principal Scientist Dr.B.S.Bhumannavar Principal Scientist Dr.(Ms.)K. Veena Kumari Senior Scientist Dr.Prasanth Mohan Raj Senior Scientist Dr.S.Ramanujam Senior Scientist Dr.N.Bakthavatsalam Senior Scientist Dr.S.Ramani Senior Scientist Dr.(Ms.)Chandish R.Ballal Senior Scientist Dr.M.Nagesh Senior Scientist Dr.S.K.Jalali Scientist SS

Mr.Sunil Joshi Scientist SS (on study leave)

Dr.T.Venkatesan Scientist SS
Dr.(Ms.)J.Poorani Scientist SS
Dr.P.Sreerama Kumar Scientist SS
Dr.K.Srinivasa Murthy Scientist SS

Dr.R.D.Prasad Scientist SS (Transferred to DOR)

Mr.R.Rangeshwaran Scientist (on study leave)

Ms.M.Pratheepa Scientist Dr.(Ms.)P.Sadhana Scientist

Central Plantation Crops Research Institute, Regional Station, Kayangulam

Dr.(Ms.) Chandrika Mohan Scientist (SS)
Dr.Murali Gopal Scientist

Kerala Agricultural University, Thrissur

Dr.(Ms.) S.Pathummal Beevi

Associate Professor

Dr.(Ms.) K.R. Lyla

Assistant Professor

Mahatma Phule Krishi Vidyapeeth, Pune

Dr.S.A.Ghorpade

Entomologist

Dr.D.S.Pokharkar

Assistant Entomologist

Punjab Agricultural University, Ludhiana

Dr.S.Maninder

Entomologist

Shri. Jagmohan Singh Dr. Neelam Joshi

Assistant Entomologist

Assistant Microbiologist

Sri Inderpal Singh

Assistant Entomologist

Sher-e-Kashmir University of Agriculture and Technology, Srinagar

Dr.G.M.Zaz

Dr. Abdul Majeed Bhat

Junior Scientist

Mr.R.K.Tikoo

Junior Scientist

Tamil Nadu Agricultural University, Coimbatore

Dr.R.Balagurunathan

Associate Professor

Dr.N.Sathiah

Assistant Professor

Y.S.Parmar University of Horticulture and Forestry, Nauni, Solan

Dr.P.R.Gupta

Senior Entomologist

Dr.Anil Sood

Assistant Entomologist

18. ANY OTHER RELEVENT INFORMATION SUCH AS SPECIAL INFRASTRUCTURAL DEVELOPMENT

18.1. Equipments

The infrastructure facilities, were strengthened and several equipments (Digital display Shaking Water Bath, Columns and Detectors, Centrifuge/Pelletizer, Fermentor, Deepfreeze Solar water heater, Digital camera, Spectrophotometer, Laminar flow, Close circuit camera, Security Gadgets, Computer with scanner) were procured during 2001-02.

18.2.Library

The library has a collection of 1,616 books, 940 volumes of journals, 46 bulletins and several miscellaneous publications including several reprints on various aspects of biological control. Nine foreign and fifteen Indian Journals have been subscribed. CABPEST CD has been upgraded up to February 2002. New CDs - Crop Protection Compendium, Root Knot Nematode Taxonomic Data Base, Glossary of Plant Nematology & Related Terms, and AGRIS CDROM – May, 2001 were procured.

18.3. Aris Cell

Four computers were further upgraded with Pentium IV and the old server was upgraded with the latest version.

18.4. National Insect Reference Collection

The PDBC has 3,495 authentically identified species belonging to 216 families under 16 orders. The collection includes representatives of the orders Hymenoptera, Coleoptera, Hemiptera, Orthoptera, Strepsiptera, Thysanoptera, Neuroptera, Diptera, Lepidoptera, etc. encompassing crop pests, parasitoids and predators. The information is available in the form of a catalogue.

18.5. Buildings

An amount of Rs.32.80 lakhs was deposited with CPWD, Bangalore, for construction of a hostel facility including training hall and furniture and fixtures. Two floors on the existing building were constructed for establishment of mass production units and the second installment of Rs.13.35 lakh was deposited with CPWD, Bangalore, for construction of Quarantine laboratory with glass house and net house facility.

2. निष्पदित सारांश

2.1 मौलिक अनुसंघान

बारह प्राकृतिक शतुओं को आयात करने के लिए आयात स्वीकृति प्रदान करने हेतु प्रस्ताव भेजा गया।

2.1.2 परपोषी कीटों और प्राकृतिक शत्रुओं का रखरखाव, बहोत्पादन और भेजना

निम्नलिखित परपोषी कीटों, परजीवी कीटों और परभक्षी कीटों के संवर्धनों का रखरखाव किया गया।

परपोषी कीट - कोरसेरा सफेलोनिका , स्मोडोप्टेरा लिट्यूरा, हेलिकोवर्षा आर्मिजेरा, थ्योरिमीआ ओपरकुलेला, एकीया जनेटा, सीसामिआ इन्फेरेन्स, इरिआस विटेल्ला, एयोटिस स्पे., गंगारा थायर्सिस, ओपिसिना एरेनोसेल्ला, डायफेनिआ इंडिका, इरिआस इन्सुलाना, नेफेलोक्नोसिस मेडिनेलिस, काइलो पारटीलस, एक्नोनिटा स्टाइक्स, डायफेनिया पुलवेरूलेंटेलिस और प्लटेल्ला जाइलोस्टेल्ला.

परजीवी कीट - केम्पोलेटिस क्लोरिडए, इरीबोरस अर्जेन्टिओपिलोसस, टेलेनोमस रेमस, कोपिडोसोमा कोइहेल्री, लेप्टोमेस्टिक्स डेक्टाईलोपी, ट्रायकोग्रामेटॉयडिआ आर्मिजेस, ट्राइकोग्रामा एकीए, ट्राइकोग्रामा बेसिलिएन्सी, ट्राइकोग्रामा किलोनिस, ट्राइकोग्रामा डेन्ड्रोलिमी, ट्राइकोग्रामा इवानेसेन्स, ट्राइकोग्रामा जेपोनिकम, ट्राइकोग्रामा प्रेटिओजम, ट्राइकोग्रामा स्पे. (इटेलियन विभेद), ट्रा. एम्बियोफेगम और ट्राइकोग्रामेटॉयडिआ बेक्टरे को पाला गया।

परभक्षी कीट - एन्थोकोरिङ्स में *कार्डिअस्टेथस एकिजगुअस, ब्लाप्टोस्टेथस पालेसेन्स, ओरीअस* स्पे. और? अर्नुल्फस स्पे. को पाला गया।

