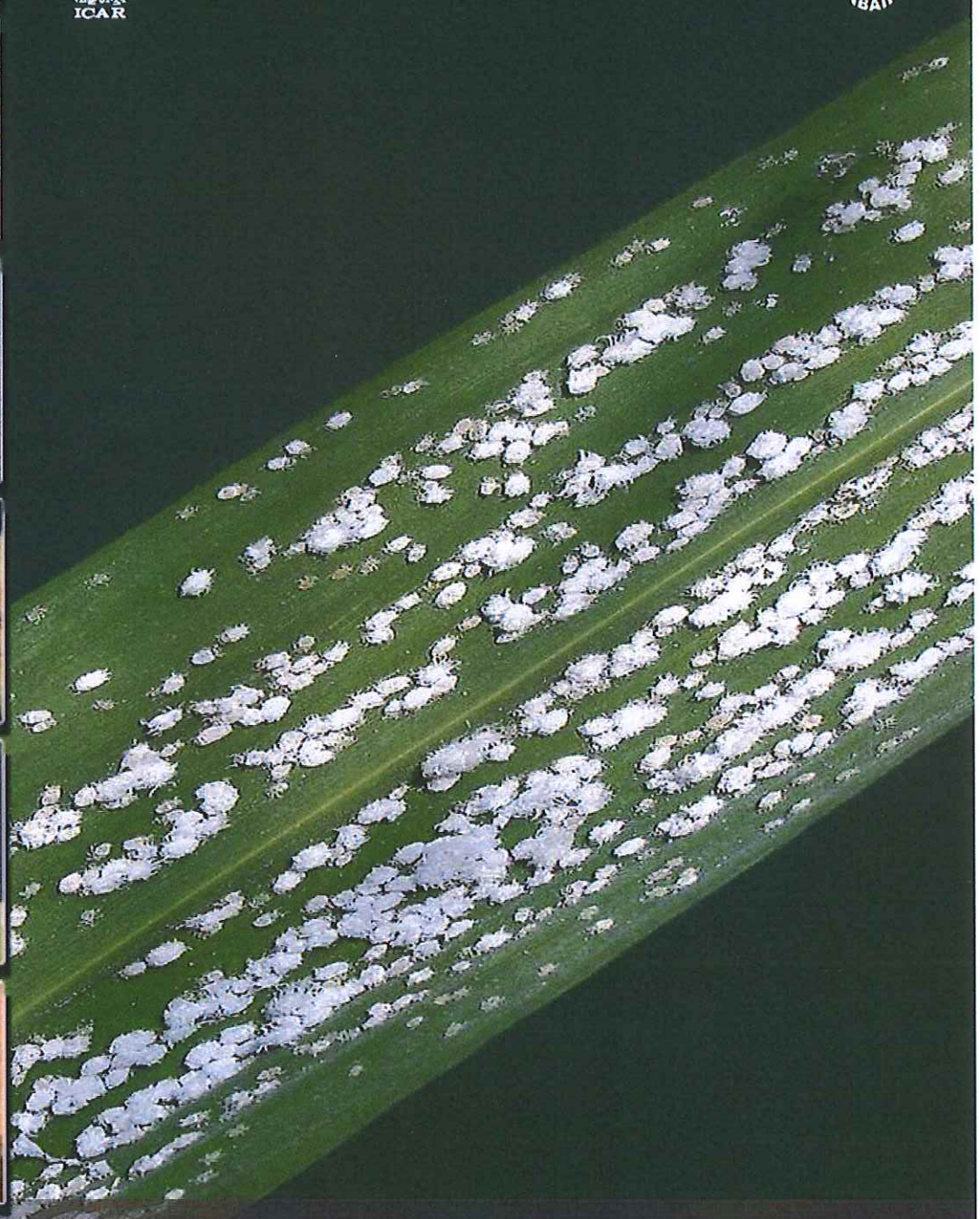
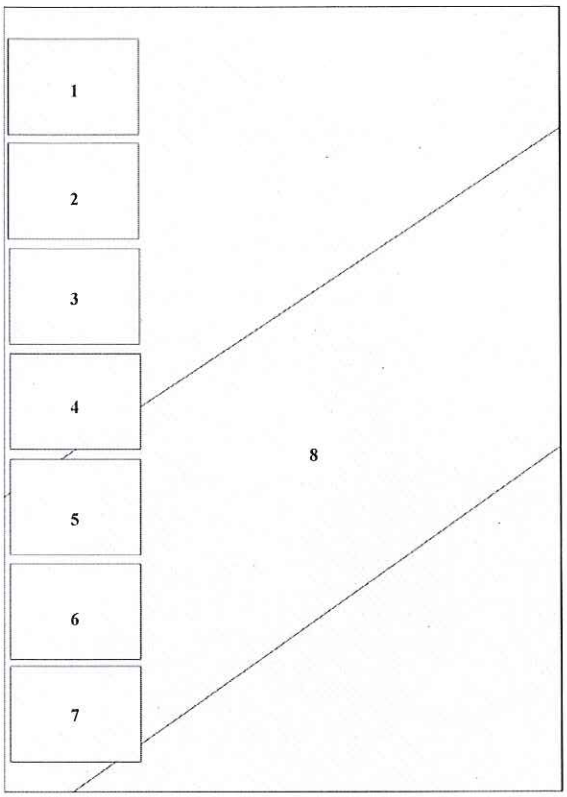
Biological Control of Sugarcane Pests in India



All India Co-ordinated Research Project on Biological Control of Crop Pests

ICAR- National Bureau of Agricultural Insect Resources, Bengaluru, India



Front Cover

1. Early shoot borer, *Chilo infuscatellus* Snellen (Lepidoptera: Crambidae)
2. Maize stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae)
3. Internode borer, *Chilo sacchariphagus indicus* (Kapur) (Lepidoptera: Crambidae)
4. Sugarcane top borer, *Scirpophaga excerptalis* (Walker) (Lepidoptera: Crambidae)
5. Pink stem borer, *Sesamia inferens* (Walker) (Lepidoptera: Noctuidae)
6. Sugarcane scale, *Melanaspis glomerata* (Green) (Hemiptera: Diaspididae)
7. Indian sugarcane leafhopper, *Pyrilla perpusilla* Walker (Hemiptera: Lophophidae)
8. Sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner (Hemiptera: Aphididae)

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Cover design: Sunil Joshi

Biological Control of Sugarcane Pests in India

(Indian Council of Agricultural Research)

Dedicated to Biocontrol Workers
of AICRP family

All India Co-ordinated Research Project on Biological Control of Crop Pests
ICAR-National Bureau of Agricultural Insect Resources
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Compiled and edited by	:	Abraham Verghese, Sunil Joshi, Prashanth Mohanraj, S. K. Jalali, B. Ramanujam, M. Nagesh, R. J. Rabindra, Jagadeesh Patil, Maninder, Jagmohan Singh, Jaspal Singh Virk, Vikas Jindal, Naveen Agarwal, K. S. Sangha, Neelam Joshi, Ramandeep Kaur, Rabinder Kaur, S. Easwaramoorthy, J. Srinaath, N. Geetha, A. Basit, D. K. Saikia, Anjumoni Devi, Rudranarayana Borkakati, Balagurunathan, N. Sathaiah, P. Karupchamy, M. Kalyanasundaram, S. Sridharan, P. A. Saravan, N. Hariprasada Rao, Ganeswara Rao, S. A. Ghorpade, D. S. Pokharkar, R. V. Nakat, S. M. Galande, B. K. Mishra, Bhagabhan Patro, Arun Baitha, S. J. Rahman and G. Anitha
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FOREWORD

The All India Co-ordinated Research Project on Biological Control of Crop Pests with its headquarters at Bangalore was established by the ICAR in 1977. Consistent efforts of a group of dedicated workers for over 39 years have resulted in achieving significant progress in both basic and applied aspects of research on Biological Control of Crop Pests.

I am happy that the achievements of last 15 years of work on sugarcane pests have been consolidated into a bulletin. I am confident that the information provided in the publication entitled 'Biological Control of Sugarcane Pests in India' will be useful to all those interested in the discipline of Biological Control. I congratulate the team of workers on sugarcane crop under AICRP-BC and scientists of NBAIR, Bengaluru, for bringing out this useful publication.

(Abraham Verghese)
Director and Project Co-ordinator, AICRP-BC
ICAR-NBAIR, H.A. Farm Post, Bellary Road,
Bengaluru-560 024, Karnataka, India

Place: Bengaluru
Dated: 30.04.2016

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Biological Control of Sugarcane Pests in India

About Sugarcane

Sugarcane refers to any of six to 37 species (depending on which taxonomic system is used) of tall perennial grasses of the genus *Saccharum* (family Poaceae, tribe Andropogoneae) (Source: http://www.sugarcane.res.in/index.php/en/2014-04-28-11-31-50/about-sugarcane; https://en.wikipedia.org/wiki/Sugarcane). They have stout, jointed, fibrous stalks that are rich in sugar and measure two to six metres (six to 19 feet) tall. Most sugarcane species can be crossed and the major commercial cultivars are complex hybrids.

Sugarcane, *Saccharum officinarum* L., is the old sugar source for mankind since years and more recently, a replacement for fossil fuel for motor vehicles. Native to warm temperate to tropical regions of South Asia, it was first grown in South East Asia and Western India. Around 327 B.C., it was an important crop in the Indian sub-continent. It was introduced to Egypt around 647 A.D. and about one century later to Spain (755 A.D.). Since then, the cultivation of sugarcane was extended to nearly all tropical and sub-tropical regions. Portuguese and Spaniards took it to the New World early in the XVI century. It was introduced to the United States of America (Louisiana) around 1741.

Botanically, sugarcane belongs to the Andropogonae tribe of the family Gramineae, order Glumiflorae, class Monocotyledoneae, subdivision Angiospermae, division Embryophita siphonogama. The subtribe is Sacharae and the genus *Saccharum* is derived from the Sanskrit "sarkara = white sugar", a reminder that the plant reached the Mediterranean region from India.

In India, sugarcane is considered as one of the major industrial crops, which is cultivated under diverse agro-climatic conditions. Though India tops the world in the total area under sugarcane cultivation (51 lakh hectares), but Brazil leads the world in sugarcane productivity in 2013 with a 739 267 TMT harvest. India is the second largest producer with 341200 TMT tons, and China the third largest producer with 125 536 TMT tons harvest (Source: https://en.wikipedia.org/wiki/Sugarcane#Production). The average worldwide yield of sugarcane crops in 2013 was 70.77 tons per hectare. The most productive farms in the world were in Peru with a nationwide average sugarcane crop yield of 133.71 tons per hectare.

The main product of sugarcane is sucrose, which accumulates in the stalk internodes. Sucrose, extracted and purified in specialized mill factories, is used as raw material in human food industries or is fermented to produce ethanol, a low pollution fuel. Ethanol is produced on a large scale by the Brazilian sugarcane industry. Sugarcane products include table sugar, falernum, molasses, rum, cachaça (a traditional spirit from Brazil), bagasse and ethanol.

The energy production in terms of calorific value of individual plant parts (leaf, leaf sheath and stem) at different growth phases of sugarcane (formative, grand growth and maturity) in selected sugarcane. The leaf and stem dry mass content was high in Co 94008 and thus the total dry mass production was also high (4.32 kg/m^2) in this variety. The average partitioning of dry mass in to leaf, sheath ant stem was 16.87, 9.31 and 73.82%, respectively, suggesting greater dry mass production by stem. The energy production potential in the leaf tissue varied from a minimum of 2681 kcal/kg in Co 0314 to a maximum of 4025 kcal/kg in Co 99004 at formative phase. Varieties Co 94008 and Co 86032 recorded 3607 and 3228 kcal/kg, respectively. In the sheath tissue, the calorific value varied from a minimum of 2371

kcal/kg in Co 99004 to a maximum of 3805 kcal/kg in Co 86032. The stem of variety Co 99004 recorded a maximum of 3488 kcal/kg followed by Co 86032, which has recorded 3295 kcal/kg (Source: SBI, Coimbatore).

Sugarcane cultivation requires a tropical or temperate climate, with a minimum of 60 centimeters (24 in) of annual moisture. It is one of the most efficient photosynthesizers in the plant kingdom. It is a C4 plant, able to convert up to one percent of incident solar energy into biomass. In prime growing regions, such as Puerto Rico, India, Pakistan, Peru, Brazil, Bolivia, Colombia, Australia, Ecuador, Cuba, the Philippines, El Salvador and Hawaii, sugarcane can produce 20 lb (9 kg) for each square meter exposed to the sun.

India is the second largest producer of sugarcane next to Brazil. Presently, about 4 million hectares of land is under sugarcane with an average yield of 70 tonnes per hectare. India is the largest single producer of sugar including traditional cane sugar sweeteners, khandsari and Gur equivalent to 26 million tonnes raw value followed by Brazil in the second place at 18.5 million tonnes. Even in respect of white crystal sugar, India has ranked No.1 position in 7 out of last 10 years.

Sugarcane Insect Pests

The cane yield is markedly influenced by many factors such as biotic and abiotic stresses, soil, variety and cultural practices. Pests are known to inflict considerable losses in cane yield as well as sugar output. More than 125 insect species are reported to attack sugarcane crop from germination to harvest (Isaac, 1937; Box, 1953). Gupta (1957) and David *et al.* (1986) in their review listed about 18 as major and another 20 as minor insect pests. Based on the feeding habit, the pests infesting sugarcane may be broadly classified as borers, sucking pests, subterranean pests, defoliators and non-insect pests. Among the borers, there are more than a dozen that regularly damage the crop in different regions and at crop growth stage. The major sucking pests are pyrilla, woolly aphid, whiteflies, mealybugs, lygaeid bugs, mites and scale insect. Amongst subterranean pests, white grubs, termites, root aphids and mealybugs are prominent insects, there are few defoliators like leaf rollers, skippers, grass hoppers and occasionally important army worms. Many times non-insect pests such as rats, squirrels, jackals and nematodes also exert considerable damage on crops.

There are two distinct growth stages of crops, which gets infested by different insect pests. At shoot stage, i.e., up to 4 months of growth, insects that cause considerable losses are shoot, top, pink, root and stalk borers, termites, and at cane stage, *i.e.*, from 4th months onwards, termites, white grubs, woolly aphids, pyrilla whiteflies, mites internode borer, mealybug and scale insect. Nearing harvest, many non-insect pests also cause serious losses.

Use of insecticides in sugarcane would carry serious residue problems into sugar, jaggery, molasses, etc,. As these are also consumed without cooking, breakdown of residues is ruled out, so can be hazardous to human health. Use of insecticides also affect other non-target fauna. In many sugarcane growing areas, groundwater is polluted because of these insecticides. So, use of non-insecticidal measures and biological control is advocated.

This publication brings out information on biological control of sugarcane pests carried out under AICRP on Biological Control for the last two decades at different centres. The results are summarized under tissue borers, woolly aphid, other sucking pests and white grubs.

A. Field evaluation on tissue borers

A.1 Top shoot borer, *Scirpophaga excerptalis*

A.1.1 At Lucknow

Field evaluation of temperature tolerant strain of *Trichogramma japonicum* and pupal parasitoid, *Tetrastichus howardi* against sugarcane top borer, *Scirpophaga excerptalis* was carried out at Lucknow (var. CoLk 8102). The schedule followed was: release of the egg parasitoid, *T. japonicum* @100000 adults/ha at weekly interval (at start of egg laying in each brood (*i.e.* 3 releases each in III, IV and V broods) and *T. howardi* @ 5,000adults/ha once at pupal stage in each brood and application of Carbofuran @ 1kg.a.i/ha against 3rd brood of top borer only in synchronization with pest activity (last week of June). The observations on the incidence of top borer were made in each brood by counting the dead hearts and total shoots in each row in the release as well as control plots.

The incidence of the top borer (II brood) ranged from 2.96-5.07% and was at par with control (Table 1).

Table 1. Field evaluation of temperature tolerant strain of *Trichogramma japonicum* and *Tetrastichus howardi* against sugarcane top borer, *Scirpophaga excerptalis*

Treatment	Incidence of top borer				Yield (t/ha)
	II brood	III brood	IV brood	V brood	
Trichogramma japonicum	5.02	3.62	6.43	6.04	69.72
Tetrastichus howardi	3.64	3.72	6.13	7.03	66.38
T.j+T.howardi	2.96	4.51	6.8	11.84	68.94
Carbofuran	3.73	2.49	4.8	5.48	69.71
Control	5.07	5.79	8.52	13.61	59.99
CD ($P \leq 0.05$)	NS	1.93	1.06	1.41	2.72

The incidence of III brood ranged from 2.49 to 5.79%. The incidence was significantly lower under bioagent release and carbofuran application than control. The suppressive role of bioagents was also significant in IV and V brood of top borer than control (Table 1). In general, incidence of top borer was low (5.07-13.61) due to high temperature. Significantly higher cane yield was observed in bioagent & chemical treatment than control. The treatments were targeted only against top borer, whereas infestation of other pests likes stalk borer, internode borer, termites, pyrilla etc also affected the cane yield.

A.1.2 At Punjab

A.1.2.1 At Kapurthala

Field evaluation of *T. japonicum* against Top borer, *S. excerptalis* was carried out at village Khera (Distt. Kapurthala). It was compared with chemical control and untreated control. The plot size was 0.2 ha for each treatments. The parasitoid, *T. japonicum* was released 8 times at 10 days interval during April to June @ 50,000 per

ha. In chemical control, phorate (Thimet 10G) @ 30kg/ha was applied during first week of July. Each plot was divided into 5 parts to record the observations. The egg masses of *S. excerptalis* were collected to record per cent parasitization.

The data presented in Table 2 revealed that the incidence of top borer in control (20.20%) was significantly higher than in release and chemical control plots. The lowest incidence was recorded in chemical control (9.80%) and it was at par with releases of *T. japonicum* (10.20%). The reduction in damage over control was 49.50 per cent in release fields and 51.48 per cent in chemical control. The mean parasitism of eggs of *S. excerptalis* in release field was 25.32 per cent and no parasitism was observed in chemical control (Table 2). The yield in control (634.00q/ha) was significantly lower than release fields (686.75q/ha) and chemical control (693.75q/ha), the latter two were at par with each other. The cost: benefit ratio in release fields was 1:7.86 as compared to 1:3.13 in chemical control.

It can be concluded that 8 releases of *T. japonicum* at 10 days interval during April to June @ 50,000 per ha proved as effective as chemical control for the control of top borer and reduced the incidence of top borer by 49.50 per cent.

Table 2. Field evaluation of *Trichogramma japonicum* against *Scirpophaga excerptalis* at village Khera (Distt. Kapurthala) Punjab during 2005

Temperature	Plot size (ha)	Period and no. release/insecticide application	Incidence of *S. excerptalis*	Per cent reduction over control	Per cent parasitism	Yield (q/ha)	Cost: Benefit ratio
T. japonicum	0.2	April to June (8)	10.2[a]	49.5	25.3[a]	686.8[a]	1:7.86
Chemical control (Phorate 10G @ 30kg /ha)	0.2	1st week of July (1)	9.8[a]	51.5	0.0[b]	693.8[a]	1:3.13
Control	0.2	-	20.2[b]	-	0.0[b]	634.0[b]	-
CV	-	-	8.6		8.5	9.7	

Note: Releases made @5000/ha at 10 days interval; Variety: CoJ 83

A.1.2.2 At Jalandhar

During 2006

Field evaluation of *T. japonicum* against top borer, *S. excerptalis* was carried out at village Gohawar (Distt. Jalandhar). It was compared with chemical control and untreated control. The plot size was 0.2 ha for each treatment. The parasitoid, *T. japonicum* was released 8 times at 10 days interval during April to June @ 50,000 per ha. In chemical control, phorate (Thimet 10G) @ 30kg/ha was applied during first week of July. Each plot was divided into 5 parts to record the observations. The egg masses of *S. excerptalis* were collected to record per cent parasitisation.