प्रतिवेदन काल के दौरान स्मो. लिट्यूरा, है. आर्मिजेरा, को. सिफेलोनिका, टे. रेमस, ट्रा. किलोनिस, ट्रा. जेपोनिकम, ट्राय. बेक्टरे, ट्रा. प्रेटिओजम, ट्रा. ब्रेसिलिएन्सी, ट्रा. एम्ब्रियोफेगम, ट्रा. डेन्ड्रोलिमी, ट्रा. एकीए, के. क्लोरिडिए, को. कोइहेल्री, का. एकिजगुअस और ब्ला. पालेसेन्स को विभिन्न अनुसंधान केन्द्रों को भेजा गया। अनुसंधानकर्ताओं, किसानों और निजी कम्पनियों के अनुरोध पर न्युक्लियस संवर्धनों को लगातार भेजा गया। इस दौरान जै नि प नि से विभिन्न प्रयोगशालाओं को हेलिकोवर्षा आर्मिजेरा और स्मो. लिट्यूरा संवर्धनों को लगातार भेजा गया। परपोषी संवर्धन के बहुगुणन के लिए अनेक कोष्ठों वाली पच्चीस ट्रे (मल्टीसेलुलर ट्रे) विभिन्न केन्द्रों को भेजी गयी।

2.1.3 भारतीय परभक्षी कीट कोक्सीनेलिड का जीववर्गीकरण अध्ययन

भारत के विभिन्न भागों से पाँच नई जातियां, जो की *प्रोटोप्लोटिना* मियाटेक, *माइक्रोसिरेन्जियम* मियाटेक, *सायनोनिकिमोर्फा* मियाटेक, *धानियस* अहमद और *ओर्टेलिआ* मूल्सेन्ट वशं से संबंधित हैं, अभिलेखित की गई। चेट्टाली (कुर्ग, कर्नाटक) और उसके आसपास के क्षेत्रों में कोक्सीनेलिडों का सर्वेक्षण किया गया। भारतीय क्षेत्रों में प्राय: पाये जाने वाले कोक्सीनेलिडों के पहचान निर्देश का संकलन किया जा रहा है।

2.1.4 प्राकृतिक शत्रुओं का सर्वेक्षण

विभिन्न फसलों से है. *आर्मिजेरा* और *स्पो. लिट्यूरा* की सूंडियों को एकदित किया गया और पाया कि 0 से 18% तक परजीवीकरण इक्निमोनिड द्वारा किया गया तथा डालीकस पर सबसे अधिक परजीवीकरण पाया गया।

आरियस टेन्टिलस और आ. मैक्सीडेन्टेक्स को विभिन्न फसल पारिस्थितिक तंत्रों से एकत्रित किया गया।

2.1.5 पालने / संवर्धन की तकनीकों का मानकीकरण और प्राकृतिक शत्रुओं का अध्ययन

प्रयोगशाला में इ. अर्जेन्टीओपिलोसस को आधिक संख्या में गुणित करने के लिए एक उत्तम विधि विकसित की गई। विभिन्न परजीवी कीट - परपोषी अनुपात - 1:5, 1:10, 1:15, 1:20, 1:25 का जॉन परीक्षण किया गया। अधिकतम परजीवीकरण प्रतिशत प्राप्त करने के लिए 1:5 को सर्वोत्तम पाया गया।

इरीबोरस अर्जेटीओपिलोसस का चिकपी (मटर) और कपास के पौधों पर पिंजड़ों में अध्ययन किया गया। कपास के पौधों पर परजीवीकरण विस्तार 18 से 45% और 1:5 उत्तम अनुपात पाया गया। चिकपी के पौधों पर परजीवीकरण विस्तार 9 से 40% तक पाया गया।

के. क्लोरीडीए और इ. अर्जेन्टीओपिलोसस के बीच अंतः प्रक्रिया के अध्ययन को पिंजडे में परखा गया। इ. अर्जेन्टीओपिलोसस के साथ की अपेक्षा केवल के. क्लोरीडिए द्वारा अधिकतम परीजीवीकरण पाया गया। यद्यपि के. क्लोरिडिए द्वारा परजीवित करने के 18 घंटों के बाद इ. अर्जेन्टीओपिलोसस से परजीवित कराया जाता है तो बाद वाला, परपोषी को सामान्यतः परजीवित करता है। इसी प्रकार यादि केवल इ. अर्जेन्टीओपिलोसस को परपोषी सूंडी परजीवित होने देते हैं तो अंतः प्रक्रिया की स्थित की अपेक्षा अत्याधिक परजीवीकरण प्राप्त होता है। यदि के. क्लोरिडिए द्वारा परजीवित करने के 24 या 48 घंटे के बाद इ. अर्जेन्टीओपिलोसस से परजीवित कराया जाता है तो किसी भी परजीवित सूंडी से पहले वाला नही निकलता है। परजीवीकरण के इस क्रम का यदि विचार न किया जाये तो के. क्लोरिडिए उत्कृष्ट पाया जाता है। समूह में परजीवीकरण करने के भी इसी तरह के परिणम मिले हैं। के. क्लोरिडिए की दक्षता इ. अर्जेन्टीओपिलोसस की उपस्थित से प्रभावित नहीं हुई, किन्तु के. क्लोरिडिए की उपस्थित से इ. अर्जेन्टीओपिलोसस की दक्षता पर बुरा प्रभाव दिखाई दिया।

एन्थोकोरिड, ब्लाप्टोस्टेथस पालेसेन्स (मक्का के पारिस्थितिक तंत्र से) को को. सफेलोनिका पर पालने की विधि का मानकीकरण किया गया। सेमवर्गीय फिलयों के ऊपर अण्डिनिक्षेपण के लिए प्रयोग किया गया। इनका कुल विकास काल 20 दिन और नर और मादा का आयुकाल, माध्य क्रमशः 64.4 और 53.2 दिन पाया गया। मादा की जननक्षमता 143 निम्फ और इसकी 58% संतित मादा पैदा होती हैं। एक निम्फ औसतन 87 अण्डों का, प्रौढ नर 373 अंडों और मादा 408 अण्डों का भक्षण कर सकते हैं।

परभक्षी कीट सेसीडोमाइड्स और माइटों को आधिक मात्रा में गुणित करने की विधि को विकसित करने कि लिए अध्ययन किए जा रहे हैं।

2.1.6 प्राकृतिक शत्रुओं का व्यवहारिक अध्ययन

क्षेत्र और प्रयोगशाला में अनोपचारित पौधों की अपेक्षा एल - ट्रायप्टोफेन (0.66%) द्वारा उपचारित पौधे का. कारनीआ को अधिकतम अण्डिनिक्षेपण के लिए आकर्षित करते हैं। क्षेत्रीय दशाओं में को. सफेलोनिका के अण्डों के कार्ड पर, कोरसेरा शल्क निष्कर्ष को ट्राइकोसेन और पेन्टाकोसेन का 0.1% और 0.2% छिड़काव करने से ट्राइकोग्रामा किलोनिस द्वारा परजीवीकरण बढता है। केरोमोन्स के यौगिकों का बहुचयानित दशाओं के परीक्षण में देखा गया की नोनोकोसेन और हेक्साकोसेन, ट्रा. किलोनिस द्वारा परजीवीकरण को बढाते हैं। हे. आर्मिजेरा के शल्कों के केरोमोन यौगिकों जैसे डोडेकेन और टाईकोसेन के प्रयोग में पाया गया कि का. कारनिया के प्रौढ सकारात्मक प्रतिक्रिया दिखाते हैं।

कपास के विभिन्न वंशानुप्रकारों में है. आर्मिजेस के अण्डे 22.22 से 48.88% तक परजीवित पाये गये। सबसे अधिक परजीविकरण जी-कॉट-10 (48.88%), इसके बाद सी पी डी 428 (39.99%) पाया गया। सबसे कम परजीविकरण सहाना (22.22%) प्रजाति पर पाया गया। आल्फेक्टोमीटर प्रतिक्रिया में कपास की पत्तियां आधिकतम आकर्षण सी पी डी 428 (50%), इसके बाद सी पी डी 423 (43.33%) और सी पी डी 447 (43.33%) दर्शांती है।

आपेक्षिक प्रतिक्रिया अध्ययन में ट्रा. किलोनिस के प्रति सात रसायनों के बहुचयनित ओस्फेक्टेमीटर पर छोड़ने के 25 मिनट के अन्दर पेन्टाकोसेन से आधिकतम प्रतिक्रिया दर्शाई, तदोपरान्त हेनाइकोसेन और ट्राइकोसेन (सभी 0.1%) इन तीनों यौगिकों की 0.05% सान्द्रता से कें, सफेलोनिका के अण्डो का ट्रा. कीलोनिस द्वारा परजीवीकरण बढ़ा पाया गया। कपास की विभिन्न प्रजातियाँ / संकर की पत्तियों और गूलरों पर हे. आर्मिजेस की मादाओं के ई ए जी प्रतिक्रिया परीक्षण में देखा गया कि सबसे अधिक आकर्षण जी - कॉटन - 10 (-1.176 एम वी), इसके बाद डी एच बी 105 (-1.005 एम वी) और सी पी डी 447 (-0.824 एम वी) पर आकर्षित होती हैं। कपास गूलरों की परिस्थित में ई ए जी की अधिकतम प्रतिक्रिया डी एच एच 11 (-0.990 एम वी), इसके बाद जी - कॉटन - 10 (-0.856) दर्शाई।

कपास की विभिन्न प्रजातियों / संकरों की पत्तियों से 42 यौगिकों और गूलरों से 27 यौगिकों को बनाया या पहचाना. गया।

2.1.7 परपोषी कीटों और प्राकृतिक शत्रुओं के लिए कृत्रिम आहार

ओपिसिना एरेनोसेल्ला को पालने के लिए टोडी पाम की पत्तियों के पाउडर आधारित आहार को सर्वोत्तम पाया गया, यह आधिक मात्रा में प्यूपा बनने और मादा प्रीढ बनने के लिए उत्तम पाया गया।

क्रा. कारनिया के लाखों (1 दिन की आयु वाले) को 15 वंशों तक सफलता पूर्वक कृत्रिम आहार पर पाला गया। क्रा. कारनिआ को कृत्रिम आहार पर पालने पर प्रौढ के निकलने की औसतन प्रतिशत और कोरसेरा पर पालने की औसतन प्रतिशत क्रमशः 85.7% और 86% पाई गई। कृत्रिम आहार को फ्रीज में (5° से. ग्रे. पर) 200 दिनों तक रखा जा सकता है। कृत्रिम आहार पर पाले गये क्रा. कारनिआ तम्बाकू पर माइजस परिकि के प्रति प्रभावी और अन्य परभक्षी कीटों की तुलना में उत्तम पाये गये।

2.1.8 ट्राइकोग्रामेटिड्स के विभेदों में सुधार 💯

्रा. किलोनिस को $36\pm15^{\circ}$ से. पे. पर 55 पीढीयों तक लगातार पालने से उसने इस उच्च तापक्रम को अपना लिया। इस तापक्रम पर पहले वंश का परजीवीकरण 41% और आयुकाल एक दिन से कम पाया गया जबिक अन्य *सुग्राह्य* विभेदों द्वारा 5 प्रतिशत परजीवीकरण आधिक पाया जाता है। 55 पीढीयों के बाद परजीविकरण 90 प्रतिशत और आयुकाल 4 दिन से अधिक पाया गया।

टेलेनोमस रेमस को 30 पीढ़ीयों तक लगातार पालने के बाद 72.2 प्रतिशत परजीविकरण और आयुकाल 7.8 दिन पाया गया। यद्यपि 32º से. प्रे. तक लिंग अनुपात मादा बहुल था और जब 34º से.ग्रे. पर देखा तो नर बहुल था। यह विभेद उच्च तापक्रम दशाओं में स्पो. लिट्यूरा के प्रति छोड़ने के लिए उपयुक्त है।

्राइकोग्रामा किलोनिस के 'एण्डोग्राम' विभेद को बहु कीटनाशक सहिष्णु विभेद के रूप में विकसित कर प्रयोग किया गया। अब यह विभेद 0.09% ए-डोसलफान, 0.05% मोनोक्रोटोफॉस और 0.002% फेनवेलीरेट के सिहण्णु हो चुका है। सभी कीटनाशकों के प्रयोग के 6 घन्टों के बाद 90-95% परजीवीकरण और जीवनकाल 15-40 प्रतिशत पाया गया।

कीट पालने वाले पिंजड़े (30 सेमी³) में *ट्रा. किलोनिस* की 30 पीढीयाँ पालने के बाद इस विभेद में परपोषी को ढूँढने की बहुत अधिक क्षमता और यह 50.6 से 77 अण्डें / मादा परजीवित कर सकती है।

अनेक जलवायुवीय दशाओं में हे. आर्मिजेरा के प्रति 6 विभिन्न जातियों के परीक्षण में ट्रा. किलोनिस और ट्रा. ब्रेसीलिएन्सी ने 25° - 35° से. प्रे. तक और ट्रा. प्रेंटिओजम 18-- 25° से. प्रे पर प्रभावी पाये गये। ट्राइकोग्रामा एकीए भी अधिकतम तापक्रम पर प्रभावपूर्ण ढंग से अण्डों को परजीवित करते हैं, किन्तु ट्रा. किलोनिस और ट्रा. ब्रेसिलिएन्सी की तरह प्रभावी नहीं होते हैं। ट्रा. इवानेसेन्स अधिक तापक्रम की अपेक्षा कम तापक्रम पर अधिक प्रभावी होते हैं। पिरणाम दर्शाते हैं कि हें. आर्मिजेरा के प्रति, ट्रा. किलोनिस और ट्रा. ब्रेसिलिएन्सी को 25° और 35° से. प्रे. के बीच और ट्रा. प्रेंटिओजम को 18° और 25° से. प्रे. के बीच का तापक्रम अच्छा समझा जाता है। इन प्रजातियों का विकास काल 30° से. प्रे. और 35° से. प्रे. 7.0 से 9.0 दिन, 25° से. प्रे. पर 11.0 से 12.2 दिन, 20° से. प्रे पर 15.4 से 21.0

दिन और 18º से. ग्रे. पर 17 से 30 दिन पाया गया। 18º से. ग्रे. और 35º से. ग्रे. तापक्रम पर अनेक प्रजातियाँ उत्पन होने में असमर्थ रही, फिर भी थोड़ा, परजीवीकरण देखा गया।

प्रभावपूर्ण ढंग से परपोषी उपयोग, परजीवीकरण और अधिक परजीवीकरण से बचने के लिए परजीवी कीटः परपोषी अण्डों का अनुपात 1:50-- 60 अण्डे सर्वोत्तम होता है।