The incidence of top borer in control (15.7%) was significantly higher than in release and chemical control plots (Table 3). The lowest incidence was recorded in chemical control (7.6%) and it was on a par with releases of *T. japonicum* (7.7%). The reduction in damage over control was 51.2 per cent in release fields and 51.6 per cent in chemical control. The mean parasitism of eggs of *S. excerptalis* in release field was

25.5 per cent and 1.3 and 1.4 per cent in chemical control and control (Table 27). The yield in control (711.6 q/ha) was significantly lower than release fields (771.8q/ha) and chemical control (772.8q/ha) the later two were on a par with each other. The cost: benefit ratio was 1:13.2 in release field as compared to 1: 5.9 in control. It can be concluded that 8 releases of *T. japonicum* at 10 days interval during April to June @ 50,000 per ha proved as effective as chemical control for the control of top borer and reduced the incidence of top borer by 51.2 per cent. The pooled data of three years (2004 to 2006) revealed that 8 releases at 10 days interval of *T. japonicum* during April to June @ 50,000 per ha reduced the incidence of top borer by 50.8 per cent. The cost: benefit ratio of release field (1:18.6) was higher than chemical control (1: 9.6) (Table 4).

Table 3. Field evaluation of *Trichogramma japonicum* against *Scirpophaga excerptalis* at village Gohawar (Distt. Jalandhar) Punjab during 2006

Treatments	Plot size (ha)	Period and no. release/insecticide application	Incidence of *S. excerptalis*	Per cent reduction over control	Per cent parasitism	Yield (q/ha)	Cost: Benefit ratio
T. japonicum	0.2	Mid April to end June (8)	7.7[a]	51.2	25.5[a]	771.8[a]	1:13.2
Chemical control (Phorate 10G @ 30kg /ha)	0.2	1st week of July (1)	7.6[a]	51.6	1.3[b]	772.8[a]	1:5.9
Control	0.2	-	15.7[b]	-	1.4[b]	711.6[b]	-
CV	-	-	10.6	-	7.3	8.1	-

Note: Releases made @5000/ha at 10 days interval; Variety: Coj 88

Table 4. Field evaluation of *Trichogramma japonicum* against *Scirpophaga excerptalis* at village Gohawar (Distt. Jalandhar) Punjab during 2004-06

Treatments	Plot size (ha)	Period and no. release/insecticide application	Incidence of *S. excerptalis* (2004-06)	Per cent reduction over control	Per cent parasitism	Yield (q/ha)	Cost: Benefit ratio
T. japonicum	0.2	Mid April to end June (8)	8.5[a]	50.8	23.4[a]	733.0	1:18.6
Chemical control (Phorate 10G @ 30kg /ha)	0.2	1st week of July (1)	8.2[a]	52.2	1.6[b]	736.6	1:9.6
Control	0.2	-	17.2[b]	-	1.9[b]	655.4	-

Note: Eight Releases made @50,000/ha at 10 days interval in each years

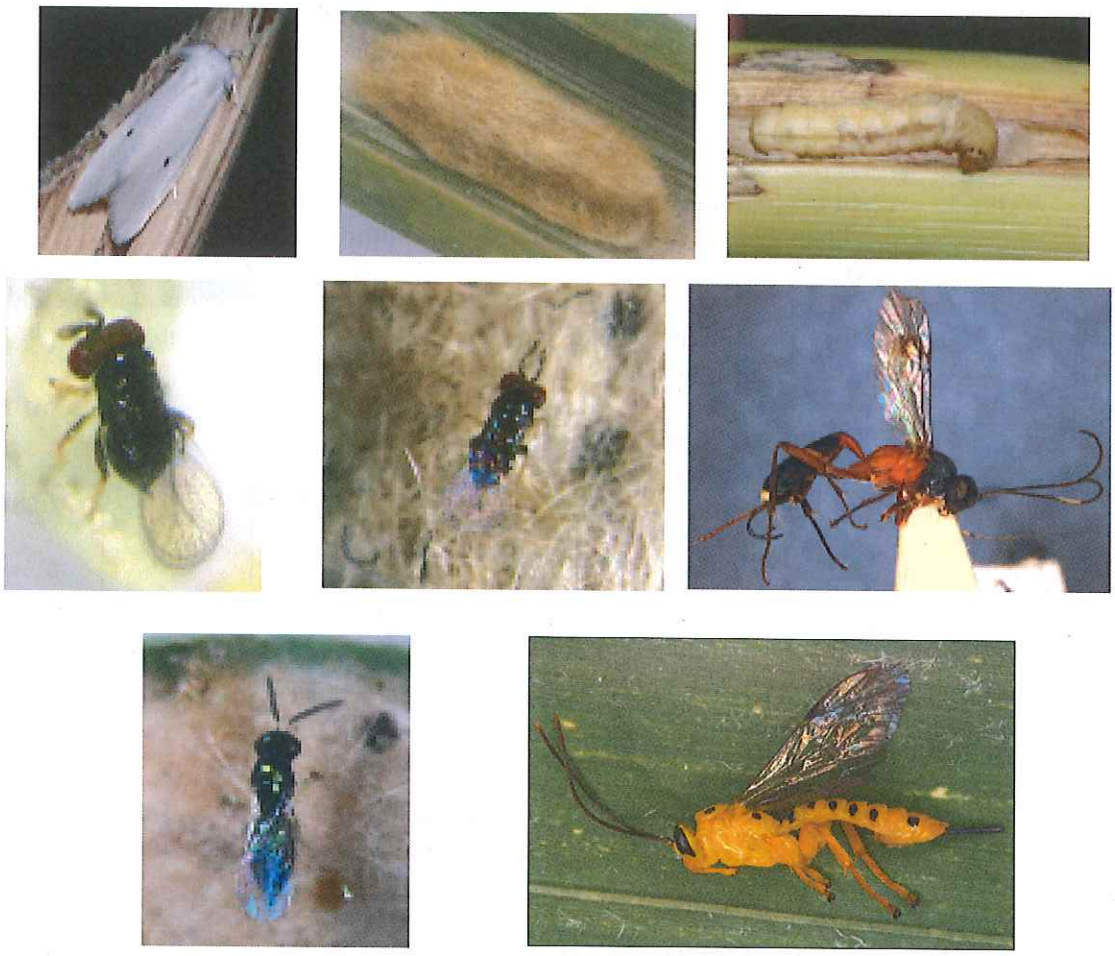


Plate 1. Sugarcane top shoot borer, *Scirpophaga excerptalis* and its natural enemies

A.2 Plassey borer, *Chilo tumidicostalis*

A.2.1 At Assam

A.2.1.1 During 2005

The field evaluation of *Trichogramma chilonis* against *Chilo tumidicostalis* was conducted at Sugarcane Research Station, Buralikson. Plots where *Trichogramma chilonis* was released @ 50,000/ha at 10 days interval and Farmers' practice plot were the two treatments.

The farmers plot was chosen from a farmer's field located in a village near the SRS, Buralikson. The sugarcane variety Dhansiri (CoBLN 9605) was grown in the two locations. The parasitoids were released @ 50,000/ha at 10 days intervals and altogether 9 releases were made in the released plot. The first release was made after 50 DAP. The observations were made on the percent incidence of *Chilo tumidicostalis* in the second fortnight of June 2005 onwards (Table 5). The egg parasitism was determined by placing *Corcyra cephalonica* egg cards containing 50 eggs per card at 5 spots. The data presented in Table 3 revealed that the percent infestation of *C. tumidicostalis* before the field release of this parasitoid was 37.0 per cent against 42.0 per cent in the farmers' field. However, the percent parasitism of *Trichogramma* spp. in the experimental plot prior to release of the parasitoid was 14 per cent in comparison to 9.0 per cent in the farmers plot. Post release records showed that *T. chilonis* had good impact in reducing the mean percent incidence of *C. tumidicostalis* in the released plot which was 20.0 percent against 45.0 per cent in the farmers plot. Similarly, post treatment parasitism of 34.0 per cent was recorded in the released plot as against 12.0 percent in farmers plot. The released plot registered higher yield (78.0 t/ha) whereas in farmers practice plot, the yield was only 54.0 t/ha.

A.2.1.2 During 2006

The field evaluation of *Trichogramma chilonis* @ 50000/ha, 9 times during the season against *Chilo tumidicostalis* was compared with farmers' field and trial was conducted at Sugarcane Research Station, Buralikson. Farmers' field located in a village near to SRS, Buralikson and the variety was Dhansiri (CoBLN 9605). Observations were made on percent incidence of the pest in the last fortnight of May onwards for the both cropping season. The natural egg parasitism was determined by placing sentinel cards of *C. cephalonica.*

Mean data for two years (2005 and 2006) presented in Table 6 revealed that the percent infestation of *C. tumidicostalis* before the field release of parasitoid was 36.5 per cent against 45.0 per cent in the farmers field. Moreover, the percent parasitism of *Trichogramma* spp. in the experimental plot prior to release of the parasitoid was 16.6 per cent compared to 10.3 per cent in the farmers field. After post release of parasitoids, the results showed that *T. chilonis* had good impact in reducing the percent incidence of *C. tumidicostalis* in the released plot, which was 23.0 per cent only as against 49.5 per cent in the farmers' field. Similarly, the post treatment parasitism of 30.2 per cent was observed in the plot of *T. chilonis*, whereas it was only 13.4 per cent in farmers field. As regards yield, the mean observations of subsequent years showed that the maximum yield 79.2 t/ha was registered in the released plot. In farmer's field it was only 58.0 t/ha.

Table 5. Evaluation of *Trichogramma chilonis* against Plassey borer

Treatment	Pretreatment			Post treatment			Percentage reduction in damage over control	Yield (t/ha)
	Egg parasitism	No. of healthy cane (%)	No. of infected cane (%)	No. of healthy cane (%)	No. of infected cane (%)	Egg parasitism		
Trichogramma chilonis released plot @ 50,000/ha	14.0	63.0	37.0	80.0	20.0	34.0	44.4	78.0
Farmers practice	9.0	58.0	42.0	55.0	45.0	12.0	-	54.0

9 releases @ 50,000/ha at 10 days interval; variety: Dhansiri (CoBLN 9605)

Table 6. Evaluation of *Trichogramma chilonis* against Plassey borer

Treatment	Pretreatment									Post treatment									Percentage reduction in damage over control			Yield (t/ha)		
	Egg parasitism			No. of healthy cane (%)			No. of infected cane (%)			No. of healthy cane (%)			No. of infected cane (%)			Egg parasitism								
	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
1. *Trichogramma chilonis* released plot	14.0	19.2	16.6	63.0	64.0	63.5	37.0	36.0	36.5	80.0	74.0	77.0	20.0	26.0	23.0	34.0	26.9	30.2	44.4	30.0	37.2	78.0	80.5	79.2
2. Farmers practice	9.0	11.6	10.3	58.0	52.0	55.0	42.0	48.0	45.0	55.0	46.0	50.5	45.0	54.0	49.5	12.0	14.8	13.4	-	-	-	54.0	62.0	58.0

9 releases @ 50,000/ha at 10 days interval
Variety: Dhansiri (COBLN 9605)

A.2.1.3 During 2007

Large scale demonstration of effectiveness of *T. chilonis* against the Plassey borer was carried out in a farmer's field on Co BLN 9605 variety at Halowa Gaon in Golaghat district over an area of 10 ha. Eleven releases of *T. chilonis* were made @ 50,000/ha/release at 10 days interval from June middle to end of October, 2007.

The release of *T. chilonis* resulted in significantly reduced infested cane and higher cane yield (82,500 kg/ha) than in farmers' practice (Fig. 1).

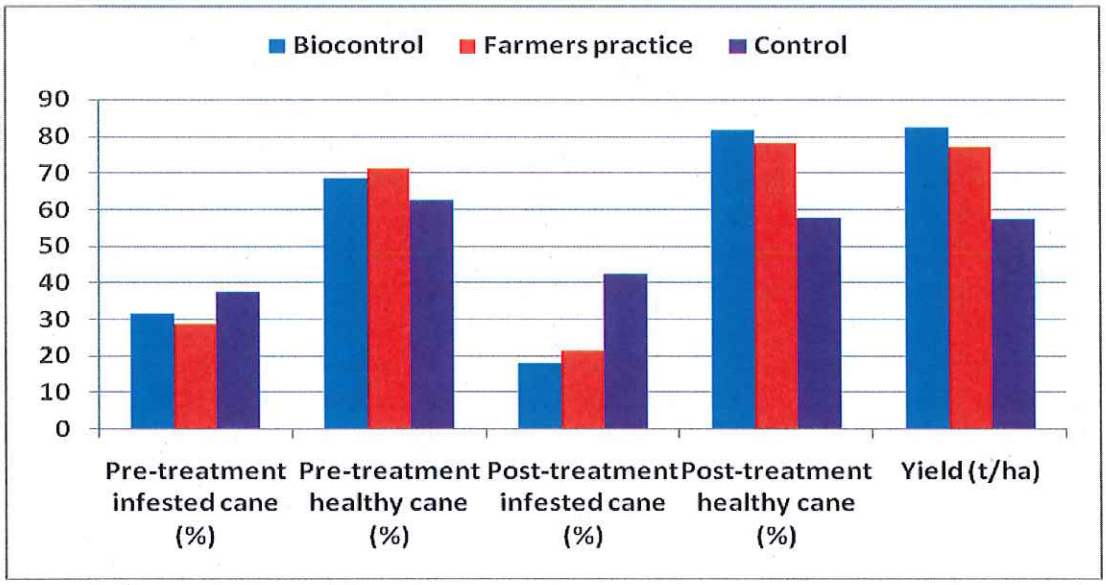


Fig. 1. Evaluation of *Trichogramma chilonis* against Plassey borer

A.3 Early shoot borer, *Chilo infuscatellus*

A.3.1 At Punjab

A.3.1.1 At Nawanshahar and Kapurthala

A.3.1.1.1 During 2005

Field evaluation of temperature tolerant strain (TTS) of *T. chilonis* developed by PDBC was carried out at village Mehli (Distt. Nawanshahar) and village Khera (Distt Kapurthala). It was compared with local strain of *T. chilonis,* chemical control and untreated control at Mehli, but was compared with chemical control and untreated control at village Khera. Both the strains of *T. chilonis* were released 8 times, from mid April to end June, at 10 days interval @ 50,000 per ha. In chemical control, cartap hydrochloride (Padan 4G) was applied @ 25 kg/ha, after 45 days of planting. The plot size was 0.2 ha for each treatment at village Mehli. However, at village Khera, plot size was 5 ha for temperature tolerant strain and 0.4ha each for chemical control and untreated control. Each plot was sub-divided into 5 parts to record the observations. Egg masses of early shoot borer were collected from each plot to record parasitisation.

The data presented in Table 7 revealed that the incidence of early shoot borer at Mehli in control was significantly higher than both the strains of *T. chilonis* and chemical control. The incidence in control was 13.60 per cent and it was significantly higher than all other treatments. The incidence in temperature tolerant strain of *T. chilonis* (6.40%) was at par with chemical control (6.20%) and Ludhiana strain of *T. chilonis* (6.60%). The parasitism in temperature tolerant strain (31.04%) was slightly higher than Ludhiana strain (27.68%). No parasitisation was observed in control and chemical control. The yield in plots where temperature tolerant strain was released (771.75q/ha) was at par with chemical control (762.25q/ha), which in turn was at par with Ludhiana strain (759.50q/ha) and was significantly higher than control (706.37q/ha). The cost: benefit ratio was highest in temperature tolerant strain (1:8.60) followed by *T. chilonis* local strain (1:6.99) and chemical control (1:3.98).

At village Khera (Table 8), the incidence of shoot borer in control (13.80%) was significantly higher than chemical control and release fields. The incidence in temperature tolerant strain of *T. chilonis* was 6.80 and it was at par with chemical control (6.60%). The reduction in damage over control was 50.72 per cent in temperature tolerant strain and 52.17 per cent in chemical control. The parasitism was very high (28.74%) in release fields and parasitism was not observed in control and chemical control plots. The yield in control (632.25q/ha) was significantly lower than in chemical control (683.12q/ha) and releases of *T. chilonis* (679.75q/ha). The cost: benefit ratio in temperature tolerant strain (1:6.25) was higher than in chemical control (1:3.63). It can be concluded that 8 releases of temperature tolerant strain of *T. chilonis* developed by PDBC, Bangalore @50,000per ha was at par with chemical control for the management of early shoot borer, and reduced the incidence by 50 to 53 per cent. The cost benefit ratio was higher than chemical control.

Table 7. Field evaluation of *Trichogramma chilonis* (Temp. tolerant strain) against *Chilo infuscatellus* at village Mehli (Distt. Nawanshahar) Punjab during 2005

Treatment	Plot size (ha).	Period and no. of release/Insecticide application	Incidence of *C. infuscatellus*	Per cent reduction over control	Per cent egg parasitism	Yield (q/ha)	Cost: benefit ratio
T. chilonis (Temperature tolerant strain)	0.2	Mid April to end June (8)	6.4[a]	52.9	31.04[b]	771.7[a]	1:8.60
T. chilonis (Local strain)	0.2	Mid April to end June (8)	6.6[a]	51.5	27.68[b]	759.5[b]	1:6.99
Chemical control (Padan @25kg/ha)	0.2	45DAT	6.2[a]	54.4	0.00[a]	762.3[ab]	1:3.98
Control	0.2	-	13.6[b]	-	0.00[a]	706.4[c]	-
CV	-	-	8.78	-	9.67	9.87	

Variety: Coj 88 ; Note: Releases made @50,000/ha at 10 days interval

Table 8. **Demonstration of *Trichogramma chilonis* (Temp. tolerant strain) against *Chilo infuscatellus* at village Khera (Distt. Kapurthala) Punjab during 2005**

Treatment	Plot size (ha)	Period and no. of release/Insecticide application	Incidence of *C. infuscatellus*	Per cent reduction over control	Per cent egg parasitism	Yield (q/ha)	Cost: Benefit ratio
T. chilonis (Temperature tolerant strain)	5	Mid April to end June (8)	6.8^{a}	50.7	28.7^{b}	679.8^{b}	1: 6.25
Chemical control Padan4g@ 25kg/ha	0.4	45 DAT(1)	6.6^{a}	52.2	0.0^{a}	683.1^{b}	1: 3.63
Control	0.4	-	13.8^{b}	-	0.0^{a}	632.3^{a}	-
CV	-	-	9.17		14.42	9.32	

Note: Releases made @50,000/ha at 10 days interval; Variety: CoJ 83

A.3.1.1.2 During 2009

Demonstrations on use of temperature tolerant strain (tts) of *T. chilonis* developed by PDBC were conducted at village Jasso Majara (Dist. Jalandhar) and village Paddi Khalsa (Dist. Kapurthala). It was compared with chemical control and untreated control. *T. chilonis* was released 8 times, during mid - April to end – June, at 10 days interval @ 50,000 ha^{-1}. In chemical control, cartap hydrochloride (Padan 4G) was applied @ 25 kg ha^{-1}, after 45 days of planting.

The data presented in Table 9 revealed that the mean incidence of early shoot borer at both the villages, *viz.*, Jasso Majara and Paddi Khalsa in control (12.7%) were significantly higher than temperature tolerant strain of *T. chilonis* (5.3%) and chemical control (5.1%). The mean incidence in temperature tolerant strain of *T. chilonis* was on a par with chemical control. Thus percent incidence reduction in release fields and chemical control over untreated control was 58.9 and 60.1, respectively. The mean yield in chemical control (728.5 q ha^{-1}) and temperature tolerant strain of *T. chilonis* (718.5 q ha^{-1}) was on a par but yield in these two was significantly higher than control (645.5 q ha^{-1}). The cost benefit ratio in temperature tolerant strain of *T. chilonis* (1: 21.9) was higher than chemical control (1: 8.5).

It can be concluded that 8 releases of temperature tolerant strain of *T. chilonis* developed by PDBC, Bangalore @50,000 ha^{-1} was on a par with chemical control for the management of early shoot borer *C. infuscatellus*, and reduced the incidence by 58.9 per cent over untreated control. When data of three years (2007-2009) was pooled, the mean incidence of early shoot borer in control (13.4%) was significantly higher than temperature tolerant strain of *T. chilonis* (5.7%) and chemical control (5.5%). Thus, mean percent incidence reduction in release fields and chemical control over untreated control was 58.2 and 60.1, respectively. The mean incidence in temperature tolerant strain of *T. chilonis* was on a par with chemical control (Table 10). The mean yield in chemical control (709.8 q ha^{-1}) and temperature tolerant strain of *T. chilonis* (696.2 q ha^{-1}) was on a par but yield in these two was significantly higher than control (638.3 q ha^{-1}). The cost benefit ratio in temperature tolerant strain of *T. chilonis* (1: 17.4) was higher than chemical control (1: 7.4) (Table 11).