2.1.9 कीट रोगाण्विक विषाणुओं और कवकों का अध्ययन

कोकोनट स्किपर, गंगारा थार्यासंस और मोटल्ट इमिप्रेन्ट सफेद तितली, केटोप्सिलिया पायरेन्थे से न्यूक्लियो पोलीहैड्रोसिस विषाणुओं को, अरण्डी के सेमिलुपर, एकिआ जनेटा से एक ग्रेनुलोसिस विषाणु को, मक्का तना बेधक, काइलो पारटीलस से एक पाक्सवायरस को भारत में पहली बार पृथक किया गया और इनकी रोगाण्विक क्षमता का परीक्षण किया गया। धान के पत्ती मोड़क कीट नेफेलोक्रोसिस मेडिनेलिस और नारियल के काले सिर वाली सूँडी, ओपीसिना एरेनोसेल्ला से एक अज्ञात न्युक्लीयर पोलीहैड्रोसिस विषाणु को पृथक किया गया।

ग. थायासिंस के न्युक्लीयर पोलीहैङ्रोसिस विषाणु के अधिक मात्रा में गुणन करने के लिए नर लाखें प्रयोग करने की अपेक्षा मादा लाखें प्रयोग करने पर पी ओ बी की संख्या 4 - 5 गुणा अधिक होने के परिणाम मिले।

एस एम ऐ वाई माध्यम के साथ क्लोरेम्फेनिकल (50 पी पी एम) और रोज बंगाल (100 पी पी एम) का प्रयोग करके हैं. आर्मिजेरा और स्में. लिट्यूरा के क्षेत्र प्रसित असंक्रमित लारवों से नेम्युरिआ रिलेई को सफलतापूर्वक पृथक किया जा सकता है। नें. रिलेई (33), मेटारहाजियम एनाइसोप्लिए (3) और वर्टिसिलियम लिकेनाई (14) को अनेक परपोषियों से पृथक किया गया और गुलाब के माँहु में. रोजीफोर्मिस से प्युजेरियम स्में. को पृथक किया गया। नें. रिलेई के पृथककरण ने रि-- 26 और ने रि--17 (हें. आर्मिजेरा के प्रति) और ने रि--17, नो रि--26, नो रि--3, नो रि--7 और नो रि--12 (स्मों. लिट्यूरा की प्रति) को जब 8.5 x 108 कोनिडिआ / मिली. बीजाणु निस्पन्दन के साथ मिलाकर छिडकाव करते हैं तो तीसरे निरूप के लाखे 100% मरे पाये गये। प्रयुजेरियम स्में. को जब 7.9 x106 बीजाणु / मिली. की दर से बिवेरिया बेसीआना, में. एनाइसोप्लिए और व. लिकेनाई को क्रमशः 3x109, 2x109 और 1.1 x 109 बीजाणु / ग्रा. और अरण्डी की खली (क्रमशः 2x109, 2x109 और 1x109 बीजाणु / ग्राम) मिलाकर प्रयोग करने से गुलाब के माँहु (में. रोजीफोर्मिस) के प्रौढ 73.6% और निम्फ 63.8% मरे पाये गये। ज्वार के अलावा रेशमकीट के सूखे प्युपों का पाउडर भी बि. बेसीआना (1.3x109 बीजाणु / ग्राम) और में. एनाईसोप्लिए (3.6 x 109 बीजाणु / ग्राम के लिए एक अच्छा अधोस्तर सिंद हुआ। में. एनाईसोप्लिए (1.7 x 109 बीजाणु / ग्राम) के अधिक वर्धन के लिए स्पेन्ट माल्ट और बेवर्स यीस्ट (10:1) अच्छे साबित हुए। प्रयोगशाला में व. लिकेनाई को अधिक मात्रा में गुणन करने के लिए सोया आटा शीरा माध्यम के ग्रेड फर्मेन्टर विधि का मानकीकरण किया गया। फर्मेन्टर से कवक बायोमास का प्रयोग करके व. लिकेनाई का टाल्क आधारित नियमन तैयार किया गया।

2.1.10 कीट रोगाण्विक सुत्रकृमि

पी डी बी सी में हेटेरोरहाब्डिटिस बेक्टोरओफोरा, हे. इन्डिका, स्टेइनर्नेमा कार्पोकेप्रो और स्टे. बाइकोर्नुटम पृथक किये गये और ये पाँच कीटों के प्रति परीक्षण में प्रभावी पाये गये।

गेलेरिआ मेलोनेल्ला में सभी पृथककरणों का संतति उत्पादन सबसे आधिक पाया गया। है. वेक्टेरिओफोरा का सबसे अधिक उत्पादन गेलेरिआ में, इसके बाद स्यो. लिट्यूरा और है. आर्मिजेरा मे पाया गया। स्टेइनर्नेमा पृथककरणों मे से, स्टे. बाइकोर्नुटम सभी कीटों में अधिक उत्पादन देता है।

ठोस माध्यम में अधिक मात्रा में उत्पादन के लिए वाउटस माध्यम सभी प्रथककरणों के लिए उत्तम पाया गया। स्टे. कार्पोकेप्से 1.4 और 7.2 की अधिकतम उत्पादन 78.9 लाख / 250 मिली. फ्लास्क प्राप्त करने के लिए, कुत्ते को खिलाने वाले बिस्केट + बीफ निष्कर्ष माध्यम उचित पाया गया। सी टी आर आई, राजहमुन्द्री में तम्बाकु की नर्सरी में स्यो. लिट्यूरा के प्रति स्टे. कार्पोकेप्से 6.11 और है. इन्डिका 13.3 के टाल्क आधारित नियमन बहुत प्रभावी पाये गये।

2.1.11 पादप परजीवी सूत्रकृमियों का जैविक नियात्रण

पायसीलोमाइकस लिलेसिनस के दो विभेद, *वर्टिसिलियम क्लेमायडोस्पोरियम* और *पास्नुरिया पेनीट्रंस* के एक-एक विभेद प्रथक किये गये और उनकी जैव दक्षता का परीक्षण मूलग्रन्थि और रेनिफोर्म सूत्रकृमियों के प्रति किया गया।

प्रयोगशाला में सूत्रकृमि के प्रति प्रतिरोधी कवक का जैव विश्लेषण आसानी और शीघ्रता से करने के लिए एक विधि विकसित की गई। द्रव संवर्धन (पी डी ब्रोथ) में $Ca\ Co_3$ और काइटिन (0.01%) मिलाने से *पा. लिलेसिनस* और व. क्लेमायडोस्पोरियम की वृद्दि और बीजाणु अधिक मात्रा में बनने की क्रिया अधिक हुई। माध्यम में उत्पन्न हुई कवक में निम्न विशेषताये हैं - बाजार में उपलब्ध है, कम लागत वाले अवयव जैसे कपास बीज मील, मूगॅफली बीज मील, जिजेली मील, ग्लूकोज और कोर्न काव पाउडर से मिलकर बना होता है। ग्लास हाउस में टमाटर और लोबिया पर मूलग्रन्थि और रोनिफोर्म सूत्रकृमियों के प्रति क्रमशः *पा. लिलेसिनस* और व. क्लेमायडोस्पोरियम के विधिन्न पृथककरणों की दक्षता का तुलनात्मक मूल्यांकन किया गया। टमाटर और लोबिया की फसल में लाल लेटेराइट मृदा में *मि. इन्कोग्निटा* और रो. रोनिफोर्मिस को नियंत्रित करने के लिए *पा. लिलेसिनस* और बलुई दोमट मृदा के लिए व. क्लेमायडोस्पोरियम के प्रयोग की संस्तृति की गई।

एक अकेलें कवक विशेष की अपेक्षा *पा. लिलोसिनस* और *व. क्लेमायडोस्पोरियम* के साथ शुष्क गोवर की खाद / खली का प्रयोग और प्रकाश प्रयोग का समेकित प्रबंध करने से *मिलॉयडोगाइने इन्कोगिनटा* के अंड समृहां पर इनका कवकीय स्थापन कर पूरा इक देता है। *पा. लिलोसिनस* (ज्वार के दानों पर गुणित) के वायुवीय बीजाणु सब्मर्ज बीजाणुओं की (आलू ब्रोथ में) अपेक्षा अधिक प्रभावी पाये गये। ज्वार के दानों पर गुणित और टाल्क नियमित *पा. लिलोसिनस* को 4-6 कि ग्रा / एकड एवं नीम की खली (150 - 200 कि ग्रा. की दर से) के साथ प्रयोग करने से क्राइसेन्थिमम में मुल अन्यि सुनक्रमियों की संख्या को नियंत्रित करता है और फूलों की उपज को 18 से 24 % तक बढ़ा देता है।

2.1.12 खरपतवार रोगाणु

निरन्तर सर्वेक्षण करने से, जलकुंभी के विभिन्न रोगाणुओं जैसे आल्टरनेरिआ आइकोर्निए, आ. आल्टरनेटा और कैकोरियोरा स्मे. पृथक किये गये। इन रोगणुओं के एपिफाइटोटिक्स के संचरण के लिए दक्षिण - पश्चिम मानसून के तुरन्त बाद का समय (अगस्त के बाद) उत्तम पाया गया। बंगलोर और उसके आसपास के जलाशयों में अगस्त 2001 से फरवरी 2002 तक 2 आल्टरनेरिआ स्मे., केकोरियोरा स्मे., लेसिओडिंग्लोडिआ थीओब्रोमे, अनेक प्युजेरियम स्मे., ड्रेक्सलेरा फोमा और नाइयोरयोरा स्मे. से प्राकृतिक रूप में प्रसित पाये गये।

कपास, भिण्डी, मटर, अरहर, धान, अरण्डी, गुलाब, नारियल, नींबू, कॉफी, आम और अमरूद जो कि निम्न 10 कूलों से संबंधित हैं - मालवेसी, पेपिलओर्निसी, पोओसी, युफोर्बिऐसी, रोजेसी, पालमेई, रूटेसी, रयुबेसी, एनेकार्डिऐसी और मायर्टेसी, इन फसलों में *आल्टरनेरिआ* स्पे. का सुन्नाही होना नहीं दर्शाया। जबिक भिण्डी में फायटोटोक्सीटी के लक्षण देखे गये। रोनाणुओं की कार्यदक्षता, बहोत्पादन और नियमन के परीक्षण वर्ष के दौरान जारी रहे।

2.1.13 सॉफ्टवेयर का विकास

सॉफ्टवेयर ''पी डी बी सी - इन्फोबेस'' का सी डी वर्जन बनाया गया और स्वचालित बनाया गया। सॉफ्टवेयर में मल्टीमिडिया कम्पोनेन्ट्स के विकास का कार्य चल रहा है।

हेलिकोवर्षा आर्मिजेरा पर एक सॉफ्टवेयर - ''हेलिको - इनफो'' को एम एस - एक्सेस 97 में तैयार किया गया, इसमें कीट की टेक्सोनोमी, परपोषी पौधे, वितरण, प्राकृतिक शत्रु और विशेष फसल में जैविक नियंत्रण के लिए आवश्यक मापदंड अपनाने के निर्देश विस्तृत रूप से दिये गये हैं।

सॉफ्टवेयर ''सेफर पेस्टीसाइड इन बायोकन्ट्रोल'' को विज्युअल बेसिक 6.0 का विकास किया गया, जिसमें फसलों, कीटों और प्राकृतिक शृतुओं के लिए प्रयोग आधारित सुरक्षित कीटनाशकों की पहचान करने में मदद मिलती हैं।

2.2 गन्ने के हानिकारक कीटों का जैविक नियंत्रण

पं कृ वि वि, लुधियाना में *ट्राइकोग्रामा किलोनिस* को अप्रैल - जून माह के दौरान 10 दिनों के अन्तराल पर 8 बार 50,000 प्रति हैंबटेयर की दर से छोड़ने पर पूर्वकालिक कोंपल बेधक के ग्रसन को 51.7% तक नियंत्रित करता है। जैव नियंत्रण भी रासायनिक नियंत्रण के समान ही प्रभावी पाया गया। परजीवी कीट छोड़े गये क्षेत्रों में अंड़ परजीवीकरण बहुत अधिक (56%) पाया गया।

मई-जुलाई माह के दौरान *ट्राइकोग्रामा जेपोनिकम* को अगोला बेधक के अंड समूह के दिखाई पडने पर 4 बारी में 50,000 प्रति हेक्टेयर की दर से छोड़ने पर अगोला बेधक के ग्रसन को 50.7% तक कम कर देता है।

्रा. किलोनिस के प्रभाव को विस्तृत क्षेत्र प्रदर्शन में 40 हेक्टेयर क्षेत्र पर जुलाई - सितम्बर माह के दौरान साप्ताहिक अन्तराल पर 11 बार परजीवी कीटों को छोड़ने पर वृन्त बेधक को 60.82% तक नियंत्रित किया जा सका। परजीवी कीट छोड़े गये क्षेत्रों में परजीवीकरण 79.50% और जिन क्षेत्रों में परजीवी कीट नहीं छोड़े गये थे उनमें परजीवीकरण 6.27% पाया गया।

राज्य की दो चीनी मिलों के सहयोग से किये गयो विस्तृत क्षेत्र प्रदर्शन में 1400 हेक्टेयर क्षेत्र में जुलाई - अक्टूबर के दौरान ट्रा. किलोनिस को 10 दिनों के अन्तराल पर 50,000 प्रति हेक्टेयर की दर से 12 बारी छोड़ा गया, जिससे वृन्त बेधक के ग्रसन को 60% कम किया जा सका।

ग. प्र. सं., कीयम्बटूर में, परपोषी चयन के अध्ययन में ट्रा. किलोनिस द्वारा कोंपल बेधक के अंड़े अत्याधिक परजीवीत, इसके बाद पोरी बेधक और को. सफेलोनिका के अण्ड़ों को चुनते हैं। 'Y' आकार की ओल्फेक्टोमीटर टयूब में दो चयन परीक्षण में पाया गया कि को. सफेलोनिका पर पाले गये ट्रा. किलोनिस के प्रौढ पोरी बेधक की अपेक्षा कोंपल बेधक की तरफ ज्यादा आकर्षित होते है। ट्रा. किलोनिस की वर्तमान पीढ़ी में परजीवीकरण दर में परपोषी का कोई प्रभाव नहीं दिखाई दिया।