Table 9. Demonstration of *T. chilonis* (Temp. tolerant strain) against *C. infuscatellus* at village Jasso Majra (Distt. Jalandhar) and Paddi Khalsa (Distt. Kapurthala) during 2009

Treatments	Incidence of *C. infuscatellus* (%)			Per cent reduction over control			Yield (q/ha)			Cost: Benefit ratio
	Jasso Majra	Paddi Khalsa	Mean	Jasso Majra	Paddi Khalsa	Mean	Jasso Majra	Paddi Khalsa	Mean	
T. chilonis (Temperature tolerant strain)	4.3	6.2	5.3[a]	61.5	56.3	58. 9	735.0	702.0	718.5[a]	1:21.9
Chemical control (Padan @25kg/ha)	4.1	6.1	5.1[a]	63.1	57.1	60.1	746.0	709.0	728.5[a]	1:8.5
Control	11.1	14.3	12. 7[b]	-	-	-	649.0	642.0	645.5[b]	-
CV			15.55						16.18	

Note: 8 releases of *T. chilonis* were made @50,000/ha at 10 days interval during April to end June; Padan 4G@ 25kg/ha was applied after 45 DOP

Table 10. Demonstration of *T. chilonis* (Temp. tolerant strain) against *C. infuscatellus* at during 2007 to 2009 (pooled)

Treatments	Incidence of *C. infuscatellus* (%)				Per cent reduction over control				Yield (q/ha)				Cost: Benefit ratio
	2007	2008	2009	Mean	2007	2008	2009	Mean	2007	2008	2009	Mean	
T. chilonis (Temperature tolerant strain)	7.1	4.6	5.3	5.7[a]	52.7	62.9	58.9	58.2	680.0	690.0	718.5	696.2[a]	1:17.4
Chemical control (Padan @25kg/ha)	7.0	4.5	5.1	5.5[a]	53.3	63.3	60.1	58.9	699.5	701.5	728.5	709.8[a]	1:7.4
Control	15.0	12.4	12.7	13.4[b]	-	-	-	-	629.5	640.0	645.5	638.3[b]	
CV				16.21									

Note: 8 releases of *T. chilonis* were made @50,000/ha at 10 days interval during April to end June; Padan 4G@ 25kg/ha was applied after 45 days of planting; Cost of insecticide: Rs 70/kg; Tricho card : Rs. 30/card; Sugarcane price: 180/q

Table 11. Cost: benefit analysis for demonstration of *T. chilonis* (TTS) against *C. infuscatellus* during 2007 to 2009

Treatments	Yield (kg/ha)	Add. Yield over control (kg/ha)	Value of Yield/ha	Cost of Treatment (Rs/ha)	Net Return (Rs/ha)	C:B ratio
T. chilonis (TTS)	69620	5790	10422	600	9822	17.4
Chemical control (Padan @25kg/ha)	70980	7150	12870	1750	11120	7.4
Control	638.3					

Cost of insecticide:Rs 70/kg; Trichocard : Rs30/card; Sugarcane price: 180/q

A.3.2 At Tamil Nadu

The heat tolerant strain ((HT) maintained at 40°C is currently under trial in two locations namely Katturu at Andhra Pradesh and Vellore, Tamil Nadu under the aegis of Sudalagunta Sugars and Vellore Cooperative sugars. The heat tolerant strain as well as the ordinary strain (OS) of the *T. chilonis* were released six times @ 2cc/acre at weekly intervals in treatment plots and a control plot (Contrl) without the release of the parasitoid was maintained. The observations on shoot borer incidence were taken through the assessment of "dead hearts" (DH) at fortnightly intervals.

Of the three trials, in two trials the dead heart percentage was significantly lower in plots released with heat tolerant strain than in control plots while the plots with ordinary strain showed mixed trend (Fig. 2 and 3). Similarly the cane count in the plots showed significant difference in one of the three trials with the heat tolerant strain being the best of the three treatments.

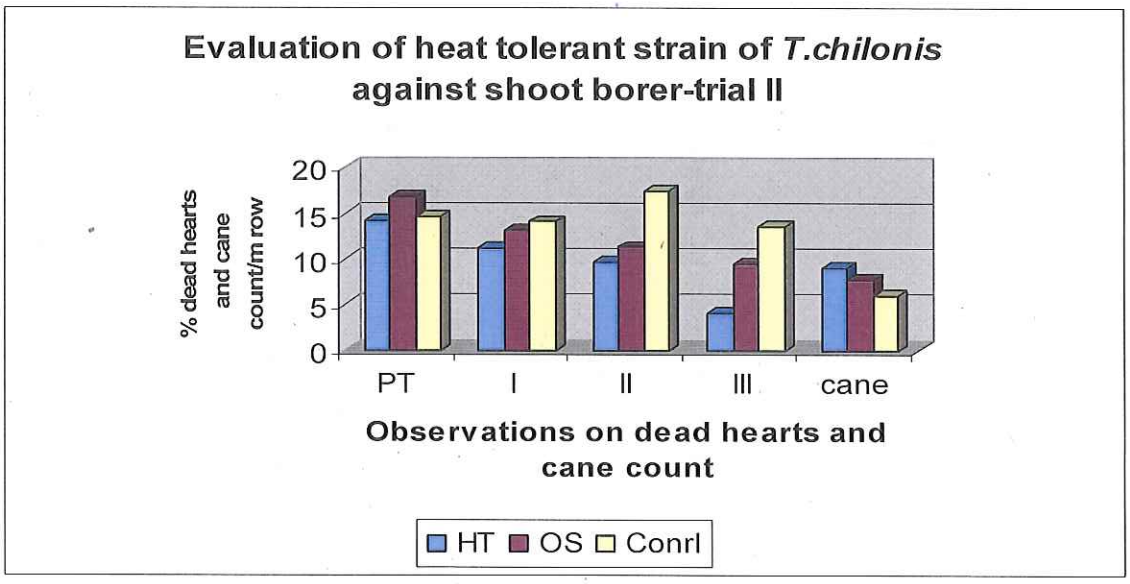


Fig. 2. Evaluation of heat tolerant strain of *T. chilonis* against shoot borer (Trial II)

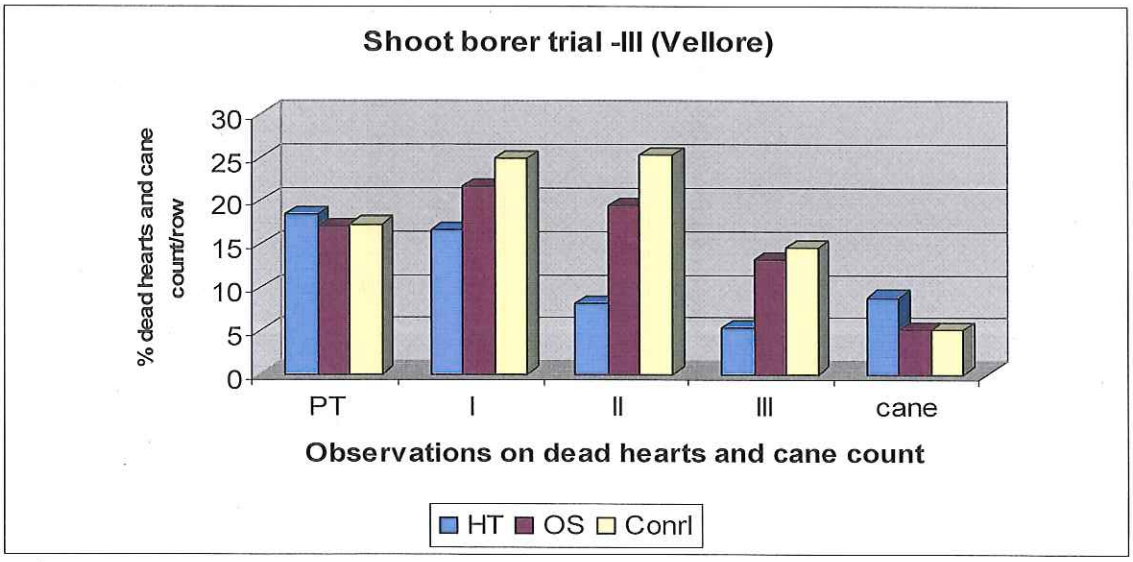


Fig. 3. Evaluation of heat tolerant strain of *T. chilonis* against shoot borer (Trial II)

A.3.3 At Maharashtra

Demonstration on effectiveness of *T. chilonis* TTS against ESB in sugarcane was conducted on the farm of Agronomy, College of Agriculture, Pune. Planting of sugarcane cv. Co 265 @ 25,000 setts/ha was done on 23/01/2012 over 1.0 ha with at 90 x 30 cm plant spacing. Nucleus culture of the parasitoid was obtained from the NBAII, Bangalore and mass cultured in the Biocontrol laboratory. The treatments comprised eight releases of *T. chilonis* TTS @ 50,000 adults/ha at weekly interval, farmers' practice- three sprays of chlorpyriphos 0.05% and untreated control. A control plot maintained at 200 m distance from parasitoid released plot. Each treatment plot divided into 10 subplots as replicates. Release of parasitoids started from 22/3/2012. The pre-release observations on infestation of ESB (% dead hearts) and number of tillers per clump were recorded at 15 spots in each subplot. Similarly, post counts of dead hearts and number of tillers at each spot were recorded at 15 days interval from initiation of parasitoids' release up to 4 months old crop. Yield was recorded on per plot basis and converted in to MT per ha. Data on per cent dead hearts and number of tillers per clump transformed to arc sin and $\sqrt{x+0.5}$ values respectively, before statistical analysis.

The results in Table 12 indicate that eight releases of *T. chilonis* TTS @ 50,000 parasitoids/ha at weekly interval starting from 45 days after emergence of shoots found significantly superior to untreated control in reducing the ESB infestation (6.7% dead hearts) and increased number of tillers (10.9 tillers/clump) as well as cane yield (144.9 MT/ha). It was, however, statistically comparable with chemical control.

Table 12. Efficacy of *T. chilonis* TTS against ESB on Sugarcane

Treatment	Dead hearts (%)		No. of tillers/clump		Yield (MT/ha)
	Pre-count	Post count	Pre-count	Post count	
T1: *T. chilonis* @ 50,000parasitoids/ha	9.8 [a]	6.7 [a]	8.3 [a]	10.9 [a]	144.9 [a]
T2: Farmers practice- chlorpyriphos 0.05%	10.0 [a]	7.5 [a]	8.6 [a]	10.3 [a]	144.0 [a]
T3: Untreated control	10.0 [a]	15.8 [b]	8.5 [a]	7.2 [b]	132.2 [b]
CD ($p \leq 0.05$)	NS	2.07	NS	0.41	5.60

A.4 Granulosis virus of *Chilo infuscatellus*

A.4.1 Collections of isolates from different factory zones and assess the virulence of GV isolates on *Chilo infuscatellus*

The viral isolates from Assam and Gujarat were scaled up for further studies. Bioassays for the all other isolates (Karnal, KCP Sugars, Sakthi, Coimbatore, Dharani, Saraswathi and Harinagar) against various instars have been completed and overlapping fiducial limits of the low LC_{50} values of many of the isolates indicated uniform high virulence against II and III instars larvae. However there were marked differences in the virulence of the isolates when tested against IV instar in the mortality as well as sub-lethal effects. All the isolates have been scaled up for persistence studies in summer in pot culture. The virus was effective in reducing the

incidence of shoot borer in pot culture. The persistence of semi purified suspension of Coimbatore isolate of the virus was high for 48 hrs protecting more than 85 % of the plants from the shoot borer infestation which was reduced to less than 40% on seventh day. The recovery of the granulo virus of shoot borer was possible throughout the year varying from 6.4 % to 31.2% with the highest incidence in February 2010. The fungal species *B. bassiana* and *M. anisopliae* were recovered during Sept 2009.-Jan.10 samples while *Sturmiopsis* was recorded in Sept. and Oct. samples and in Dec09- Jan 10 samples the latter recording highest incidence.

A.4.2 Development of granulosis virus as a microbial pesticide for shoot borer management (SBI)

a. Virulence of the viral isolates against shoot borer:

In vivo assays on diet reared larvae of various instars of shoot borer with the nine isolates of granulosis virus have been completed. The virulence of the isolates was found to be homogeneously high with the overlapping values of fiducial limits when tested against IInd and IIIrd instars. However, there were significant differences when tested against IVth instar larvae shoot borer. Among the latent effects and sub-lethal effects recorded, pupal mosaics and deformed adults were the highest in number in case of Assam isolate.

b. Efficacy of the granulosis virus in pot culture

On 30 days old sugarcane plants semi purified virus was sprayed. The virus-sprayed plants were exposed to ambient sunlight and temperature and first instar larvae were inoculated in the plants which were exposed to sunlight for either 24 hrs/2 days/3 days and so on upto 7 days. Another set of plants were inoculated with second instar larvae of shoot borer. The persistence of semi purified suspension of Coimbatore and Karnal isolate of the virus was the highest while that of Assam isolate was the lowest (Fig. 4).

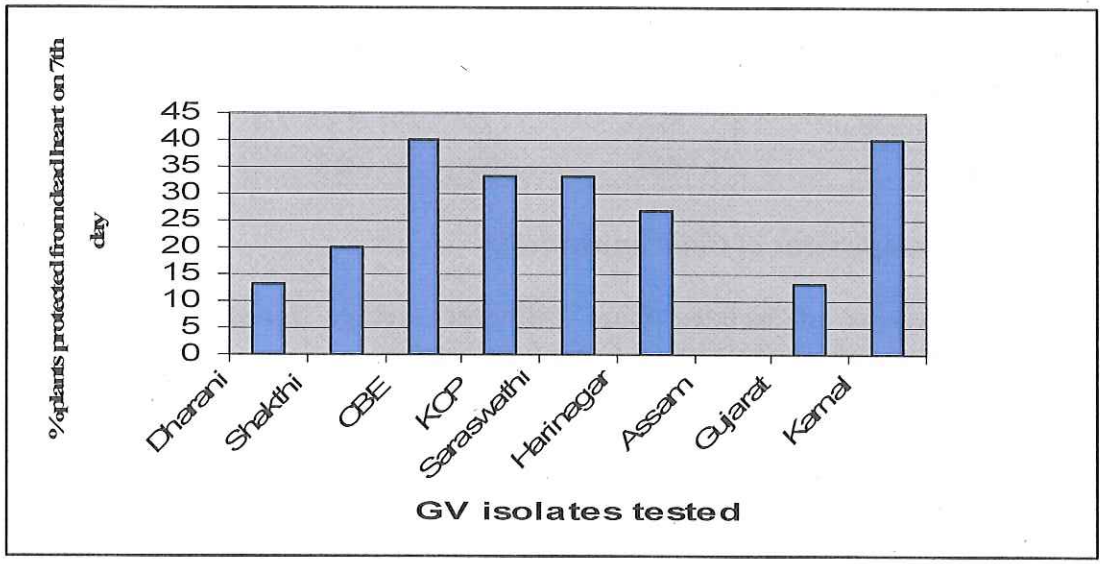


Fig. 4. Persistence of GV isolates in pot culture

c. Efforts to improve the efficacy of mass production of GV

In order to produce the virus in efficient manner, inoculation of virus at egg stage itself was attempted so as to economise the labour and diet involved in two step rearing *i.e.*, rearing the neonate larvae in a set of diet up to III instar and inoculation of virus *per os* and then transferring it into another set of diet for further rearing to harvest the virus. However despite high level of virus induced larval mortality (~95%), the virus harvest was modest due to the early death of larvae. Dosage standardization for egg surface contamination to reduce premature death resulted in larval pupal mosaics rather than development of virosed larvae into full growth.

Of the all other instars tested to improve virus harvest while being reared on diet, late third instar with lower inoculums or fourth instar with higher inoculums produced good results with least number of mosaics and high percent of virosed larvae (> 85 %). Hence, it is absolutely necessary to rear the shoot borer larvae in two steps i.e., the larvae are to be reared up to IIIrd/IVth instar in a set of diet and after inoculation with virus can be transferred to another set of diet for further rearing. The standardization of mass rearing of shoot borer for virus production resulted in a recovery of 37.5% of IV instar larvae in group rearing while single vial rearing of larvae resulted in a recovery of 75-80% in different batches.

d. Natural incidence of GV

Fortnightly collection of shoot borer larvae from the field indicated that the granulosis virus was more active during Oct. - Dec. than during Feb. - April 2010. The lowest recovery (14.3%) of GV was in April and the highest incidence (33.2%) was in October 2010. Among the natural enemies, the most commonly recorded was *Sturmiopsis inferens* with the highest incidence (21.5%) during September 2010. Among the entomophagous fungi, *Metarhizium anisopliae* was recovered highest (10.8%) during October and *Beauveria bassiana* was rarely observed in the samples (Fig. 5).

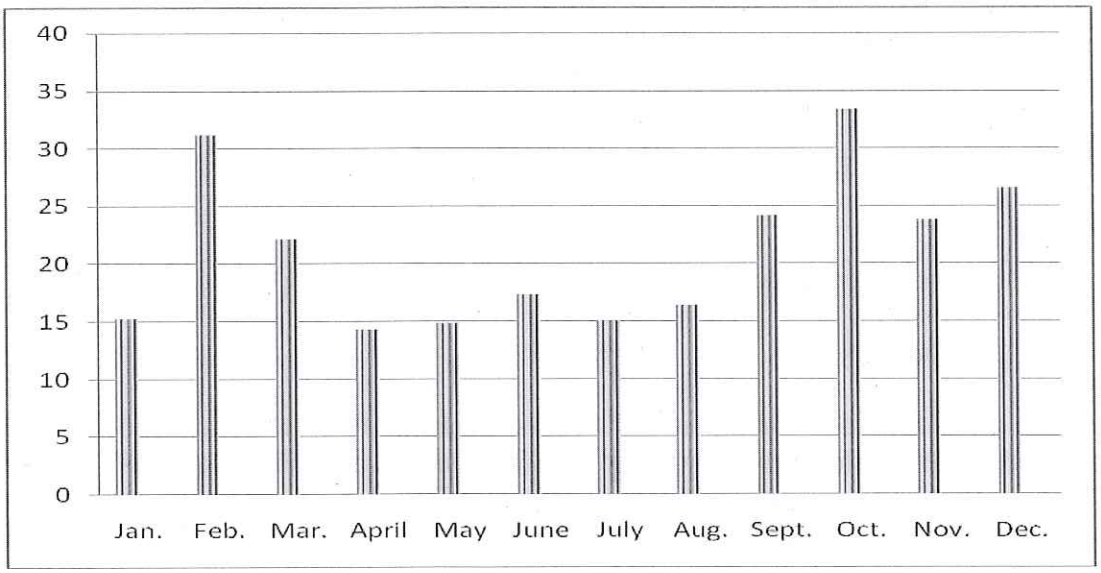


Fig. 5. Per cent GV incidence during the year 2010

A.5 Stalk borer, *Chilo auricilius* and internode borer, *C. sacchariphagus indicus*

A.5.1 At Punjab

A.5.1.1 During 2008

A large scale field demonstration on efficacy of *T. chilonis* for the management of *Chilo auricilius* was conducted over an area of 40 ha at village Paddi Khalsa (Dist. Kapurthala). *T. chilonis* was released 12 times at 10 days interval during July to October @ 50,000 per ha. The incidence of stalk borer was significantly lower (5.6%) in the release field in comparison to control (12.8%). The percent parasitisation was significantly higher in release fields (55.6%) as compared to control (4.9 %).

A.5.1.2 During 2009

The efficacy of *T. chilonis* was demonstrated over an area of 40 ha at village Chachrari (Distt. Kapurthala) for the management of stalk borer, *Chilo auricilius*. The parasitoids were released 12 times at 10 days interval during July to October @ 50,000 ha^{-1}. The control plot was 0.4 ha. The incidence of stalk borer and percent parasitism was recorded from both the plots.