कई क्षेत्रीय परीक्षणों में पोरी बेधक के प्रति *ट्रा. किलोनिस* को छोड़ने से पोरी बेधक के संक्रमण को काफी कम किया जा सका।

कोंपल बेधक के प्रति स्टरिमयाप्सिस इनफेरेन्स के 10-38 मादायें / एकड की दर से सात क्षेत्रीय परीक्षणों में पाया कि कोंपल बेधकों का ग्रसन कम और कुछ परीक्षणों में परजीवीकरण की दर अधिक पाई गई। प्रयोगशाला में सातवें महीने में बनने वाले स्ट. इनफेरेन्स के प्रौढों का नर अनुपात अधिक जबिक अन्य में मादा अनुपात अधिक होता है। मादाओं की सम्भोग दर प्राय: अत्याधिक पाई गई। अगोला बेधक उत्कृष्ट परपोषी कीट पाया गया।

क्षेत्र में, प्रैस-मड नियमित *बिवेरिआ बोन्गनिआर्टि* केवल अकेले या कीटनाशकों के साथ मिलाकर श्वेत ग्रब्ज के प्रित प्रयोग करने से ग्रब्जों की संख्या कम और ग्रसन भी कम करता है। पूर्वकालिक परीक्षणात्मक प्लाटों से एकित्रत ग्रबों में काफी संक्रमण देखा गया जिससे प्रयोग किये गये कवक की सफलता सिद्द होती है। प्रयोगशाला में जैवविश्लेषण करने पर पता चलता है कि प्रैस-मड या लिग्नाइट के साथ कवक का नियमन ग्रबों के लए बहुत घातक सिद्द होता है।

बि. ब्रोन्गनिआर्टि, बि. बेसिआना और मेटारहाजियम एनाइसोप्लिए के वृद्दि मापदंड़ पर माध्यम पी एच का कोई सुस्पष्ट असर दिखाई नहीं दिया। कवक की तीनों प्रजातियाँ ट्रा. किलोनिस के निकलने पर कोई बुरा प्रभाव नहीं डालती, किन्तु इनके प्रभाव से मकडी, हिपासा ग्रीनेलिए और ब्रेकोनिड़, कोटेशिआ फ्लेविपस पर काफी घातक प्रभाव पड़ा। विवेरिआ ब्रोन्गनिआर्टि को बोम्बेक्स मोराई के लिए सुरक्षित किन्तु अन्य दो कवक लाखों के लिए घातक सिंद हुए। ये तीनों प्रजातियाँ एफिस फ्लोरिया के लिए विवेली पायी गयी।

2.3 कपास के हानिकारक कीटों का जैविक नियंत्रण

म फु क वि, पुणे में कपास के चूसने वाले कीटों के साथ-साथ गूलर सूंडियों का नियंत्रण करने के लिए आई पी एम की विधियाँ प्रभावी पाई गई और इनके प्रयोग से कपास की गुणवत्ता भी अच्छी पाई गई।

आ एन जी र कु वि वि, हैदराबाद में बी आई पी एम, जैवनियंत्रण वाली विधियों के मूल्यांकन की तुलना, किसानों द्वारा अपनाई जाने वाली विधियों और अनोपचारित प्लाटों से की गयी। किसानों द्वारा अपनाई गई प्रक्रियाओं और अनोपचारित प्लाटों के अपेक्षा वी आई पी एम विधि अपनाने पर प्लाटों में स्कवैर और गूलर की क्षित और नूसनेवाले कीटों की संख्या बहुत कम पाई गई। बी आई पी एम विधि में रासायनिक कीटनाशकों के कम छिड़काव और प्राकृतिक शवुओं का अधिक संख्या हुआ, यद्यपि किसान द्वारा अपनाई गई प्रक्रिया से उपज अधिक प्राप्त हुई फिर भी किसान द्वारा अपनाई विधियों की अपेक्षा वी आई पी एम विधियाँ अपनाने से लागत - लाभ अनुपात अधिक मिला।

पं कृ वि वि, लुधियाना में जुलाई - सितम्बर माह के दौरान ट्रा. किलोनिस को 1,50,000/हें /सप्ताह की दर से 12 बार छोड़ने पर भी कपास की गूलर सूंडियों को नियंत्रित करने में कम प्रभावी पाया गया। यद्यपि ट्रा. किलोनिस (1,50,000/हें /सप्ताह की दर से) को कीटनाशाकों (साप्ताहिक अन्तराल पर 9 बार छिड़काव) के साथ समेकित रूप से प्रयोग करने पर गूलर सूंडियों को सफलता पूर्वक नियंत्रित किया गया।

गु कृ वि वि, आनन्द में कपास पीडक प्रबंधन पर किए गए अध्ययन में पाया कि कीटनाशकों के प्रयोग की अपेक्षा आई पी एम विधियों के द्वारा चूसनेवाले कीटों और गूलर सूँडियों को अधिक सफलता पूर्वक नियंत्रित किया जा सकता है। आई पी एम विधियाँ कपास की फसल में कालियों और गूलरों को अधिक सुराक्षित रख पाती हैं। क्षेत्रों में कीटनाशक उपचार की अपेक्षा ट्रा. किलोनिस को क्राइसोपरला कारनीआ के साथ आप्लावित रूप से छोड़ने पर चूसने वाले कीटों और गूलर सृंडियों की संख्या को सफलतापूर्वक कम किया जा सका।

कपास में *हेलिकोवर्षा आर्मिजेरा* के प्रति कीटाहारी सूत्रकृपि *हेटेरोरहब्डिटिज इंडिका* और स्टेइनर्नेमा कार्योकेप्रे प्रभावी पाये गये।

2.4 तम्बाकू के हानिकारक कीटों का जैविक नियंत्रण

सी टी आर आई, राजहमुन्द्री में स्टेइनर्नेमा कार्योकेप्ये का टाल्क आधारित नियमन 1×10^5 आईजे / वर्ग सेमी. की दर से एन पी वी 1.5×10^{12} पी आई बी / हे. के साथ प्रयोग करने से स्यो. लिट्यूरा द्वारा नर्सरी मे नवोद्भिदों की क्षित को कम (3.4%) िकया जा सका। अनोपचारित क्षेत्र (26.88%) की अपेक्षा केवल ई पी एन को 4×10^5 आई जे / वर्ग सेमी. की दर से प्रयोग करने नवोद्भिदों की क्षित को कम (4.88%) िकया जा सका।