The incidence of stalk borer in control was 10.8 per cent as compared to 4.8 per cent in release field, which resulted in 55.4 per cent reduction in damage (Table 13). The percent parasitisation in release fields was high (54.8%) as compared to control (4.6 %). It can be concluded that 12 releases of *T. chilonis* at 50,000 ha^{-1} at 10 days interval proved effective and reduced the incidence of stalk borer by 55.4 per cent.

Table 13. Large-scale demonstration of the effectiveness of *T. chilonis* against *C. auricilius* at Vill. Chachrari (Distt. Kapurthala) in Punjab during 2009

Treatments	Plot size (ha)	Incidence of *C. auricilius*	Per cent reduction in damage over control	Per cent parasitism
Release field	40.0	4.8^{a}	55.4	54.8^{a}
Control	0.4	10.8^{b}	-	4.6^{b}
CV	-		-	17.8

Note: 12 releases were made @50,000 ha^{-1} at 10 days interval during July to end October

A.5.2 At Tamil Nadu

Large scale field demonstration of *T. chilonis* against the internode borer in trial 1 carried out at four locations on variety Co 86032 in 8 ha area and the results compared with control. The parasitoid, *T. chilonis* was released 8 times at 10 days interval during September to November @ 1,00,000 per ha. The incidence of internode borer was significantly reduced by *T. chilonis* release. The mean incidence of inernode borer in parasitoid release plot was 12.1% and the intensity of damage was 2.9% which was significantly lower as compared to control (22.0% and 10.0%,

respectively). Significantly higher yield (1,15,200 kg/ha) was recorded in parasitoid release plots compared to control.

In trial 2, evaluation of *T. chilonis* @ 12.5 cc per hectare against internode borer revealed that the incidence of INB was 52.4% in release plot compared to 74.8% in control. The yield in released plot was significantly higher (153400 kg/ha) than control and there was a 29.95% reduction in the INB incidence and 13.29% increase in yields in parasitoid released plots compared to control plots.

Two field trials were conducted in farmers fields to compare the effect of six releases and continuous release of *T. chilonis*. Continuous release of *T. chilonis* has resulted in lowest incidence (41.3%), intensity of damage (2.1%), dead hearts (8.9%) and highest yield (202060 kg/ha) as compared to six releases and control.

A.5.3 At Maharashtra

A.5.3.1 During 2008

Field demonstration of *T. chilonis* (TTS and SAS strains) against internode borer on sugarcane revealed that six releases @ 1 lakh/ha/release found effective in reducing the pest incidence and intensity in sugarcane.

Field evaluation of *T. chilonis* against internode borer was done in combination with INB Pheromone. *T. chilonis* was released @ 12.5 cc per hectare. Release of *T. chilonis* either alone or in combination of pheromone significantly reduced INB incidence and increased the yields compared to control (Table 14).

Table 14. Evaluation of *T. chilonis* in combination with pheromone against internode borer

Treatment	Incidence of INB (%)	Intensity of INB (%)	Yield (kg/ha)
T. chilonis	43.68[a]	2.34[a]	1,38,100[a]
Pheromone	52.2[a]	2.68[a]	1,27,900[b]
T. chilonis + pheromone	44.4[a]	2.42[a]	1,35,300[a]
Control	63.23[b]	4.15[b]	1,21,620[c]

A.5.3.2 During 2009

The planting of sugarcane (cv. Co 86032) was done on 03/02/2009 at 90 x 90 cm spacing over 1 ha on the research farm of Agronomy Section, AC, Pune. Nucleus cultures of *T. chilonis* (TTS and SAS) strains were obtained from the NBAII, Bangalore and mass cultured in the laboratory. Each treatment plot divided into 10 subplots as replicates and at least 10 canes from each subplot detrashed to expose youngest internode. These nodes marked with black paint and release of parasitoids was done at such spots. The treatments comprised release of *T. chilonis* TTS and *T. chilonis* SAS each @ 1 lakh parasitoids (5 Trichocards)/ha and untreated control. The parasitoids were released six times at weekly interval starting from 25/8/2009. Pre-count and post-treatment counts (a week after six releases) were recorded. Control plot maintained at 200 m distance from the parasitoid released plots.

Observations were recorded on the pest incidence and intensity by detrashing entire canes and counting bored holes after six releases. Yield data were recorded by weighing 50 canes from each treatment plots at harvest.

The data in Table 15 showed significant differences in *T. chilonis* released plots and untreated control in respect of incidence and intensity of INB after six releases of the parasitoids. The TTS strain of *T. chilonis* found effective with 5.9% incidence and 1.2% intensity of INB, followed by the SAS strain of the parasitoid as against 24.2% incidence and 2.8% intensity in control plot.

Table 15. Efficacy of *Trichogramma chilonis* against INB on sugarcane

Treatment	Pre-count (%)		Post count (%)		Yield (kg /50 canes)
	Incidence	Intensity	Incidence	Intensity	
T. chilonis TTS @ 1 lakh ha^{-1}	3.6^{a}	0.7^{a}	5.9^{a}	1.2^{a}	82.0^{a}
T. chilonis SAS @ 1 lakh ha^{-1}	3.8^{a}	0.7^{a}	13.2^{b}	1.6^{b}	75.2^{b}
Untreated control	3.6^{a}	0.8^{a}	24.2^{c}	2.8^{c}	71.7^{b}
CV (%)	7.8	8.1	6.4	7.6	8.3

A.5.3.3 During 2010

The experiment was laid out on the research farm of Agronomy Section, College of Agriculture, Pune and planting of sugarcane (cv. Co 671) was done on 09/01/2010 at 90 x 90 cm spacing over 1.5 ha. Nucleus cultures of *T. chilonis* (TTS and SAS) strains were obtained from the NBAII, and mass cultured. Each treatment plot divided into 10 subplots as replicates and at least 10 canes from each subplot detrashed to expose youngest internode. These nodes were marked with black paint and release of parasitoids was done at such spots. The treatments comprised release of *T. chilonis* TTS and *T. chilonis* SAS each @ 1 lakh adults/ha and untreated control. Control plot was maintained at 200 m distance from the parasitoid released plots. Six releases of the parasitoids were made at weekly interval starting from 06/9/2010. Pre and post-treatment (after six releases) observations were recorded on incidence and intensity of INB by detrashing entire canes and counting bored holes. Per cent figures of INB incidence and intensity were transformed to arc sin values before statistical analysis. Yield data were recorded by weighing 50 canes from each treatment plots at harvest.

Data in Table 16 shows significant differences in *T. chilonis* released plots and untreated control in respect of per cent incidence and intensity of INB after six releases of the parasitoids. The TTS of *T. chilonis* found effective with 6.9% incidence, 1.2% intensity of INB and 89.9 kg yield per 50 canes, followed by the SAS of the parasitoid as against 28.6% incidence and 3.4% intensity in control plot.

Table 16. Efficacy of *Trichogramma chilonis* against INB on sugarcane

Treatment	Pre-count (%)		Post count (%)		Yield (kg/50 canes)
	Incidence	Intensity	Incidence	Intensity	
T1: *T. chilonis* TTS @ 1 lakh/ha	4.0 ^{a}	0.7 ^{a}	6.9 ^{a}	1.2 ^{a}	89.9 ^{a}
T2: *T. chilonis* SAS	3.9 ^{a}	0.6 ^{a}	14.1 ^{b}	1.7 ^{b}	84.6 ^{a}

@ 1 lakh/ha					
T3: Untreated control	4.1 [a]	0.7 [a]	28.6 [c]	3.4 [c]	76.4 [a]
CV (%)	13.2	15.0	14.2	13.4	13.5

Pooled analysis of three years data revealed that six releases of TTS of *T. chilonis* @ 1 lakh adults/ha was significantly superior to SAS of the parasitoid showing 7.3% incidence and 1.2% intensity of INB in sugarcane with the yield of 85.9 kg per 50 canes. However, both the strains were statistically effectively as compared to untreated control (Table 17).

Table 17. Efficacy of *Trichogramma chilonis* against INB on sugarcane (Pooled data of 2008-09, 2009-10 and 2010-11)

Treatment	Pre-count (%)		Post count (%)		Yield (kg/50 canes)
	Incidence	Intensity	Incidence	Intensity	
T1: *T. chilonis* TTS @ 1 lakh/ha	3.6 [a]	0.6 [a]	7.3 [a]	1.2 [a]	85.9 [a]
T2: *T. chilonis* SAS @ 1 lakh/ha	3.9 [a]	0.6 [a]	13.2 [b]	1.6 [b]	79.9 [a]
T3: Untreated control	4.0 [a]	0.7 [a]	26.5 [c]	2.8 [c]	74.0 [b]
CV (%)	10.1	5.7	5.2	5.4	7.8

A.5.4 At Uttar Pradesh

A field trial was conducted at IISR research farm on sugarcane variety CoLk8102. The treatments were: a) release of *T. chilonis* @ 50,000 /ha from July to October at 10 days interval, b) release of *Cotesia flavipes* @ 500 gravid females/ha from July to November at 7 days interval and c) release of *Tetrastichus howardi* @ 5000 adults/ha at monthly interval from July to November.

T. chilonis release plots recorded lowest internode borer incidence (5.6%) compared to *C. flavipes* or *T. howardi* released fields, but *C. flavipes* release plots recorded lowest incidence of stalk borer (5.6%) followed by *T. howardi* and *T. chilonis*. Highest yield was recorded in *T. chilonis* release plots (Table 18).

Table 18. Evaluation of six and continuous releases of *T. chilonis* against internode borer

Treatment	Incidence of INB (%)	Incidence of stalk borer (%)	Yield (kg/ha)
T. chilonis-	5.6[a]	13.4[b]	60,710[a]
Cotesia flavipes	7.5a	5.6[a]	51,440[b]
Tetrastichus howardi	9.7[b]	10.9[b]	46,990[cd]
Removal of dry leaves, late shoots and water shoots	7.8[b]	13.4[c]	50,110[bc]
T. c + *C. f* + *T. h.* + removal of dry leaves, late shoots and water shoots	7.6[b]	11.0[b]	48,840[bc]
Control	12.7[d]	17.3[d]	43,840[d]

A.5.5 At Odisha

The crop was planted during November-December. First release of *T. chilonis* was made on 5th December after taking pre-release ESB infestation which ranged from 15.9 to 17.2%. Release of *T. chilonis* continued till 4th week of February. Observations on incidence of ESB were recorded each week starting from 2nd week of December till the 4th week of February. The incidence of ESB ranged from 5.5 to 24.7%, the lowest being in *T. chilonis* released plots. Parasitoid release resulted in significant reduction of ESB population as compared to pesticide application, which resulted in 16.9% ESB incidence. The control plots had 24.7% ESB incidence.

Similarly, internode borer incidence was also least in parasitoid released plots (4.8%) as compared to 5.6% in insecticide treatment and 10.2% in untreated control. However, the pest incidence was based upon only two observations as the crop is only four month old now. Observation on the incidence of internode borer will continue. (Table 19).

Table 19. Demonstration on the use of *T. chilonis* against early shoot borer and internode borer of sugarcane in farmers' field

Treatments	Early shoot borer (%)		Internode borer(%)	
	Pre release	Post release**	Pre release	Post release***
Release of *T.chilonis* after 45 DAG @ 50,000/ha at weekly intervals. Total of 10-12 releases will be made	15.9 (4.05)	5.5 (2.45)	5.4 (2.43)	4.8 (2.30)
Farmers' practice *	17.2 (4.21)	12.9 (3.66)	6.9 (2.72)	5.6 (2.47)
Untreated control	16.4 (4.11)	24.7 (5.02)	7.1 (2.76)	10.2 (3.27)
C.D (I=0.05)	NS	(0.94)	(0.24)	(0.18)

Figures in parentheses are square root transformations; application of Phorate, Carbofuran or imidacloprid granules at varying doses during earthing up and spraying of rynaxypyr, monocrotophos, profenophos; ** mean of ten observations; *** mean of two observations

B. Large scale demonstration of bioagents on tissue borers

B.1 Top borer, *Scripophaga excerptalis*

B.1.1 At Punjab

B.1.1.1 At Jalandhar

B.1.1.1.1 During 2008

Large scale field demonstration of temperature tolerant strain of *T. japonicum* against the top borer, *Scirpophaga excerptalis* was carried out at villages Rawalpindi (Distt. Kapurthala) and Mehli (Distt. Jalandhar) and the results compared with chemical control. The parasitoid, *T. japonicum* was released 8 times at 10 days interval during April to June @ 50,000 per ha in 100 hectare area. In chemical control, phorate (Thimet 10G) @ 30 kg/ha was applied during the last week of June.

When *T. japonicum* was released, the incidence of top borer was significantly reduced, the mean parasitism was 23.6% and the yield was enhanced significantly with a cost:benefit ratio of 1:10.7 (Table 20).

Table 20. Demonstration of *T. japonicum* (temperature-tolerant strain) against *S. excerptalis* at village Rawalpindi (Distt. Kapurthala) and Mehli (Distt. Jalandhar) during 2008

Treatments	Incidence of *S. excerptalis* (%)	Parasitism (%)	Yield (kg/ha)	Cost: Benefit ratio
Trichogramma japonicum (temperature tolerant strain)	7.4 [a]	23.6[a]	72,230 [a]	1: 10.7
Chemical control (Thimet 10G @ 30 kg/ha)	6.9 [a]	2.4 [b]	73,100 [a]	1: 3.7
Control	15.6 [b]	2.6 [b]	68,330 [b]	

Means followed by the same letter in a column are not significantly different ($P \leq 0.05$)

B.1.1.1.2 During 2009

It can be concluded that eight releases of *T. japonicum* at 10 days interval @ 50,000 ha^{-1} in 100 hectares was as effective as chemical control for the control of top borer. The pooled data of two years (2008 and 2009) revealed that the mean incidence of top borer in control (14.1%) was significantly higher than treated area. The incidence recorded in chemical control (6.1%), which was at par with *T. japonicum* releases fields (6.5%). The reduction in incidence over control was 53.8 and 57.2 per cent in release fields and chemical control, respectively. The mean egg mass parasitism of *S. excerptalis* in release field was 26.8 per cent as compared to 2.4 percent in chemical and 2.8 per cent in control (Table 21). The yield in control (659.7 q ha^{-1}) was significantly lower than release fields (716.6 q ha^{-1}) and chemical control (724.7 q ha^{-1}), the latter two were at par with each other. The cost benefit ratio in *T. japonicum* (1: 17.1) was higher than chemical control (1: 5.6) (Table 22 and 23). **Note:** The technology has been recommended (included in Package of Practices) and has been transferred to Sugar Mills of Punjab.

B.1.1.1.3 During 2010

Large-scale demonstrations of effectiveness of *T. japonicum* against Top borer, *S. excerptalis* were carried out at village Gohawar and Paddi Khalsa (Distt Jalandhar). The parasitoid, *T. japonicum* was released 8 times at 10 days interval from April to June @ 50,000 per ha in 400 hectares. In chemical control, phorate (Thimet 10G) @ 30kg/ha was applied during last week of June. The incidence of top borer and yield was recorded from six locations in each treatment. The egg masses of *S. excerptalis* were collected to record percent parasitisation.

The data presented in Table 24 revealed that the incidence of top borer in control was significantly higher (14.8%) as compared to chemical control (6.3%) which was at par with *T. japonicum* releases fields (6.7%). The reduction in incidence over control was 53.1 and 57.8 per cent in release fields and chemical control, respectively. The mean parasitism of eggs of *S. excerptalis* in release field was 34.3 per cent as compared to 2.7 percent in chemical control and 3.1 per cent in control. The yield in control (655.4 q/ha) was significantly lower than release fields (724.2q/ha) and chemical control (731.7 q/ha), the latter two were at par with each other. The cost benefit ratio in *T. japonicum* (1: 20.6) was higher than chemical control (1: 6.5). It can be concluded that eight releases of *T. japonicum* at 10 days

Table 21. Large scale demonstration of *Trichogramma japonicum* against *Scirpophaga excerptalis* at village Jasso Majara and Mehli (Dist. Jalandhar) in Punjab during 2009

Treatments	Incidence of *Scirpophaga excerptalis* (%)			Per cent reduction over control			Per cent parasitism			Yield (q ha^{-1})			Cost: Benefit ratio
	Jasso Majra	Mehli	Mean	Jasso Majra	Mehli	Mean	Jasso Majra	Mehli	Mean	Jasso Majra	Mehli	Mean	
T. japonicum	5.5	5.9	5.7	57.4	51.7	54.5	24.4	35.4	29.9	730.3	691.5	710.9	1:22.4
Phorate 10G @30kg ha^{-1}	5.0	5.5	5.3	61.2	55.2	58.2	2.2	2.4	2.3	739.5	697.3	718.4	1:7.1
Control	13.0	12.2	12.6				3.0	2.8	2.9	647.5	624.8	636.1	
CV			15.90									14.28	

*Releases made @50,000/ha; numbers of releases are given in parentheses; pre-release incidence was less than one per cent; cost of insecticide: Rs. 70 / kg; Trichocard: Rs. 30 /card; sugarcane price: Rs. 180/q

Table 22. Cost: Benefit analysis for demonstration of *Trichogramma japonicum* against *Scirpophaga excerptalis* in Punjab during 2008 and 2009 (pooled)

Treatments	Yield (kg ha^{-1})	Add. yield over control (kg ha^{-1})	Value of yield ha^{-1}	Cost of Treatment (Rs/ha)	Net Return (Rs / ha)	C: B ratio
T. japonicum	71660	5690	10242	600	9642	17.1
Phorate 10G @30kg ha^{-1}	72470	6500	11700	2100	9600	5.6
Control	65970					

Cost of insecticide: Rs 70 / kg; Trichocard : Rs. 30 / card; Sugarcane price: 180 /q

Table 23. Large-scale demonstration of *Trichogramma japonicum* against *Scirpophaga excerptalis* in Punjab during 2008 and 2009 (pooled)

Treatments	Incidence of *S. excerptalis* (%)			Per cent reduction over control			Per cent parasitism			Yield (q ha^{-1})			Cost: Benefit ratio
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean	
T. japonicum	7.4	5.7	6.5[a]	53.0	54.51	53.8	23.6	29.9	26.8[a]	722.3	710.9	716.6[a]	1: 17.1
Phorate 10G @30 kg ha^{-1}	6.9	5.3	6.1[a]	56.1	58.20	57.2	2.4	2.3	2.4[b]	731	718.4	724.7[a]	1: 6.7
Control	15.6	12.6	14.1[b]	-			2.6	2.9	2.8[b]	683.3	636.1	659.7[b]	
CV			11.64									9.86	

*Releases made @50,000/ha; numbers of releases are given in parentheses; pre-release incidence was less than two per cent; cost of insecticide: Rs. 70 / kg; Trichocard: Rs. 30 / card; sugarcane price: Rs. 180/ q

Table 24. Large scale demonstration of *Trichogramma japonicum* against *Scirpophaga excerptalis* at village Gohawar (G) and Paddi Khalsa (PK) (Dist. Jalandhar) in Punjab during 2010

Treatments	Incidence of *S. excerptalis* (%)			Per cent reduction over control			Per cent parasitism			Yield (q/ha)			Cost: Benefit ratio
	G	PK	Mean	G	PK	Mean	G	PK	Mean	G	PK	Mean	
T. japonicum	6.2	7.1	6.7[a]	56.6	53.6	55.1	30.2	38.4	34.3[a]	746.4	702.0	724.2[a]	1: 20.6
Phorate 10G @30kg/ha	6.1	6.4	6.3[a]	57.3	58.2	57.8	2.8	2.6	2.7[b]	752.8	710.6	731.7[a]	1: 6.5
Control	14.3	15.3	14.8[b]	-	-	-	3.0	3.2	3.1[b]	678.8	632.0	655.4[b]	
CV			13.6						26.5			14.6	

*Releases made @50,000/ha; numbers of releases are given in parentheses; pre-release incidence was less than one per cent; cost of insecticide: Rs. 70/kg; Tricho card: Rs30/card; Sugarcane price: Rs 180/q

interval during April to June @ 50,000 per ha proved as effective as chemical control for the control of top borer.