2.5 दलहनी फसल के हानिकारक कीटों का जैविक नियंत्रण

आ एन जी र कृ वि वि, हैदराबाद में अरहर फसल तन्त्र में फली बेधक के प्रति है. एन पी वी, बी टी और नीम बीज अर्क के विभिन्न जैव नियन्त्रण आधारित क्रमों में उपचारों की दक्षता का मृल्यांकन किया गया। है. एन पी वी - नीम बीज अर्क को फूल आने के प्रारम्भ होने पर प्रत्येक छिड़काव के बीच 10 दिन के अन्तराल पर क्रमवार प्रयोग करना अन्य उपचारों से उत्तम पाया गया, इस प्रयोग से *हेलिकोवर्षा आर्मिजेरा* के लारवों की संख्या कम हुई और फली मक्खी और फली वेस्प द्वारा होने वाली क्षिति को कम किया गया। इसके प्रयोग से अच्छी उपज प्राप्त होने के परिणाम प्राप्त हए।

गु. कृ वि वि, आनन्द में अनोपचारित क्षेत्रों की अपेक्षा *बी टी - हे.* एन पी वी का प्रयोग करने से अधिकतम उपज के साथ-साथ *हैलिकोवर्पा आर्मिजेरा* के लाखों की संख्या कम, फली और दाने कम क्षतिग्रस्त पाये गये। अरहर में कीटाहारी सुत्रकृष्मि, *हेटेरोरहब्डिटिस* स्पे. को *हैलिकोवर्पा* के प्रति प्रभावी पाया गया।

2.6 धान के हानिकारक कीटों का जैविक नियंत्रण

म फु कू वि, पुणे में पत्ती मोडक कीट और तना बेधक कीट के ग्रसन को कम करने और अत्याधिक उपज प्राप्त करने के लिए अंड परजीवी कीटों *ट्रा. जेपोनिकम* और *ट्रा. किलोनिस* प्रत्येक को 1,00,000 / हे. / सप्ताह की दर से तीन बार में छोड़ना प्रभावी पाया गया।

आ कृ वि वि, जोरहाट में बोरहोला क्षेत्र में रबी 2001 मौसम के दौरान ट्राइकोग्रामा जेपोनिकम और ट्रा. किलोनिस को 50,000/हे./सप्ताह और 1,00,000/हे./सप्ताह की दर से किसान के खेत में पौध रोपण के 30 दिनों के बाद से आप्लावित रूप से छोड़ने के तीन सप्ताह के बाद तना बेधक (केवल 2.39% ग्रसन) का सफलता पूर्वक नियंत्रण किया गया। रोन्गामाटी, डेरागाँव (आसाम) में इसी प्रकार का परीक्षण खरीफ 2001 मौसम के दौरान किया गया, इसमें परजीवी कीट छोड़ने के 3 सप्ताह के बाद 'डेडहर्ट' केवल 4.46% पाया गया।

बोरहोला में रबी 2001 मौसम के दौरान धान में जैवनियंत्रण आधारित आई पी एम विधि का मूल्यांकन किया गया और परिणाम से पता चला कि ट्राइकोग्रामा छोड़ने के तीन सप्ताह के बाद तना बेधक का सफलता पूर्वक नियंत्रण (केवल 2.58% ग्रसन) पाया जबिक आनोपचारित प्लाट में ग्रसन 7.51% था। इसी प्रकार का परीक्षण रोन्गामाटी (डेरागाँव) में खरीफ 2001 मौसम के दौरान किया गया जिसमें परजीवी कीट छोड़े गये क्षेत्र में केवल 2.84% ग्रसन जबिक अनोपचारित क्षेत्र में 7.59% ग्रसन पाया गया।

पं कृ वि वि, लुधियाना में रोपण के 30 दिनों के बाद *ट्रा. किलोनिस* और *ट्रा. जेपोनिकम* को 1,00,000/ है. साप्ताहिक अन्तराल पर 7 बार छोड़ने से पत्ती मोड़क कीट और तना बेधक कीटों को नियंत्रित करने के लिए प्रभावी पाया गया जो कि रासायनिक नियंत्रण से कहीं अधिक था। यद्यपि परजीवी कीटों को कम संख्या मे छोड़ना अप्रभावी पाया गया।

आई पी एम (ट्रा. जेपोनिकम और ट्रा. किलोनिस को 1,00,000 / हे. / सप्ताह की दर से) विस्तृत प्रदर्शन में पत्ती मोडक कीट और तना बेधक कीट को नियंत्रित करने के लिए अल्यधिक प्रभावी पाया गया।

2.7 तिलहनी फसलों के हानिकारक कीटों का जैविक नियंत्रण

पं कृ वि वि, लुधियाना में सरसों के माँहू के नियंत्रण के लिए रासायनिक नियंत्रण अतिउत्तम पाया गया। यद्यपि जैव कारकों में *वर्टिसिलियम लिकेनाई* (10⁸ कोनिङ्जि / मिली.) की अपेक्षा *इक्षिओडोन स्कुटेलेरिस* (15,000 प्रथम निरूपीय लारवे / हे.) अधिक प्रभावी पाये गये।

2.8 नारियल के हानिकारक कीटों का जैविक नियंत्रण

आ एन जी र कृ वि वि, हैदराबाद में नारियल माइट के प्रति हिसुँटेल्ला थोम्पसोनाई आधारित नियमन, माइकोहिट (माइकोहिट [1%] को 15 दिनों के अन्तराल पर 3 बार छिडकाव) का दक्षता परीक्षण किया गया। माइकोहिट प्रयोग करने पर माइट कालोनी में कोई कवकजाल नहीं बना और परिणाम स्वरूप माइट की संख्या को कम नहीं कर पाए।

2.9 फल वृक्षों के हानिकारक कीटों का जैविक नियंत्रण

शे क कृ वि वि वि और प्रौ., श्रीनगर में सेनजोस स्केल के परजीवी कीट, एनकार्सिआ पर्निसिओसी और एफायटिस प्रोक्लिआ छोड़े गये क्षेत्रों में स्थापित हो गये और उनके द्वारा 28.37%और 48% के बीच परजीवीकरण पाया गया।

वाई एस पी यू एच और एफ, सोलन में सेब वृक्षों पर मेलाधियान (0.05%), एण्डोसल्फान (0.05%) और प्रोफेनोफोस (0.05%) द्वारा 10,15 और 30 दिन के छिड़काव के बाद क्राईसोपरला कारनीआ के लाखों को छोड़ना सुरक्षित पाया गया। जब इन कीटनाशकों को मध्य नवम्बर माह में छिड़काव किया गया तो एफिलिनस माली की शिशिरलंघन संख्या पर इन कीटनाशकों का कोई बुरा प्रभाव नहीं पड़ा।

सेब वृक्षों पर अक्टूबर माह के अखिर में *क्राईसोपरला कारनीआ* को 4 लारवे / माहूँ कालोनी की दर से छोड़ने पर और परभक्षी चीटियों के साथ ही साथ माहूँ कालोनी पर आने के सहयोग से वुली सेब माहू का प्रभावपूर्ण ढंग से नियंत्रित किया गया।

2.10 सब्जियों वाली फसलों के हानिकारक कीटों का जैविक नियंत्रण

म फु कृ वि, पुणे में टमाटर के फल बेधक कीट को नियंत्रित करने के लिए हैं. एन पी वी को 250 एल ई / है. $(1.5 \times 10^{12} \text{ पी ओ बी / है.})$ साप्ताहिक अन्तराल पर 5 बार छिड़काब और ट्रा. ग्रेटिओजम 50,000 प्रैंढ / हे. / छोड़ना 5 सप्ताहों तक छोड़ना + हे. एन पी वी को 250 एल ई / हे. की दर से तीन छिड़काब करना, पहला छिड़काब

50% फूल आने पर परजीवी कीट छोड़ने के 5 दिनों के बाद करने पर अत्याधिक प्रभावी पाया गया। इसके प्रयोग करने से सुँडियों की संख्या कम, फल कम क्षतिग्रस्त और उपज अत्याधिक प्राप्त हुई।

पातगोभी में डायमण्ड ब्लेक मौथ को नियंत्रित करने के लिए *ट्रा. बेक्टरे* को 50,000 प्रौढ / हे. / बार की दर से पौध रोपण के 25 दिनों के बाद साप्ताहिक अन्तराल पर 5 बार छोड़ना अनोपचारित क्षेत्र की अपेक्षा उत्कृष्ट पाया गया। फूल आने पर डेल्फिन डब्लयु जी को 1 किया. / हे. की दर से 10 दिनों के अन्तराल पर 5 बार छिड़काब करना बहुत प्रभावी पाया गया।

बैंगन में फूल आने पर डेल्फिन डब्लयु जी को 1 किया. / हे. की दर से 10 दिनों के अन्तराल पर 5 बार छिडकाव करने पर ले. ओरबोनेलिस के प्रति अत्याधिक प्रभावी पाया गया।

आ एन जी आर कु वि वि, हैदराबाद में ट्रा. किलोनिस छोड़ने के साथ-साथ बी टी के दो नियमनों डाइपेल और डेल्फिन का ले. ओरबोनेलिस के प्रति प्रयोग करके इनकी दक्षता का परीक्षण किया गया। फसल क्षति को ध्यान में रखते हुए यद्यपि अनोपचारित और उपचारित क्षेत्रों में अन्तर स्पष्ट दिखाई पड़ा, किन्तु आपस में उपचारों में कुछ ज्यादा अन्तर नहीं दिखाई पड़ा।

वाई एस पी यू एव और एफ, सोलन मे, ग्रीनहाऊस में अलंकृत पौधों और सब्जियों वाली फसलों पर श्वेत मक्खी, ट्रायल्युरोइस वेपोरेरिओरम का यसन बहुत अधिक बढ़ा। श्वेत मक्खी का अत्याधिक ग्रसन सेम की फली पर जून से सितम्बर तक देखा गया और इनकी विकासशील अवस्थाओं को कोक्सीनेलिङ, सिरेन्जियम मोन्टेजिएरी के लाखो द्वारा भक्षण किया गया। अगस्त माह के दौरान एनकारिया ट्रान्सवेना के द्वारा 58.8% प्यूपे परजीवित पाये गये।

प कृ वि वि, लुधियाना में टमाटर फल बेधक कीट के प्रबंधन के लिए ट्रा. जेपोनिकम (50,000 / है. की दर से सप्ताहिक अन्तराल पर 5 बार छोड़ना) + हे. एन पी वी के 3 छिड़काव (1.5 \times 10 12 पी ओ बी / है.) + एन्डोसल्फान के 3 छिड़काव (1.5 \times 10 12 पी ओ बी / है.) + एन्डोसल्फान के 3 छिड़काव (1.5 दिन के अन्तर पर 2.5 ली/है. की दर से) के प्रयोग अत्याधिक प्रभावी साबित हुए। जबिक केवल है. एन पी वी या केवल 21. प्रेटिओजम का प्रयोग करना कम प्रभावी पाया गया।

गु कृ वि वि, आनन्द में, पातगोभी पर *खु. जाइलोस्टेल्ला* को नियंत्रित करने के लिए *बे. श्युरिन्जिएन्सिस* के विभिन्न नियमनों में मूल्यांकन किया गया, इनमें से *बी टी के* I कीट संख्या कम करने में अल्याधिक प्रभावी पाया गया। टमाटर में रासायनिक कीटनाशक उपचारित और अनोपचारित क्षेत्र की अपेक्षा *ट्राइकोग्रामा ग्रेटिओजम* + हे. एन पी वी (तीन छिड़काव) और आई पी एम विधियाँ अपनाना उत्कृष्ट पाया गया।

2.11 आलू की फसल के हानिकारक कीटों का जैविक नियंत्रण

म फु कृ वि, पुणे में आलू के खेत में आलू की कन्द मौथ को नियंत्रित करने के लिए पौध रोपण के 45 दिनों के बाद खेत में 5 मी. की दूरियों पर छेददार प्लास्टिक शीशियों में लटका कर *को. कोइहेल्री,* को 1,250 ममीज / है.

बार और कि. ब्लैकवर्नी को 1,50,000 प्युपे / हे. / बार की दर से साप्ताहिक अन्तराल पर 4 बार छोड़ना प्रभावी पाया गया। विस्तृत रूप से परजीवी कीट छोड़ने के प्रदर्शन में अनोपचारित क्षेत्रों की अपेक्षा *को. कोड़हेल्री* को 50,000 प्रौढ / हे. / बार और कि. ब्लैकवर्नी को 15,000 प्रौढ / हे. / बार आलू की पौध रोपण के 45 दिनों के बाद साप्ताहिक अन्तराल पर 4 बार छोड़ने पर आलू कन्द मौथ के ग्रसन को कम करने के लिए अत्याधिक प्रभावी पाया गया।

देशी भण्डार गृहों में को. कोइहेल्री 1 ममी / 4 किया. कन्द और कि. ब्लैकबर्मी 2 प्रौढ / किया. कन्द की दर से 15 दिनों के अन्तराल पर छोड़ने की विधि अत्याधिक प्रभावी पायी गयी, परिणामस्वरूप आलू कन्द मौथ द्वारा कन्दों का प्रसन क्रमश: 10.83% और 19.20% ही पाया गया। बी टी को 1 प्राम / किया. कन्द की दर से एक महिने के अन्तराल पर प्रयोग करना भी प्रभावी पाया गया।

2.12 खरपतवारों का जैविक नियंत्रण

आ कृ वि वि, जोरहाट में विदेशी विविल कीटों, *नीओकेटिना आईकोर्निए* और *नी. बूकी* को जलकुंभी के क्षेत्रों में छोड़ने पर जलकुंभी का सफलतापूर्वक नियंत्रण करने की उपलब्धि प्राप्त कर ली है। शिबसागर जिले के दिशांगमुख क्षेत्र में 700 हेक्टेयर से भी अधिक क्षेत्र के जलाशयों को खरपतवार रहित कर दिया गया है।



Participants in a National Seminar for Industrial Entrepreneurs Engaged in Production of Biocontrol agents held on 27-2-2002



Russian Scientists discussing with the Project Director, Dr. S.P. Singh during their visit



Practical training being imparted to the trainees of the NATP-TOE on "Biological Control of Crop Pests"



Participants during the Hindi Divas Celebrations held on September 14,2001.



Participants of the Symposium on "Biocontrol Based Pest Management for Quality Crop Protection in the Current Millennium" held at PAU, Ludhiana from July 18-19,2001.



Participants during the Tenth Biocontrol Worker's Group Meeting held at PAU, Ludhiana from July 20-21,2001