B.1.1.1.4 During 2011

Large-scale demonstrations on effectiveness of *T. japonicum* against top borer, *S. excerptalis* were carried out at village Paddi Khalsa (Distt Jalandhar). It was compared with chemical control and untreated control. The parasitoid, *T. japonicum* was released 8 times at 10 days interval from April to June @ 50,000 per ha in 1000 hectares. In chemical control, phorate (Thimet 10G) @ 30kg/ha was applied during last week of June. The incidence of top borer and yield was recorded from six locations in each treatment. The egg masses of *S. excerptalis* were collected to record percent parasitisation.

The data presented in Table 25 revealed that the incidence of top borer in control (13.6%) was significantly higher than *Trichogramma* released and chemical control plots. The incidence recorded in chemical control (5.0%) was at par with *T. japonicum* released fields (5.4%). The reduction in incidence over control was 60.3 and 63.2 per cent in *Trichogramma* released and chemical control plots, respectively. The mean parasitism of eggs of *S. excerptalis* in *Trichogramma* released field was 45.0 per cent as compared to 2.8 percent in chemical control and 3.0 per cent in control (Table 25). The yield in control (752.8 q/ha) was significantly lower than release fields (812.0 q/ha) and chemical control (824.0 q/ha), the latter two were at par with each other. The cost benefit ratio in *T. japonicum* (1:22.7) was higher than chemical control (1:9.1).

It can be concluded that eight releases of *T. japonicum* at 10 days interval during April to June @ 50,000 per ha proved as effective as chemical control for the control of top borer.

Table 25. Large scale demonstration of *Trichogramma japonicum* against *Scirpophaga excerptalis* at village Paddi Khalsa (Distt Jalandhar) in Punjab during 2011

Treatments	Incidence of *Scirpophaga excerptalis* (%)	Per cent reduction over control	Per cent parasitism	Yield (q/ha)	Cost: Benefit ratio
T. japonicum	5.4	60.3	45.0	812.0	1:22.7
Phorate 10G @30kg/ha	5.0	63.2	2.8	824.0	1:9.1
Control	13.6		3.0	752.8	

*Releases made @50,000/ha; numbers of releases are given in parentheses; pre-release incidence was less than one per cent; cost of insecticide: Rs 60/kg; Tricho card: Rs30/card; sugarcane price: Rs 230/q

B.1.1.1.5 During 2012

Large-scale demonstrations of effectiveness of *T. japonicum* against top borer, *S. excerptalis* were carried out at village Rawalpindi (Dist. Jalandhar) in 20 ha area. It was compared with chemical control and untreated control. The parasitoid, *T. japonicum* was released 8 times at 10 days interval from April to June @ 50,000 per ha. In chemical control, phorate (Thimet 10G) @ 25kg/ha was applied during last week of June.

The data presented in Table 26 revealed that the incidence of top borer in control (15.9%) was significantly higher than releases and chemical control. The incidence recorded in chemical control (5.8%) was at par with *T. japonicum* releases fields (6.0%). The reduction in incidence over control was 62.3 and 63.5 per cent in release fields and chemical control, respectively. The mean parasitism of eggs of *S. excerptalis* in released field was 47.2 per cent as compared to 1.9 percent in chemical control and 3.0 per cent in control. The yield in control (732.8 q/ha) was significantly lower than released fields (792.0 q/ha) and chemical control (804.0 q/ha), the latter two were at par with each other. The cost benefit ratio in *T .japonicum* (18.5) was higher than chemical control (10.1). It can be concluded that eight releases of *T. japonicum* at 10 days interval during April to June @ 50,000 per ha proved as effective as chemical control for the control of top borer.

Table 26. Large scale demonstration of *Trichogramma japonicum* against *Scirpophaga excerptalis* at village Rawalpindi (Dist. Jalandhar) in Punjab during 2012

Treatments	Incidence of *Scirpophaga excerptalis* (%)	Per cent reduction over control	Per cent parasitism	Yield (q/ha)	Cost: Benefit ratio*
T. japonicum @50,000/ha	6.0[a]	62.3	47.2	792.0[a]	18.5
Phorate 10G @30kg/ha	5.8[a]	63.5	1.9	804.0[a]	10.1
Control	15.9[b]		3.0	732.8[b]	-

*Cost of insecticide: Rs 70/kg; Tricho card: Rs 40/card; sugarcane price: Rs 250/q

B.1.1.2 At Nawanshahar

B.1.1.2.1 During 2010

Large scale demonstration of effectiveness of *T. japonicum* against top borer, *Scirpophaga excerptalis* over an area of 400 hectares was carried out in collaboration with two sugar mills of the state, *i.e.*, Doaba Co-operative Sugar Mills Ltd., Nawanshahar and Morinda Co- operative Sugar Mills Ltd., Morinda (Table 27). The egg parasitoid, *T. japonicum* was released from mid - April to end – June, at 10 days interval @ 50,000 per ha. The incidence of *Scirpophaga excerptalis* at Nawanshahar and Morinda in release fields was 1.6 and 0.6 per cent respectively. The corresponding figures in control fields were 3.0 and 1.8 per cent. The reduction in damage over control in these two mills was 46.7 and 66.7 percent, respectively. Hence, eight releases of *T. japonicum* @ 50,000 per ha at 10 days internal during mid April to end June reduced the incidence of top borer by 54.2 per cent.

B.1.1.2.2 During 2011

Large scale demonstration on effectiveness of *T. japonicum* against top borer, *Scirpophaga excerptalis* over an area of 160 hectares was carried out in collaboration with two sugar mills of the state i.e. Doaba Co- operative Sugar Mills Ltd. Nawanshahar and Morinda Co- operative Sugar Mills Ltd. Morinda (Table 28). The egg parasitoid, *T. japonicum* was released from mid - April to end – June, at 10 days

Table 27. Large scale demonstration of *Trichogramma japonicum* against *Scirpophaga excerptalis* in collaboration with Sugar Mills in Punjab during 2010

Mill area	Area covered (acres)	Incidence of *C. auricilius*		
		IPM*	Non Adopted	Reduction (%) over control
Doaba Co-op Sugar Mills Ltd, Nawanshahar	500	1.6	3.0	46.7
Morinda Co-op sugar Mills Ltd, Morinda	500	0.6	1.8	63.6
Total/ Mean	1000	1.1	2.4	54.2

interval @ 50,000 per ha. The incidence of *Scirpophaga excerptalis* at Nawanshahar and Morinda in *Trichogramma* released fields was 1.8 and 1.1 per cent respectively. The corresponding figures in control fields were 3.3 and 2.1 per cent. The reduction in damage in *Trichogramma* released fields over control in the two mill areas was 45.5 and 50.0 percent, respectively, the mean reduction being 47.7 per cent.

It can be concluded that in large-scale demonstration trials, eight releases of *T. japonicum* @ 50,000 per ha at 10 days internal during mid April to end June reduced the incidence of top borer by 47.7 per cent.

Table 28. Large scale demonstration on *Trichogramma japonicum* released against *Scirpophaga excerptalis* in collaboration with Sugar Mills in Punjab during 2011

Mill area	Area covered (acres)	Incidence of *C. auricilius*		
		IPM*	Non Adopted	Reduction (%) over control
Doaba Co-op Sugar Mills Ltd, Nawanshahar	500	1.8	3.3	45.5
Morinda Co-op sugar Mills Ltd, Morinda	500	1.1	2.1	50.0
Total/ Mean	1000	1.43	2.7	47.7

B.2 Plassey borer, *Chilo tumidicostalis*

B.2.1 At Assam

B.2.1.1 During 2008

Large scale demonstration of effectiveness of *T. chilonis* against the Plassey borer was carried out in a farmer's field on CoBLN 9605 variety at Halowagaon in Golaghat district over an area of 10 ha. Nine releases of *T. chilonis* were made @ 50,000/ha/release at 10 days interval from July second week to October first week, 2008. The release of *T. chilonis* resulted in significantly reduced infested cane and higher cane yield (84,450 kg/ha) than in farmers' practice. (Fig. 6)

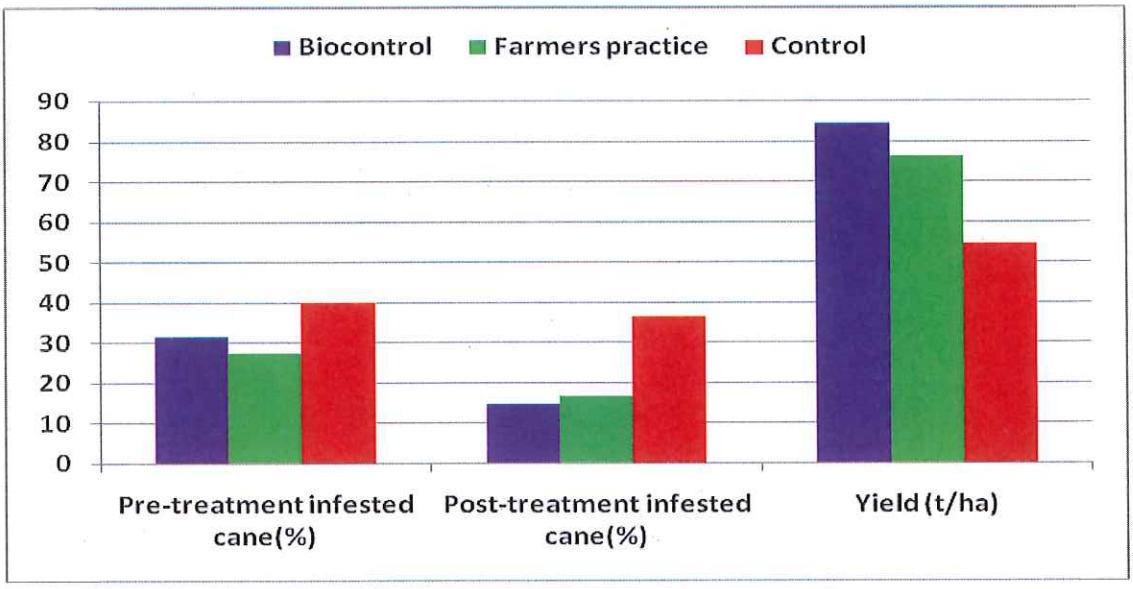


Fig. 6. Evaluation of *Trichogramma chilonis* against Plassey borer

B.2.1.2 During 2009

Large scale demonstration of *Trichgramma chilonis* against Plassey borer was carried out in the farmers' field located at Dergaon area in Golaghat district covering an area of near about 100ha. It was compared with farmers practice (Conventional farming). The sugarcane variety Dhansiri was grown in all the location.

Eleven releases of *T. chilonis* @ 50,000/ha at 10 days interval from second week of July to first week of November, 2009 was made. Observations on percent infested cane due to Plassey borer attack and healthy canes before and after treatments along with the yield were recorded, statistical analysis was carried out using't' test and results are given below.

There was no any significant difference in Plassey borer attack between *Trichogramma* released and conventional farming. However, the mean per cent of incidence in released plot was 15.87 compared to unreleased plot 24.31percent. Maximum yield (78.4t/ha) was however obtained in *Trichogramma* released plot followed by conventional farming (65.9t/ha) (Table 29). Cost benefit analysis is given in Table 31.

Similarly 4 releases of *Cotesia flavipes* @ 500/ha in mid July ,mid August,mid Sep and mid October was carried out in farmers field at Halowa Gaon,Golaghat district covering an area of 1ha. The sugarcane variety was Dhansiri . The result presented revealed that no significant difference in Plassey borer attack was observed between released and conventional farming. However, 22 per cent reduction in Plassey borer damage was observed in released area. The mean yield in *Cotesia* released area and conventional farming was 69.34t/ha, respectively (Table 30)

B.2.1.3 During 2010

Large scale demonstration of *Trichogramma chilonis* against the plassey borer, *Chilo tumidicostalis* was carried out over an area of 150 hectares in the farmer's field at Dergaon area of Golaghat district. It was compared with conventional farming (chemical control). The sugarcane variety 'Dhansiri' was grown in all the locations. In

Table 29. Evaluation of *Trichogramma chilonis* against Plassey borer

Treatment	Pre-treatment			Post -treatment			Yield t/ha
	No of infested cane (%)	No of healthy cane (%)	Egg parasitism (%)	No of infested cane (%)	No. of healthy cane (%)	Egg par asitism (%)	
T. chilonis released plot	30.70 (32.12)	69.28 (65.86)	18.2 (25.11)	15.87 (23.46)	84.11 (66.43)	34.0 (35.15)	78.4 (65.86)
Farmers practice	28.18 (31.48)	71.80 (60.48)	15.8 (23.23)	24.31 (29.47)	75.67 (60.51)	14.2 (22.08)	65.9 (60.48)
t-value	0.4582	0.0993	0.0091	0.4282	0.4301	0.0015	0.0159
Remarks	NS	NS	NS	NS	NS	NS	NS

Table 30. Evaluation of *Cotesia flavipes* against Plassey borer

Treatment	Pre-treatment			Post -treatment			Yield t/ha
	No of infested cane (%)	No of healthy cane (%)	Larval parasitism (%)	No of infested cane (%)	No. of healthy cane (%)	Larval parasitism (%)	
Cotesia flavipes released plot	28.34 (31.04)	71.62 (63.04)	9.2 (17.61)	22.50 (28.22)	77.47 (62.12)	8.4 (16.77)	69.34
Farmers practice	32.56 (33.34)	67.27 (64.48)	13.2 (21.28)	24.98 (29.95)	75.01 (60.04)	13.2 (21.24)	63.44
t-value	0.2974	0.6047	0.0021	0.0633	0.0445	0.0239	0.9245
Remark	NS	NS	NS	NS	\NS	NS	NS

Table 31. Cost-benefit analysis

Treatment	Yield (Kg/ha)	Additional yield over control (Kg/ha)	Value of Yield /ha (Rs/ha)	Cost biocontrol /Chemical treatment (Rs/ha)	Net return (Rs/ha)
Trichogramma chilonis released plot (11 released)	78,400	12,500	1,56,800	962.5	25,000
Farmers practices (chemical control)	65,900	_	1,31,800	1650.0	_

* Cost of sugarcane @ Rs.200.00/qt

farmer's practice, phosphamidon 100 EC @ 0.04%,/ endosulfan 35 Ec @ 0.07% w as used by the farmers for management of borers. Eleven releases of *T. chilonis* @ 50,000/ha/release at 10 days interval from July second week to November first week, 2011 was made. Observations on mean percent egg parasitism and infested canes due to plassey borer attack before and after treatment were recorded. Statistical analysis was done using't' test and results are given in Table.

No significant difference was observed in the incidence of *Chilo tumidicostalis* attack between *Trichogramma* released and farmers practice (chemical

control) fields (Table 32). The percent incidence of *Chilo tumidicostalis* in farmer's field was 8.6 as against 7.5 per cent in *Trichogramma* released fields with a 12.8 percent reduction in damage in biocontrol field. However, the percent egg parasitism in released fields was significantly higher (26.0) in released field, as against 8.2 % in farmer's field. The cane yield in released (70800 kg/ha) and farmer's practice (70400 kg/ha) was found to be at par with each other. In Assam, the farmers spray heavy doses of pesticides against borers and sucking pests, but from the performance of the demonstration plot, use of tricho cards have become popular among the farming community.

Table 32. Evaluation of *Trichogramma chilonis* against Plassey borer

Treatments	Pre-treatment (Mean)		Post treatment (Mean)		% reduction in damage over control	Yield t/ha
	Percent infested canes (%)	Egg parasitism (%)	Percent infested canes (%)	Egg parasitism (%)		
T. chilonis released plot 50,000/ha	16.5	15.0	7.5	26.0	12.8	70.8
Farmers' practice (chemical control)	14.3	13.4	8.6	8.2	-	70.4
t value	1.88	1.22	1.70	17.64		0.20
	NS	S*	NS	S*		NS

*S: Significant at 5% level

B.2.1.4 During 2011

Large scale demonstration of effectiveness of *T. chilonis* against plassey borer, *C. tumidocoatalis* was carried out at village, Buragaon in Golaghat district covering an area of 200 ha. It was compared with farmers practice (Chemical control). Variety Dhansiri was grown in both the locations. *T. chilonis* was released eleven times at 10 days interval from June to November @ 50,000/ha. In farmer's practice, endosulfan 35 EC @ 3ml/lit was applied four times during June to Sept. Observations on percent infested cane due to plassy borer attack & healthy canes before and after treatments along with the yield were recorded. The egg mass of *C. tumidicostalis* were collected to record per cent parasitism.

As presented in Table 33 except egg parasitism there was no significant difference in plassy borer attack between *Trichogramma* released and farmer's practice plot. The mean per cent parasitism of eggs of *C. tumidicostalis* in released field was 36.85 which were significantly different from that of farmers practice with 17.91 parasitism. The mean yield in farmer's practice (71.43 t/ha) was lower than the released field (73.32 t/ha). Cost benefit analysis presented in Table 35 showed the net return was Rs 145,678 in released plot whereas it was Rs 138,660 in farmer's practice.

In another experiment four releases of *Cotesia flavipes* @ 500/ha in mid June, mid July ,mid August and mid Sep was made at village Khonikar gaon in Golaghat district covering an area of 1ha. No significant difference in plassy borer damage was observed between released and chemical control (Table 34). The mean yield in farmer's practice plot was higher (70.4 t/ha) than the *Cotesia* released plot (63.82 t/ha).

Table 33. Evaluation of *Trichogramma chilonis* against Plassey borer

Treatment	Pre-treatment			Post –treatment			Yield t/ha
	% infested cane	% healthy cane	% egg parasitism	% infested cane	% healthy cane	% egg parasitism	
T. chilonis released plot	29.45 (32.86)	70.54 (57.13)	19.25 (26.01)	13.56 (21.61)	86.42 (68.37)	36.00 (36.85)	73.32 (58.76)
Farmers practice	30.83 (33.62)	69.16 (56.37)	16.25 (23.72)	19.23 (25.75)	80.75 (64.05)	9.50 (17.91)	71.43 (57.69)
t-value	0.7768	0.7784	0.2083	0.0719	0.0596	0.9.592	0.1510
Remarks	NS	NS	NS	NS	NS	3.1812*	NS

Table 34. Evaluation of *Cotesia flavipes* against Plassey borer

Treatment	Pre-treatment			Post -treatment			Yield t/ha
	% Infested cane	% healthy cane	% Larval parasitism	% Infested cane (%)	% healthy cane	% Larval parasitism	
Cotesia flavipes released plot	29.45 (32.86)	70.54 (57.13)	11.00 (19.27)	24.15 (29.41)	75.84 (60.57)	9.50 (17.88)	63.82 (53.04)
Farmers practice	25.41 (30.24)	74.58 (59.75)	10.00 (18.38)	15.74 (23.36)	84.24 (66.62)	14.50 (22.34)	70.40 (57.03)
t-value	0.1202	0.1200	0.4275	0.008	0.0088	0.0635	0.1160
Remark	NS	NS	NS	NS	NS	NS	NS

Table 35. Cost-benefit analysis for demonstration of *T. chilonis* against *C. tumidicostalis*

Treatment	Yield (Kg/ha)	Yield increase over control (Kg/ha)	Value of Yield /ha (Rs/ha)	Cost biocontrol / Chemical treatment (Rs/ha)	Net return (Rs/ha)
Trichogramma chilonis released plot(11 released)	73320	1890	1,46,640	962.00	1,45,678
Farmers practices (chemical control)	71430		1,42,860	4200.00	1,38,660

* Cost of sugarcane @ Rs.200.00/qt

B.2.1.5 During 2012

Large scale demonstration of *Trichogramma chilonis* against the plassey borer, *Chilo tumidicostalis* was carried out in the farmer's field located at Khanikor gaon in Golaghat district covering an area of 50 ha during 2012 -13. It was compared with Farmer's practice (Chemical control).The farmers' practice plot was taken at Sugarcane Research Station, Buralikson. The sugarcane variety 'Dhansiri' was planted in all the locations in the second week of April, 2012. In farmers' practice four rounds of profenofos 50 EC @ 0.05% was sprayed at 15 days interval. A total of eleven releases of T. chilonis @ 50,000/ha/release at 10 days interval from mid July

to November first week, 2012 was made. Observations on mean percent egg parasitism and infested canes due to *Chilo tumidicostalis* attack before and after treatment were recorded. Statistical analysis was done using't' test and results are given below.

Plate 2. *T. chilonis* released sugarcane

Plate 3. Cane infested by *C. tumidicostalis*

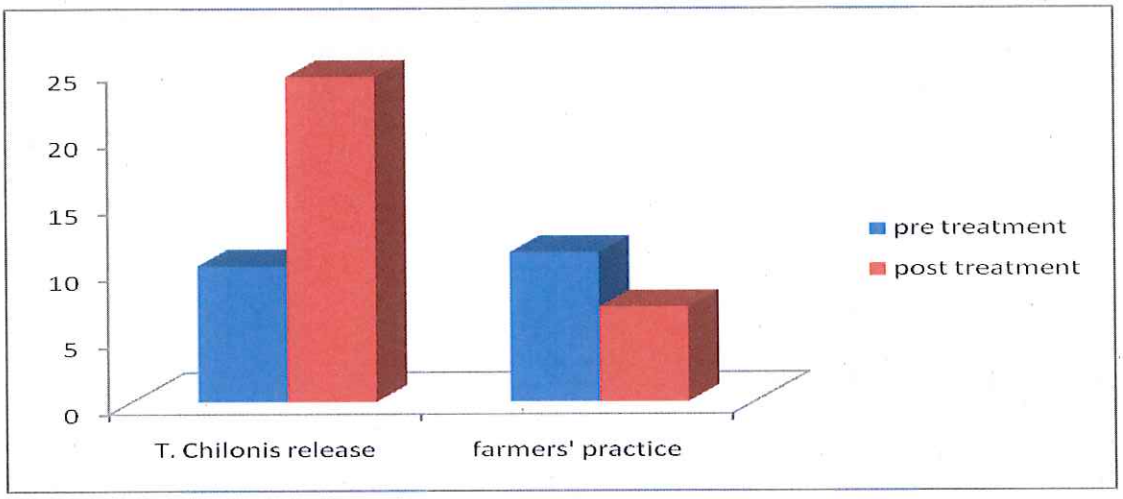


Fig. 7. Percent egg parasitization by *T. chilonis* in sugarcane

Table 36. Evaluation of *Trichogramma chilonis* against *Chilo tumidicostalis*

Treatments	Pre count		Post count			Yield q/ha
	% infested cane	% egg parasitism	% infested cane	% reduction over farmers practice	% Egg parasitism	
T. chilonis released plot @ 50000/ha	11.10 (19.17)	10.20 (18.59)	12.08 (20.88)	17.87	24.40 (29.56)	73.25
Farmer's practice (Chemical control)	12.17 (20.23)	11.20 (19.47)	14.71 (22.10)	--	7.1 (15.26)	71.39
T' value	-0.658	-1.147	-2.094		13.68	0.879
Remarks	NS	NS	NS		S*	NS

S* = Significant at 5 % value; figures in parenthesis are angular transformed values

Table 37. Cost-benefit ratio

Treatment	Yield (Kg / ha)	Additional yield over chemical control	Value of yield/ ha (Rs/ha)	Cost of bio control / chemical treatment (Rs /ha)	Net return (Rs/ ha)
Trichogramma chilonis released plot @ 50,000/ha/release	73250	1860	146500	962.5	3720
		-	142780	2164	-
Chemical control	71390			2164	

- Cost of sugarcane @Rs. 200.00 q/ha

The data presented in the table 36 revealed that the per cent incidence of *C. tumidicostalis* in chemical control plot was 14.71 compared to 12.08 per cent in parasitoid released plot and had no any significant difference between the treatments, which resulted in only 18.00. per cent reduction in damage. However, the mean per cent parasitism of eggs of *C. tumidicostalis* in parasitoid released plot was 24.4 with a significant difference from that of chemical control where it was only 7.1 . The cane yield attributed in parasitoid released and chemical plot was 73.2 t/ha and 71.39 t /ha, respectively. No significant difference was observed in respect of cane yield in both the treatments. A net return of Rs.3720 was only achieved in cane yield of IPM plot compared to chemical control plot (Table 37).

B.3 Early shoot borer, *Chilo infuscatellus*

B.3.1 At Punjab

B.3.1.1. At Kapurthala

B.3.1.1.1 During 2007

Field evaluation of temperature tolerant strain (TTS) of *T. chilonis* developed by PDBC was carried out at village Gohawar (Distt. Jalandhar) and village Paddi Khalsa (Distt Kapurthala). It was compared with chemical control and untreated control. *T. chilonis* was released 8 times, during mid - April to end – June, at 10 days interval @ 50,000 per ha. In chemical control, cartap hydrochloride (Padan 4G) was applied @ 25 kg/ha, after 45 days of planting. The plot size 20 ha for temperature tolerant strain and 0.4 ha each for chemical control and untreated control at each location. Each plot was sub-divided into 5 parts to record the observations. Egg masses of early shoot borer were collected from each plot to record parasitisation.

The data presented in Table 38 revealed that the mean incidence of early shoot borer at both the villages, *viz.,* Gohawar and Paddi Khalsa in control (17.5%) were significantly higher than temperature tolerant strain of *T. chilonis* (8.2%) and chemical control (7.7%). The mean incidence in temperature tolerant strain of *T. chilonis* was on a par with chemical control. The mean parasitisation in released field (24.7%) was significantly higher than chemical control (2.8%) and control (3.0%). The mean yield of both the locations was highest in chemical control (748.5 q/ha) followed by temperature tolerant strain of *T. chilonis* (727.5 q/ha) and control (686.0 q/ha).

Table 38. Demonstration of *T. chilonis* (Temp. tolerant strain) against *C. infuscatellus* at village Gohawar (Distt. Jalandhar) and Paddi Khalsa (Distt. Kapurthala) during 2006

Treatments	Incidence of *C. infuscatellus* (%)			Per cent reduction over control			Per cent parasitism			Yield (q/ha)		Mean	Cost: Benefit ratio
	Gohawar	Paddi khalsa	Mean	Gohawar	Paddi khalsa	Mean	Gohawar	Paddi khalsa	Mean	Gohawar	Paddi khalsa		
T. chilonis (Temperature tolerant strain)	9.0[a]	7.4[b]	8.2[a]	53.0	53.3	53.2	26.9[a]	22.6[a]	24.7[a]	757	698	727.5	1:9.1
Chemical control (Padan @25kg/ha)	8.7[a]	6.8[a]	7.7[a]	54.7	57.1	55.9	0.5[b]	5.1[b]	2.8[b]	774	723	748.5	1:6.2
Control	19.2[b]	15.8[c]	17.5[b]	-	-	-	0.5[b]	5.5[b]	3.0[b]	715	657	686.0	-
CV	7.9	8.4	-	-	-	-	10.7	9.2	-	-	-	-	-

8 releases of *T. chilonis* were made @50,000/ha at 10 days interval during April to end June; Padan 4G@ 25kg/ha was applied after 45 days of planting

Table 39. Large scale demonstration of the effectiveness of *T. chilonis* (Temp. tolerant strain) against *C. infuscatellus* in Punjab during 2005& 2006 (pooled)

Treatments	Mean Incidence of *C. infuscatellus*			Per cent reduction in damage over control			Per cent parasitism		
	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
T. chilonis (Temperature tolerant strain)	6.8	8.2	7.5	50.7	53.2	51.9	28.7	24.7	26.7
Chemical control (Padan @25kg/ha)	6.6	7.7	7.2	52.2	55.9	54.1	0.0	2.8	1.4
Control	13.8	17.5	15.6	-	-	-	0.0	3.0	1.5

8 releases of *T. chilonis* were made @50,000/ha at 10 days interval during April to end June; Padan 4G@ 25kg/ha was applied after 45 days of planting in each year

It can be concluded that 8 releases of temperature tolerant strain of *T. chilonis* developed by PDBC, Bangalore @50,000per ha was on a par with chemical control for the management of early shoot borer, and reduced the incidence by 53.2% to 55.9 per cent. The cost benefit ratio in release field (1:9.1) was higher then chemical control (1: 6.2).

The pooled data of two years (2005 &2006) at 10 days interval during end April to mid June @ 50,000 per ha reduced the incidence of stalk borer by 52 per cent. The egg parasitism in release fields was 26.7 per cent as compared to 1.5 per cent in control (Table 39).

B.3.1.1.2 During 2008

Large scale field demonstration of *T. chilonis* against the early shoot borer *C. infuscatellus* was carried out at villages Gohawar (Distt. Jalandhar) and Chachrari (Distt. Kapurthala) and the results compared with chemical control. The plot size was 100 ha and the parasitoid, *T. chilonis* was released 8 times at 10 days interval during April to June @ 50,000 per ha. In chemical control, cartap hydrochloride (Padan 4G) @ 25 kg/ha was applied 45 days after planting.

The incidence of early shoot borer was significantly reduced by *T. chilonis* release (Table 40). The mean parasitism of eggs of *C. infuscatellus* in *T. chilonis* release plot was 51.2%. The yield was significantly higher with a cost:benefit ratio of 1: 13.8.

Table 40. Demonstration of *T. chilonis* (temperature-tolerant strain) against *C. infuscatellus* at village Gohawa (Distt. Jalandhar) and Chachrari (Distt. Kapurthala) during 2007

Treatments	Incidence of *C. infuscatellus* (%)	Parasitism (%)	Yield (kg/ha)	Cost: Benefit ratio
TTrichogramma chilonis (temperature tolerant strain)	4.6 [a]	51.2[a]	69,000 [a]	1: 13.8
Chemical control (Padan @25kg/ha)	4.5 [a]	4.2 [c]	70,150 [a]	1: 6.2
Control	12.4 [b]	7.7 [b]	64,000 [b]	

Means followed by the same letter in a column are not significantly different ($P \geq 0.05$)

B.3.1.1.3 During 2011

Demonstrations on use of temperature tolerant strain (TTS) of *T. chilonis* developed by PDBC were conducted at village Chachrari (Dist. Kapurthala). It was compared with chemical control and untreated control. *T. chilonis* was released 8 times, during mid - April to end – June, at 10 days interval @ 50,000 per ha. In chemical control, cartap hydrochloride (Padan 4G) was applied @ 25 kg/ha, after 45 days of planting. The plot size was 20 ha for temperature tolerant strain and 0.4 ha each for chemical control and untreated control at each location. Each plot was sub-divided into 8 parts to record the observations.

The data presented in Table 41 revealed that the mean incidence of early shoot borer in control (11.6%) were significantly higher than in the treatment with temperature tolerant strain of *T. chilonis* (4.8%) and chemical control (4.6%). The mean incidence in the treatment with temperature tolerant strain of *T. chilonis* was on par with chemical control. Thus, percent reduction in incidence in release fields and

chemical control over untreated control were 58.6 and 60.3, respectively. The mean yield in chemical control (736.8q/ha) and temperature tolerant strain of *T. chilonis* treatment (734.6 q/ha) plots were on par, but yield in these two was significantly higher than control (681.2q/ha). The cost-benefit ratio in temperature tolerant strain of *T. chilonis* (1: 20.5) was higher than chemical control (1: 8.5).
It can be concluded that 8 releases of temperature tolerant strain of *T. chilonis* @ 50,000 per ha were on par with chemical control for the management of early shoot borer *C. infuscatellus*, and reduced the incidence by 58.6 per cent over untreated control.

Table 41. Demonstration of *T. chilonis* (Temp. tolerant strain) against *C. infuscatellus* at village Chachrari (Distt. Kapurthala) during 2011

Treatments	Incidence of *C. infuscatellus* (%)	Per cent reduction over control	Yield (q/ha)	Cost benefit ratio
T. chilonis (Temperature tolerant strain)	4.8[a]	58.6	734.6[a]	20.5
Chemical control (Padan @25kg/ha)	4.6[a]	60.3	736.8[a]	8.5
Control	11.6[b]		681.2[b]	-

8 releases of *T. chilonis* were made @50,000/ha at 10 days interval during April to end June; Padan 4G@ 25kg/ha was applied after 45 days of planting

B.3.1.2 At Nawanshahar and Morinda

B.3.1.2.1 During 2005

Large scale demonstration of effectiveness of *T. chilonis* over an area of 1430 hectares was carried out in collaboration with two sugar mills of the state i.e. Doaba Co- operative Sugar Mills Ltd. Nawanshahar and Morinda Co- operative Sugar Mills Ltd. Morinda (Table 42). The egg parasitoid, *T. chilonis* was released from July to October in both the mill areas at 10 days interval @ 50,000/ha. The incidence of *C. auricilius* at Nawanshahar and Morinda in IPM fields was 4.6 and 2.0 per cent respectively. The corresponding figures in control fields were 6.7 and 9.8 per cent. The mean reduction in damage over control in both the mills was 55.46 per cent. It can be concluded that in large scale demonstration, *T. chilonis* reduced the incidence of stalk borer by 55.46 per cent.

Table 42. Large scale demonstration of BIPM on sugarcane in two sugarcane mills in Punjab

Mill area	Area covered (hectares)	Incidence of *C. auricilius*		
		IPM	Control	Reduction (%) over control
Doaba Co-op Sugar Mills	612	3.0	8.6	65.2
Morinda Co-op sugar Mills	816	2.0	9.8	79.6
Total/ Mean	1428	1.5	9.2	72.4

B.3.1.2.2 During 2010

Large scale demonstration of effectiveness of *T. chilonis* (TTS) against early shoot borer, *C. infuscatellus* over an area of 164 hectares was carried out in collaboration with two sugar mills of the state i.e. Doaba Co- operative Sugar Mills Ltd. Nawanshahar and Morinda Co- operative Sugar Mills Ltd. Morinda (Table 43). The egg parasitoid, *T. chilonis* was released during mid - April to end – June, at 10 days interval @ 50,000 per ha.

The incidence of *C. infuscatellus* at Nawanshahar and Morinda in release fields was 2.2 and 0.8 per cent respectively. The corresponding figures in control fields were 3.6 and 1.66 per cent. It can be concluded that eight releases of *T. chilonis* (tts) @ 50,000 per ha at 10 days interval during mid April to end June reduced the incidence of early shoot borer by 43.2 per cent.

Table 43. Demonstration of *T. chilonis* (TTS) against *Chilo infuscatellus* in three Sugar Mills

Mill area	Area covered (hectares)	Incidence of *C. auricilius*		
		IPM*	Non Adopted	Reduction (%) over control
Doaba Co-op Sugar Mills Ltd, Nawanshahar	82	2.2	3.6	38.9
Morinda Co-op sugar Mills Ltd, Morinda	82	0.8	1.66	52.4
Total/ Mean	164	1.5	2.6	43.2

Note: Eight releases of *T. chilonis* were made @ 50,000/ha at 10 days interval during April to end June

B.3.1.2.3 In Collaboration with Sugar Mills

Large scale demonstration of effectiveness of *T. chilonis* (TTS) against early shoot borer, *Chilo infuscatellus* over an area of 408 hectares was carried out in collaboration with two sugar mills of the state i.e. Doaba Co- operative Sugar Mills Ltd. Nawanshahar and Morinda Co- operative Sugar Mills Ltd. Morinda (Table 44). The egg parasitoid, *T. chilonis* was released from during mid - April to June end, at 10 days interval @ 50,000 per ha during 2012.

The incidence of *C. infuscatellus* at Nawanshahar and Morinda in released fields was 11.4 and 9.3 per cent respectively (Table 44). The corresponding figures in control fields were 27.7 and 23.2 per cent. The reduction in damage over control in the field of these two mills was 58.8 and 59.9 percent, respectively. Hence the mean reduction was 59.3per cent.

It can be concluded that in large-scale demonstration, eight releases of *T. chilonis* (tts) @ 50,000 per ha at 10 days internal during mid-April to June end reduced the incidence of early shoot borer by 59.3 per cent.

Table 44. Demonstration of *T. chilonis* (Temperature tolerant strain) against early shoot borer, *C. infuscatellus* in two sugar mills of Punjab during 2012

Mill area	Area covered (hectares)	Incidence of *C. infuscatellus*		
		IPM*	Non Adopted	Reduction (%) over control
Doaba Co-op Sugar Mills Ltd, Nawanshahar	204	11.4	27.7	58.8
Morinda Co-op sugar Mills Ltd, Morinda	204	9.3	23.2	59.9
Total/ Mean	408	10.4	25.5	59.3

Note: Eight releases of *T. chilonis* were made @ 50,000/ha at 10 days interval during April to end June

B.3.1.2 At Jalandhar

B.3.1.2.1 During 2007

Field evaluation of *T. chilonis* against the early shoot borer *C. infuscatellus* was carried out at villages Nangal Khera (Distt. Jalandhar) and Paddi Khalsa (Distt. Kapurthala) and the results compared with chemical control. The plot size was 20 ha and the parasitoid, *T. chilonis* was released 8 times at 10 days interval during April to June @ 50,000 per ha. In chemical control, cartap hydrochloride (Padan 4G) @ 25 kg/ha was applied 45 days after planting.

The incidence of early shoot borer was significantly reduced by *T. chilonis* release (Table 45). The mean parasitism of eggs of *C. infuscatellus* in *T. chilonis* release plot was 50.8%. The yield was enhanced significantly a cost:benefit ratio of 1:11.1.

Table 45. Demonstration of *T. chilonis* (TTS) against *C. infuscatellus* at village Nangal Khera (Distt. Jalandhar) and Paddi Khalsa (Distt. Kapurthala) during 2007

Treatments	Incidence of *C. infuscatellus* (%)	Parasitism (%)	Yield (kg/ha)	Cost: Benefit ratio
T. chilonis (temperature tolerant strain)	7.1 [a]	50.8[a]	680.0 [a]	1: 11.1
Chemical control (Padan @25kg/ha)	7.0 [a]	3.9 [b]	699.5 [a]	1: 7.4
Control	15.0 [b]	6.8 [b]	629.5 [b]	

Means followed by the same letter in a column are not significantly different ($P \geq 0.05$)

B.3.1.2.2 During 2010

Demonstrations on use of temperature tolerant strain (TTS) of *T. chilonis* were conducted at Haripur and Mohalon village (Distt. Jalandhar). *T. chilonis* was released 8 times, during mid - April to end – June, at 10 days interval @ 50,000 per ha in 400 hectare area. In chemical control, cartap hydrochloride (Padan 4G) was applied @ 25 kg/ha, after 45 days of planting. The plot size 20 ha for temperature tolerant strain and

0.4 ha each for chemical control and untreated control at each location. Each plot was sub-divided into 8 parts to record the observations.

The data presented in Table 46 revealed that the mean incidence of early shoot borer at both the villages were significantly higher in untreated control (15.6%) than temperature tolerant strain of *T. chilonis* (6.8%) and chemical control (6.5%). Thus percent incidence reduction in release fields and chemical control over untreated control was 56.4 and 58.3 respectively. The mean yield in chemical control (726.0 q/ha) and temperature tolerant strain of *T. chilonis* (717.0 q/ha) were on par but were significantly higher than in control (653.0 q/ha). The cost benefit ratio in temperature tolerant strain of *T.chilonis* (1: 19.2) was higher than chemical control (1: 7.5). Hence it can be concluded that 8 releases of temperature tolerant strain of *T. chilonis* @50,000per ha were on a par with chemical control for the management of early shoot borer *C. infuscatellus*, and reduced the incidence by 56.4 per cent over untreated control.

Table 46. Demonstration of *T. chilonis* (Temp. tolerant strain) against *C. infuscatellus* at village Haripur (H) and Mohalon (M) (Distt. Jalandhar) during 2010

Treatments	Incidence of *C. infuscatellus* (%)			Per cent reduction over control			Yield (q/ha)			Cost benefit ratio
	Hr	M	Mean	H	M	Mean	H	M	Mean	
T. chilonis (Temperature tolerant strain)	7.2	6.3	6.8[a]	59.6	56.3	56.4	742.0	692.0	717.0[a]	1: 19.2
Chemical control (Padan @25kg/ha)	6.8	6.1	6.5[a]	61.8	57.6	58.3	748.0	704.0	726.0[a]	1: 7.5
Control	17.8	14.4	15.6[b]				662.0	644.0	653.0[b]	-
CV			13.8						16.2	

8 releases of *T. chilonis* were made @50,000/ha at 10 days interval during April to end June; Padan 4G@ 25kg/ha was applied after 45 days of planting

B.3.1.2.2 During 2012

Demonstrations on use of temperature tolerant strain (TTS) of *T. chilonis* developed by NBAII was conducted at village Paddi Khalsa (Distt. Jalandhar). It was compared with chemical control and untreated control. *T. chilonis* was released 8 times, during mid-April to June end –, at 10 days interval @ 50,000 per ha in 400 hectare. In chemical control, cartap hydrochloride (Padan 4G) was applied @ 25 kg/ha, after 45 days of planting. The plot size were 20 ha for temperature tolerant strain and 0.4 ha each for chemical control and untreated control at each location. Each plot was sub-divided into 8 parts to record the observations.

The data presented in Table 47 revealed that the mean incidence of early shoot borer in control (15.8%) were significantly higher than temperature tolerant strain of *T. chilonis* (6.6%) and chemical control (6.2%). The mean incidence in temperature tolerant strain of *T. chilonis* was on par with chemical control. Thus percent incidence reduction in released fields and chemical control over untreated control was 58.2 and 60.7 respectively. The mean yield in chemical control (765.8q/ha) and temperature tolerant strain of *T. chilonis* (756.8 q/ha) was on par but yield in these two was

significantly higher than control (690.6 q/ha). The cost benefit ratio in temperature tolerant strain of *T. chilonis* (1:20.6) was higher than chemical control (1: 10.7).

It can be concluded that 8 releases of temperature tolerant strain of *T. chilonis* @50,000per ha were on a par with chemical control for the management of early shoot borer *C. infuscatellus*, and reduced the incidence by 58.2 per cent over untreated control.

Table 47. Demonstration of *T. chilonis* (Temperature tolerant strain) against early shoot borer, *Chilo infuscatellus* at village Paddi Khalsa (Distt. Jalandhar) during 2012

Treatments	Incidence of *C. infuscatellus* (%)	Per cent reduction over control	Yield (q/ha)	Cost benefit ratio*
T. chilonis (Temperature tolerant strain)	6.6[a]	58.2	756.8[a]	20.6
Chemical control (Padan @25kg/ha)	6.2[a]	60.7	765.8[a]	10.7
Control	15.8[b]	-	690.6[b]	-

8 releases of *T. chilonis* were made @50,000/ha at 10 days interval during April to end June; Padan 4G@ 25kg/ha was applied after 45 days of planting; Cost of insecticide: Rs 70/kg, Tricho card: Rs 40/card, Sugarcane price: Rs 250/q

B.4 Stalk borer, *Chilo auricilius*

B.4.1 At Punjab

B.4.1.1 Jalandhar and Ferozepur

B.4.1.1.1 During 2005

The efficacy of *T. chilonis* was demonstrated in an area of 20 ha each at village Jandiala (Jalandhar) and village Karni Khera (Ferozepur) for the management of *Chilo auricilius*. The control plot was 0.2 ha at two locations. The incidence of stalk borer in control was 8.18 per cent as compared to 3.12 per cent in release field at Karni Khera, which resulted in 61.86 per cent reduction in damage. The per cent parasitism in release fields was high (33.57%) as compared to 5.31 per cent in control at Karni Khera (Table 48). At Jandiala, the incidence of stalk borer was 5.28 per cent and parasitism 28.84 as compared to 13.16 per cent incidence and 3.92 per cent parasitism in control thus, resulting in reduction of incidence by 59.88% (Table 48).

B.4.1.1.2 During 2006

The efficacy of *T. chilonis* was demonstrated over an area of 20 ha each at village Paddi khalsa (Distt. Jalandhar) and village Karni Khera (Distt. Ferozepur) for the management of stalk borer, *Chilo auricilius*. The parasitoids were released 12 times at 10 days interval during July to October @ 50,000 per ha. The control plot was 0.2 ha at two locations. The incidence of stalk borer and per cent parasitism was recorded from both the plots.

Table 48. Large scale demonstration of the effectiveness of *T. chilonis* against *C. auricilius* in Punjab during 2005

Treatment	Plot size (ha)		Incidence of *C. auricilius*			Per cent reduction in damage over control			Per cent parasitism	
	Karni Khera (Ferozepur)	Jandiala (Jalandhar)	Karni Khera	Jandiala	Mean	Karni Khera	Jandiala	Mean	Karni Khera	Jandiala
Release field	20	20	3.12	5.28	4.20	61.86	59.88	60.87	33.57	28.84
Control	0.2	0.2	8.18	13.16	10.67	-	-	-	5.31	3.92

Table 49. Large scale demonstration of the effectiveness of *T. chilonis* against *C. auricilius* at Paddi Khalsa (Distt. Kapurthala) and Karni Khera (Distt. Ferozepur) in Punjab during 2006

Treatments	Plot size (ha)		Incidence of *C. auricilius*			Per cent reduction in damage over control			Per cent parasitism		
	Karni Khera	Paddi khalsa	Karni Khera	Paddi khalsa	Mean	Karni Khera	Paddi khalsa	Mean	Karni Khera	Paddi khalsa	Mean
Release field	20	20	5.9	5.4	5.7	64.7	66.8	65.7	76.1	46.0	59.1
Control	0.2	0.2	16.9	16.3	16.6	-	-	-	5.0	4.9	4.9

Note: 12 releases were made @50,000/ha at 10 days interval during July to end October

The incidence of stalk borer in control was 16.9 per cent as compared to 5.9 per cent in release field at Karni Khera, which resulted in 64.7 per cent reduction in damage. The per cent parasitisation in release fields was high (76.1%) as compared to 5.0 per cent in control at Karni Khera. At Paddi Khera, the incidence of stalk borer in release field was 5.4 per cent and parasitism 46.0 as compared to 16.3 per cent incidence and 4.9 per cent parasitism in control thus, resulting in reduction of incidence by 66.8% (Table 49). It can be concluded that 12 releases of *T. chilonis* @ 50,000 per ha at 10 days interval proved effective and reduced the incidence of stalk borer by 65.7 per cent.

The pooled data of two years (2005 & 2006) also revealed that releases of *T. chilonis* reduced the incidence of stalk borer by 63.3 per cent. The parasitism in release fields was 43.9 per cent as compared to 4.4 per cent in control (Table 50).

B.4.1.2 Nawanshahar and Morainda

B.4.1.2.1 During 2006

Large scale demonstration of effectiveness of *T. chilonis* against stalk borer over an area of 1430 hectares was carried out in collaboration with two sugar mills of the state i.e. Doaba Co- operative Sugar Mills Ltd. Nawanshahar and Morinda Co- operative Sugar Mills Ltd. Morinda (Table 51). The egg parasitoid, *T. chilonis* was released from July to October in both the mill areas at 10 days interval @ 50,000/ha. The incidence of *C. auricilius* at Nawanshahar and Morinda in IPM fields was 3.9 and 1.6 per cent respectively. The corresponding figures in control fields were 5.8 and 3.2 per cent. The mean reduction in damage over control in both the mills was 42.3 per cent.

In large scale demonstration, 12 releases of T. *chilonis* @ 50,000 per ha at 10 days internal during July to October reduced the incidence of stalk borer by 42.3 per cent. The pooled data of two years (2005 & 2006) revealed that releases of *T. chilonis* reduced the incidence of stalk borer by 48.9 per cent (Table 52).

B.4.1.2.2 During 2007

Large scale demonstration of effectiveness of *T. chilonis* against the stalk borer *Chilo auricilius* over an area of 1836 hectare was carried out in collaboration with three sugar mills, *i.e.*, Doaba Co-operative Sugar Mills Ltd. Nawanshahar, Morinda Co-operative Sugar Mills Ltd. and Morinda and Nahar Sugar Mills. The incidence of *C. auricilius* at Nawanshahar, Morinda and Amloh in IPM fields was 2.8, 1.7 and 9.6 per cent respectively. The corresponding figures in control fields were 6.0, 3.6 and 30.6 per cent. The reduction in damage over control in these three mills was 53.2, 53.8 and 68.7 per cent, respectively proving the efficacy of *T. chilonis* in the control of stalk borer, *C. auricilius*.

In another field demonstration, over an area of 40 ha at village Karni Khera (Distt. Ferozepur) 12 releases of *T. chilonis* @ 50,000 per ha at 10 days interval proved effective and reduced the incidence of stalk borer by 57.3 per cent.

Table 50. Large scale demonstration of the effectiveness of *T. chilonis* against *C. auricilius* in Punjab during 2005 and 2006 (pooled)

Treatments	Mean Incidence of *C. auricilius*			Per cent reduction in damage over control			Per cent parasitism		
	2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
Release field	4.2	5.7	4.9	60.9	65.7	63.3	28.8	59.1	43.9
Control	10.7	16.6	13.6	-	-	-	3.9	4.9	4.4

Note: 12-14 releases were made at 10 days interval during July to October @ 50,000 per ha in each year

Table 51. Large-scale demonstration of biocontrol based IPM on sugarcane in two sugarcane mills in Punjab during 2006

Mill area	Area covered (hectares)	Incidence of *C. auricilius*		
		IPM*	Control	Reduction (%) over control
Doaba Co-op Sugar Mills Ltd, Nawanshahar	610	3.9	5.8	32.4
Morinda Co-op sugar Mills Ltd, Morinda	815	1.6	3.2	52.2
Total/ Mean	1425	2.7	4.5	42.3

* Twelve releases of *T. chilonis* @ 50,000 per ha at 10 days interval during July to October

Table 52. Large-scale demonstration of biocontrol based IPM on sugarcane in two sugarcane mills in Punjab during 2005& 2006 (pooled)

Mill area	Area covered during 2005&2006 (acres)	Incidence of *C. auricilius* (%)								
		IPM*			Control			Reduction (%) over control		
		2005	2006	Mean	2005	2006	Mean	2005	2006	Mean
Doaba Co-op Sugar Mills Ltd, Nawanshahar	1225	4.6	3.9	4.3	6.7	5.8	6.3	31.3	32.4	31.9
Morinda Co-op sugar Mills Ltd, Morinda	1633	2.0	1.6	1.8	9.8	3.2	6.5	79.6	52.2	65.9
Total/ Mean	2858	3.3	2.7	3.0	8.3	4.5	6.4	55.5	42.3	48.9

* Twelve releases of *T. chilonis* @ 50,000 per ha at 10 days interval during July to October during each year

B.4.1.2.3 During 2009

Large scale demonstration of effectiveness of *T. chilonis* against stalk borer over an area of 1835 hectare was carried out in collaboration with three sugar mills of the state i.e. Doaba Co- operative Sugar Mills Ltd. Nawanshahar, Morinda Co-operative Sugar Mills Ltd. Morinda and Nahar Sugar Mills Amloh (Table 53). The egg parasitoid, *T. chilonis* was released from July to October in all the three mill areas at 10 days interval @ 50,000 ha^{-1}.

The incidence of *C. auricilius* at Nawanshahar, Morinda and Amloh in IPM fields was 2.6, 0.7 and 9.3 per cent respectively. The corresponding figures in control fields were 5.7, 1.7 and 27.5 per cent. The reduction in damage over control in these three mills was 54.4, 63.8 and 66.2 per cent, respectively. Hence the mean reduction was 61.45 per cent. It can be concluded that in large-scale demonstration, 12 releases of *T. chilonis* @ 50,000 ha^{-1} at 10 days internal during July to October reduced the incidence of stalk borer by 61.45 per cent.

Table 53. Large-scale demonstration of biocontrol based IPM on sugarcane in three sugarcane mills in Punjab during 2009

Mill area	Area covered (hectares)	Incidence of *C. auricilius*		
		IPM*	Control	% reduction over control
Doaba Co-op Sugar Mills Ltd, Nawanshahar	612	2.6	5.7	54.4
Morinda Co-op sugar Mills Ltd, Morinda	816	0.6	1.7	63.8
Nahar Sugar Mills, Amloh	408	9.3	27.5	66.2
Total/ Mean	1836	4.2	11.7	61.5

* Twelve releases of *T. chilonis* @ 50,000 ha^{-1} at 10 days interval during July to October

B.4.1.2.4 During 2010

Large scale demonstration of effectiveness of *T. chilonis* against stalk borer over an area of 1836 hectares was carried out in collaboration with three sugar mills of the state i.e. Doaba Co- operative Sugar Mills Ltd. Nawanshahar, Morinda Co- operative Sugar Mills Ltd. Morinda and Nahar Sugar Mills Amloh (Table 54).

The egg parasitoid, *T. chilonis* was released from July to October in all the three mill areas at 10 days interval @ 50,000/ha. The incidence of *C. auricilius* at Nawanshahar, Morinda and Amloh in IPM fields was 3.6, 0.67 and 7.5 per cent respectively. The corresponding figures in control fields were 6.7, 1.4 and 23.5 per cent. The reduction in damage over control in these three mills was 46.3, 52.1 and 68.1 percent, respectively. Hence 12 releases of *T. chilonis* @ 50,000 per ha at 10 days internal during July to October reduced the incidence of stalk borer by 62.8 per cent.

Table 54. Large-scale demonstration of biocontrol based IPM on sugarcane in three sugarcane mills in Punjab

Mill area	Area covered (acres)	Incidence of *C. auricilius*		
		IPM*	Non Adopted	Reduction (%) over control
Doaba Co-op Sugar Mills Ltd, Nawanshahar	612	3.6	6.7	46.3
Morinda Co-op sugar Mills Ltd, Morinda	816	0.67	1.43	52.1
Nahar Sugar Mills, Amloh	408	7.5	23.5	68.1
Total/ Mean	1836	3.92	10.55	62.8

* Twelve releases of *T. chilonis* @ 50,000 per ha at 10 days interval during July to October

B.4.1.2.5 During 2011

Large scale demonstration of effectiveness of *T. chilonis* against stalk borer over an area of 2040 hectares was carried out in collaboration with three sugar mills of the state, *i.e.*, Doaba Co- operative Sugar Mills Ltd. Nawanshahar, Morinda Co- operative Sugar Mills Ltd. Morinda and Nahar Sugar Mills Amloh (Table 55). The egg parasitoid, *T. chilonis* was released from July to October in all the three mill areas at 10 days interval @ 50,000/ha.

The incidence of *C. auricilius* at Nawanshahar, Morinda and Amloh in IPM fields was 3.6, 0.67 and 7.5 per cent respectively. The corresponding figures in control fields were 6.71, 1.4 and 23.5 per cent. The reduction in damage over control in these three mills was 46.3, 53.1 and 68.1 percent, respectively. Hence, the mean reduction was 62.2 per cent.

It can be concluded that in large-scale demonstration, 12 releases of *T. chilonis* @ 50,000 per ha at 10 days internal during July to October reduced the incidence of stalk borer by 62.8 per cent.

Table 55. Large-scale demonstration of biocontrol based IPM on sugarcane in three sugarcane mills in Punjab during 2011-12

Mill area	Area covered (hectares)	Incidence of *C. auricilius*		
		IPM*	Non Adopted	Reduction (%) over control
Doaba Co-op Sugar Mills Ltd, Nawanshahar	612	12.33	28.01	55.9
Morinda Co-op sugar Mills Ltd, Morinda	816	1.82	4.3	57.7
Nahar Sugar Mills, Amloh	612	7.5	22.5	66.7
Total/ Mean	2040	7.2	18.3	60.1

* Twelve releases of *T. chilonis* @ 50,000 per ha at 10 days interval during July to October

B.4.1.2.6 During 2012

Large scale demonstration of effectiveness of *T. chilonis* against stalk borer over an area of 1428 hectares was carried out in collaboration with two sugar mills of the state i.e. Doaba Co- operative Sugar Mills Ltd. Nawanshahar and Morinda Co- operative Sugar Mills Ltd. Morinda (Table 56). The egg parasitoid, *T. chilonis* was released from July to October at 10 days interval @ 50,000/ha.

The incidence of *C. auricilius* at Nawanshahar and Morinda in IPM fields was 7.2 and 3.1 percent, respectively. The corresponding figures in control fields were 19.8 and 6.3 per cent. The reduction in damage over control in these two mills was 63.6 and 49.8 percent, respectively. Hence the mean reduction was 56.7 per cent.

It can be concluded that in large-scale demonstration, 12 releases of *T. chilonis* @ 50,000 per ha at 10 days internal during July to October reduced the incidence of stalk borer by 56.7 per cent.

Table 56. Large-scale demonstration of biocontrol based IPM against stalk borer, *Chilo auricilius*, on sugarcane in two sugarcane mills in Punjab during 2012-13

Mill area	Area covered (hectares)	Incidence of *C. auricilius*		
		IPM*	Non Adopted	Reduction (%) over control
Doaba Co-op Sugar Mills Ltd, Nawanshahar	612	7.2	19.8	63.6
Morinda Co-op sugar Mills Ltd, Morinda	816	3.1	6.3	49.8
Total/ Mean	1428	5.1	13.0	56.7

* Twelve releases of *T. chilonis* @ 50,000 per ha at 10 days interval during July to October

B.4.1.3 At Kapurthala

B.4.1.3.1 During 2010

The efficacy of *T. chilonis* was demonstrated over an area of 40 ha at Chachrari village (Distt. Kapurthala) for the management of stalk borer, *Chilo auricilius*. The parasitoids were released 12 times at 10 days interval during July to October @ 50,000 per ha.

The incidence of stalk borer in control was 7.5 per cent as compared to 3.1 per cent in release field, which resulted in 58.7 per cent reduction in damage (Table 57). The percent parasitisation in release fields was high (57.2%) as compared to control (3.6 %). Hence, 12 releases of *T. chilonis* @ 50,000 per ha at 10 days interval proved effective and reduced the incidence of stalk borer by 58.7 per cent.

Table 57. Large-scale demonstration of the effectiveness of *T. chilonis* against *C. auricilius* at Vill. Chachrari (Distt. Kapurthala) in Punjab

Treatments	Plot size (ha)	Incidence of *C. auricilius*	Per cent reduction in damage over control	Per cent parasitism
Release field	40.0	3.1[a]	58.7	57.2[a]
Control	0.4	7.5[b]	-	3.6[b]
CV	-	12.5	-	16.8

Note: 12 releases were made @50,000/ha at 10 days interval during July to end October

B.4.2 At Odisha

Demonstration of *T. chilonis* against early shoot borer and internode borer of sugarcane was carried out at farmers' field. The effectiveness of temperature tolerant

strain has been demonstrated at Rambhadeipur (Badachana),Dalabhamapur (Nimapara),Pohal (Adaspur) in 20 hectares area.

The pre-release ESB infestation ranged from 15.9 to 17.2 %. Release of *T.chilonis* for ESB continued till 4th week of February. The observations on incidence of ESB were taken each week starting from 2nd week of December till the 4th week of February. The incidence of ESB ranged from 5.5 to 24.7%, the lowest being in *T.chilonis* released plots. Parasitoid release resulted in significant reduction of ESB population as compared to pesticide application which resulted in 16.9% ESB incidence. The control plots had 24.7% ESB incidence.

Per cent pest incidence was least in parasitoid treatment (2.8%) followed by 3.9 % in pesticide applied plots and 10.4% in control. The yield was highest (128.7 t/ha) in parasitoid released plots whereas, it was 104.3 t/ha in farmers practice and 81.2 t/ha in untreated control (Table 58).

Table 58. Demonstration of Trichogramma chilonis (TTS) against shoot and internode borer

Treatments	Early shoot borer (%)		Internode borer (%)		Top shoot borer (%)#		Yield (t/ha)
	Pre release	Post release**	Pre release	Post release***	Pre Release	Post Release	
Release of *T. Chilonis*	15.9 (4.05)	5.5 (2.45)	5.4 (2.43)	11.84 (20.09)	4.2 (2.17)	2.8 (1.82)	128.7
Farmers' practice of pesticide application	17.2 (4.21)	12.9 (3.66)	6.9 (2.72)	20.65 (27.06)	4.0 (2.12)	3.9 (2.10)	104.3
Untreated control	16.4 (4.11)	24.7 (5.02)	7.1 (2.76)	39.80 (39.11)	5.7 (2.39)	10.4 (3.30)	81.2
C.D (p=0.05)	NS	(0.94)	(0.24)	(4.37)	(NS)	(0.18)	16.52

Figures in parentheses are square root transformations for ESB and top shoot borer and arc sin$\sqrt{}$ X for internode borer (Post release); *application of Phorate, carbofuran or imidacloprid granules at varying doses during earthing up and spraying of rynaxypyr, monocrotophos, profenophos; **mean of ten observations; ***mean of ten observations; #mean of five observations

C. Evaluation of with *Trichogramma chilonis* produced using Eri-silk worm eggs as factitious host

C.1 At Tamil Nadu

Eri silk worm eggs were used as a factitious host for mass production of *Trichogramma chiloris* under laboratory condition. The efficiency of *T. chilonis* produced using Eri silk worm eggs were compared with the parasitoids produced using *Corcyra* eggs in the field evaluation against sugarcane internode borer (*Chilo sacchariphagus*). The treatments were release of *T. chilonis* reared on Eri silk worm and reared on *C. cephalonica* @ 20000 / acre and untreated control. One acre for each treatment. Each treatment was separated from others and control by atleast a distance of 100 metres.

Table 58. Field evaluation of *Trichogramma chilonis* produced using Eri-silk worm eggs as factitious host

Experimental plot	Damage by INB 15 days after Release								Intensity of damage	Yield (t/ac)
	I	II	III	IV	V	VI	VII	VIII		
Release of *Trichogramma* reared on Eri Silk worm eggs @ 20,000/acre	19.2	20.1	19.8	18.6 [a]	16.4[a]	12.2 [a]	10.9 [a]	7.2 [a]	4.5 [a]	46.6 [a]
Release of *Trichogramma* reared on *Corcyra* worm eggs @ 20,000/ acre	19.4	21.3	22.1	20.5 [a]	17.8[a]	14.8 [a]	13.2 [a]	11.3 [b]	6.0 [a]	45.2 [a]
Control	18.8	20.5	22.9	23.4 [b]	22.2[b]	20.9 [b]	21.2 [b]	20.1 [c]	10.2 [b]	41.5 [b]
't' value	NS	NS	NS	2.7	3.0	4.3	4.4	3.9	3.1	

There was a significant reduction in the incidence and intensity of damage due to internode borer infestation in the release of *Trichogramma chilonis* reared on Eri Silk worm eggs @ 20,000 / acre and release of *Trichogramma* chilonis reared on *Corcyra* moth eggs @ 20,000/ acre than the unreleased fields (Table 58).

The level of damage due to INB was low in the both the parasitoid released plots whereas it was significantly high in the unreleased field. Similarly the intensity of damage in the parasitoid released fields was significantly lower as compared to the unreleased plots (Table 58). After eighth release, *Trichogramma chilonis* reared on Eri Silk worm eggs @ 20,000/acre recorded significant reduction of INB (7.2%) as compared to release of *Trichogramma* chilonis reared on *Corcyra* worm eggs @ 20,000/ acre (11.3%). The untreated control recorded higher INB incidence (20.1%).

C.2 At Karnataka

Table 59. Percent plants infested per clump by sugarcane inter node borer recorded during different releases in the sugarcane plots at ZARS, VC Farm, Mandya

Plots	2nd	3rd	4th	5th	6th	7th	8th	Post
Control	6.3	5.9	18.5	31.5	28.5	27.3	49.2[b]	41.1
ESW – Tc	7.7	9.4	16.2	27.1	25.4	29.1	25.6[a]	38.4
Cc – Tc	10.7	14.7	16.5	24.1	26	27	44.3[b]	31.6

Table 60. Percent clumps infested per plot by sugarcane inter node borer recorded during 7th, 8th and post releases in the sugarcane plots at ZARS, VC Farm, Mandya

Plots	7th	8th	Post
Control	17.1	46.1[b]	50
ESW - Tc	17.5	25.7[a]	36.9
Cc - Tc	27.7	27.5[a]	35.1

D. Sugarcane woolly aphid and its management

1. Sugarcane woolly aphid
   - **a.** Taxonomy and identification
   - **b.** Extent of damage and spread
2. Natural enemies
   - **a.** Diversity
   - **b.** Biology and feeding potential
   - **c.** Mass production techniques
3. Field evaluation and demonstration
4. Recommendations for management

D.1 Introduction

Among the control methods adopted for sugarcane pests, biological control occupies a pivotal position for several reasons. The semi-perennial nature of the crop due to its spatial and temporal continuity provides the ideal conditions for both natural as well as applied biological control. The limitations imposed by the inhospitable canopy further accentuate the reliance on biological control, except for early season pests. Several other non-insecticidal methods such as pheromones and kairomones hold promise for the future.

D.2 The Sugarcane Woolly Aphid, *Ceratovacuna lanigera* Zehntner

It is the most recent threat to sugarcane and the sugar industry in India. It is widely distributed in different countries of Asia including China, India, Indonesia, Japan, Malaysia, Myanmar, Philippines, Sri Lanka, Thailand and Vietnam; in Oceania covering Fiji and Papua New Guinea. In India, its first occurrence on sugarcane appears to be in West Bengal in late 50's (Basu and Banerjee, 1958). Later, it was reported to be occurring in Assam, Sikkim, Tripura and Uttar Pradesh (Tripathi, 1995). The pest continued to make its presence felt much later in this region though well below damaging levels.

D.2.1 Taxonomy and identification

The genus *Ceratovacuna* was erected by Zehntner in the year 1897 from specimens collected from Indonesia. The names *Oregmae* lanigera van Derenter (1906) and *Cerataphis saccharivora* Matrumara (1917) are junior synonyms. The species in this genus breed on plants belonging to the families styracaceae poaceae, Arecaceae and Orchidaceae.

Fourteen species of *Ceratovacuna* are known in the world, of which six species was only in India. They are *C. silvestrii Takahashi, C. perglandulosa* Basu, Ghosh and Raychaudhuri, *C. indica* Ghosh and Raychaudhari, nekoashi (sasaki) and *lanigera* Zehntner. Three of these species viz., *C. indicus, C. perglandulora* and *C. spinalora* are endemic. With the exception of *C. nekoashi* which is known only from Northwest Himalaya, all the others known from Northern India. In addition to these, there is a report of a species, *C. graminush* from South India. This however needs confirmation of all the specis of *Ceratovacuna, C. lanigera* is the most widely distributed species. It is known to occur in the Oriental and Pacific regions in the

following areas: India, Bangladesh, Nepal, South and South-east Asia, Fuji and Southern islands. It is a serious pest of sugarcane in parts of the oriental region.

Like most other aphids, it lives in large dense colonies sucking sap from the phloem of leaves. It excretes large amounts of honey dew resulting in the development of sooty mold.

Predators which have been used successfully in the control of *C. lanigera* such as *S. grandis* and others were studied. All the predators studied were native to our country. *D. aphidivora* and *M. igorotus* are two predators that occur in large numbers in sugarcane fields and with the potential to control the sugarcane woolly aphid. It is in this context that the Project Director, PDBC proposed the setting up of *Dipha* and *Micromus* nurseries under shade net enclosures for distribution in SWA infested sugarcane fields.

D.2.2 Effect on the Crop

The sap sucking activity of large colonies of the aphid and the development of sooty mould and the consequent reduction in photosynthesis have been reported to result in losses of 26% in yield and 15-24% in sugar content in countries like Indonesia. In India, considerable reduction in most yield and quality parameters was observed at 100% infestation but not at 25% infestation level in Assam (Gupta and Goswami, 1995). In the present epidemic area, the loss in yield at more than 75% infestation level was projected as 12-20% and loss in sugar recovery as 0.52-1.20 units in Maharashtra. In northern Karnataka, qualitative and quantitative parameters from 8-month old infested canes were significantly lower than those of healthy canes except cane girth. Observations of sugar recovery in two successive years in Belgaum district of northern Karnataka indicated lower recovery in aphid-attack year compared to the aphid-free previous year (Lingappa, 2004).

D.2.3 Host Plants

Although sugarcane is the preferred host plant of the sugarcane woolly aphid, it has been recorded on a number of other plants in India, most of which belong to the family Poaceae. Two plants belonging to the families Bixaceae and Combretaceae have also been recorded from India. No studies have however being conducted to determine whether the SWA is capable of feeding and multiplying on these hosts in India (Table 61).

Table 61. Host plants of *Ceratovacuna lanigera* recorded from India

Host Plant	Family
Bambusa arundinaceae Retz.	Poaceae
Bambusa sp.	Poaceae
Cynodon dactylon (L.) Pers.	Poaceae
Grassum sp.	Poaceae
Oplismenus sp.	Poaceae
Saccharum officinarum Linnaeus	Poaceae
Themeda sp.	Theaceae
Indet. Species	Poaceae
Xylosma longifolia	Bixaceae
Indet. Species	Combretaceae

(Source : Raychaudhuri, 1984)

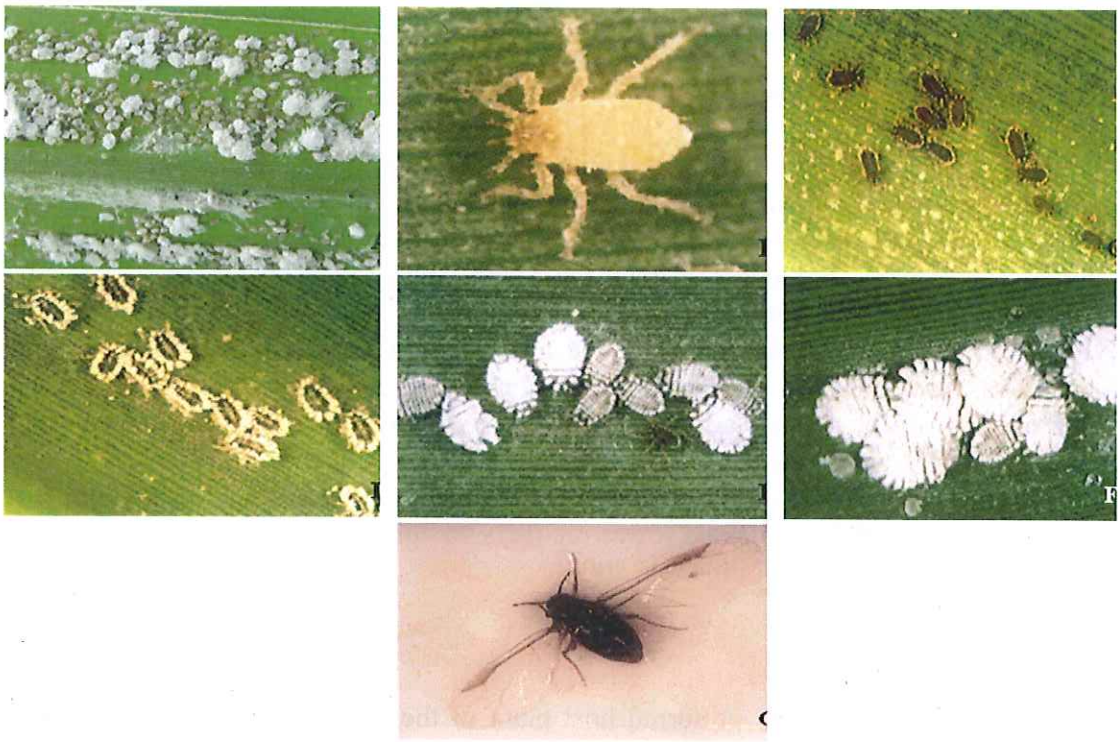


Plate 4. The Sugarcane Woolly Aphid, *Ceratovacuna lanigera* Zehntner (Hemiptera: Aphididae) A. Infestation, B. Soldier aphid, C. First instar, D. Second instar, E. Third instar, F. Adults, G. Alate

D.2.4 Natural Enemies

The natural enemies recorded on this pest from southeast Asian countries such as China, Indonesia, Malaysia, Philippines, Taiwan and Vietnam include two species of parasitoids, 12 species of predators and two species of pathogens (CABI, 2002).
In over a hundred years since the discovery and description of the sugarcane woolly aphid in the year 1897, 37 natural enemies including seven parasitoids, 27 predators and three pathogenic fungi were reported as attacking the sugarcane woolly aphid from the areas of its occurrence (Table 62). Attempts have also been made to use these insects to manage the aphid, some of which have reportedly succeeded by effecting remarkable reductions in aphid population levels.

Encarsia flavoscutellum Zehntner was the first parasitoid to be studied as a potential agent for the control of the sugarcane woolly aphid. These studies in Java, Indonesia revealed natural parasitism levels were as high as 30 per cent and it was felt that since this parasitoid attacked in the early stages of infestation by the sugarcane woolly aphid, it was not necessary to take up control measures (Hazelhoff, 1930, 1931). However when this parasitoid was introduced into Philippines and Taiwan, it failed to establish, perhaps owing to the small numbers that were released. No attempts have been made to exploit the other parasitoids for the control of sugarcane woolly aphid. It would therefore be worthwhile to explore the possibilities for the biological control of the woolly aphid in our country by introducing *E. flavoscutellum*
Synonycha grandis Thunberg has been viewed as a promising predator for the control of the sugarcane woolly aphid. In China, Chen *et al.* (1954) mass produced this large coccinellid on field collected woolly aphids and released them in the field. Field releases were successful with *S. grandis* as reported by Deng *et al.* (1987).
Coelophora biplagiata (Swartz) and *Coelophora saucia* were two other coccinellids that were introduced from Taiwan and Java and from Tonkin to Taiwan for the control of the sugarcane woolly aphid. These introductions were unsuccessful.

In India, five species of parasitoids and two species of predators, namely *Dipha aphidivora* (Meyrick) and the syrphid *Eupeodes confrater* Wiedemann were reported in Nagaland (Tripathi, 1995). Roving surveys conducted in Kolhapur, Maharashtra, during 2003 - 2004revealed seven species of predators. Of these, *D. aphidivora* appeared to be promising, as its presence was associated with low pest numbers on leaves. Three species of syrphids, two species of coccinellids and *Chrysoperla zastrovi sillemi* (Stephens) were encountered in the survey (Rabindra *et al.*, 2002). In another survey in Kolhapur and Sangli regions of Maharashtra, more or less the same natural enemies were recorded, including the brown lacewing *Micromus timidus* Hagen (Patil and Nerkar, 2004). Eight natural enemies, including *D. aphidivora* and *C. carnea*, were recorded in northern Karnataka (Lingappa, 2004).

D.2.5 Natural enemy complex of *C. lanigera*

D.2.5.1 Predators and parasitoids

The natural enemies collected during 2003-2006 outbreak of SWAincluded the following: *Cheilomemenes sexmaculata* (Coleoptera:Coccinellidae), *Chrysoperla carnea* (Neuroptera:Chrysopidae), *Eupeodes confrater* (Diptera:Syrphidae), *Dipha aphidivora* (Lepidoptera:Pyralidae), *Micromus igorotus* (Neuroptera:Hemerobiidae) and *Encarsia flavoscutellum* (Hymenoptera: Aphelinidae). In addition to these, *Synonycha grandis* and, *Anisolemnia dilatata* (both belonging to Coleoptera: Coccinellidae), were collected from colonies of the bamboo aphid, *Pseudoregma*

Table 62. Natural enemies of *Ceratovacuna lanigera* Zehntner

Natural enemy	Location
Parasitoids	
Hymenoptera	
Aphelinidae	
Aphelinus desantisi Hayat	India
Encarsia flavoscutellum Zehntner	Java
	Taiwan
	Netherlands
	Philippines
	Malaysia
	India
Braconidae	
Diaeretiella rapae M'Intosh	India
Diaeretus oregmae Gahan	Philippines
	Taiwan
Aphidius sp.	Philippines
Encyrtidae	
Anagyrus sp.	India
Chalcididae	
Antocephalus sp.	India
Predators	
COLEOPTERA	
Coccinellidae	
Anisolemnia dilatata (Fabricius)	China
Cheilomenes sexmaculata (Fabricius)	Philippines
	India
Coccinella septempunctata linnaeus	India
Coelophora biplagiata (Swartz)	Vietnam
	China
Coelophora saucia Mulsant	Formosa
Cryptogonus orbiculus (Gyllenhal)	Philippines
Curinus coeruleus Mulsant	Philippines
Harmonia octomaculata (Fabricius)	India
Pseudoscymnus kurohime (Miyatake)	Japan
Scymnus sp.	Philippines
Synonycha grandis (Thunberg)	Philippines
	China
	Japan
	Taiwan
	Indo-China
LEPIDOPTERA	
Lycaenidae	
Taraka hamada (Druce)	China
Pyralidae	
Dipha aphidivora (Meyrick)	Malaysia
	China
	India
	Taiwan
	Japan
Thiallela sp.	Philippines

DIPTERA	
Syrphidae	
Dideopsis aegrota (Fabricius)	Philippines
	India
Episyrphus balteatus (DeGeer)	India
Eupeodes confrater (Wiedemann)	India
Eupeodes corollae (Fabricius)	Philippines
Eupeodes kuroiwae (Matsumura)	Japan
Eupeodes scutellaris (Fabricius)	India
Syrphus sp.	Taiwan
NEUROPTERA	
Chrysopidae	
Chrysopa sp.	India
Chrysoperla carnea (Stephens)	Philippines
Chrysopa pallens Rambur	Philippines
	Japan
HEMEROBIIDAE	
Micromus sauteri Esben-Petersen	Philippines
	Taiwan
	Japan
Micromus timidus Hagen	Japan
HEMIPTERA	
Anthocoridae	
Orius persequens (White)	Java
ARANEAE	
Unidentified spiders	Philippines
Pathogens	
Aspergillus sp..	Philippines
Fusarium moniliforme Sheld	China
Penicillium oxallicum Currie & Thom.	China

bambusicola. These ladybirds fed on the sugarcane woolly aphid but failed to lay eggs and multiply on this host.

Of all the natural enemies collected, *E. flavoscutellum, D. aphidivora* and *M. igorotus* showed the greatest promise. In very few sugarcane fields did *E. confrater* predominate and that too during the cold period. All attention was therefore focused on the former three natural enemies.

D.2.5.2 Evaluation of fungal pathogens

D.2.5.2.1 Survey for fungal pathogens in sugarcane woolly aphid infested fields

Dead SWA samples from the districts Mandya (19 nos.), Vellore (5nos.), Chittor (6 nos.), Nizamabad (6 nos.) and Medak (6 nos.) were collected and plated on PDA. *Cladosporium oxysporum* and *Fusarium* sp. were consistently isolated from all these samples (Table 63). On artificial inoculation with these fungi on SWA, no infection/ mycosis was observed.

Table 63. Fungi isolated from dead sugarcane woolly aphids from different locations in Karnataka, Tamil Nadu and A.P.

Location	No. samples plated	Fungi isolated		
		Cladosporium oxysporum	*Fusarium* sp.	Unidentified fungi
Mandya (Karnataka)	19	12	1	6
Vellore (Tamil Nadu)	5	3	-	2
Chittor (A.P)	6	2	2	2
Nizamabad (AP)	6	3	-	3
Medak (AP)	6	4	-	2
Total	42	24	3	15

D.2.5.2.2 Testing of pathogenicity of available fungal pathogens to sugarcane woolly aphid and its predators

Among the 7 isolates of *Metarhizium anisopliae* (Ma-1, 2, 3, 4, 5, 6, 7), 4 isolates of *Beauveria bassiana* (Bb-3, 4, 5a, 6) and 5 isolates of *Vertcillium lecanii* (Vl-1, 2a, 3a, 5, 7) tested on *C. lanigera* at Kanakapura, Ma-4 isolate caused highest rate of mycosis (30.1%), followed by Bb-5a (20.5% mycosis) (Table 64). These two isolates (Ma-4 and Bb-5a) were also pathogenic to *Dipha* causing 27.6 and 15.3% mycosis, respectively and Ma-4 isolate causing 29.1% mycosis of *Micromus*. The five isolates of *V.lecanii* tested were not pathogenic on SWA, but caused 7.6-33.5% mycosis of *Micromus*.

D.2.5.2.3 Field evaluation of formulations

Four different formulations of Ma-4 isolate of *M.anisopliae* were tested on SWA at Kanakapura. The percentage of mycosis of SWA observed with these formulations were 37.4, 31.9, 30.6 and 30.1%, respectively and statistically on par with each other (Table 64).

D.2.5.2.4 Effect of serial passage of Ma-4 and B-5a isolates on SWA on their virulence

The two isolates of Ma-4 and Bb-5a were passed through *C. lanigera* for five generations and after each passage, virulence of the re-isolated culture was tested on *C. lanigera*. Slight increase in the percentage mycosis of *C. lanigera* was observed with the re-isolated cultures after 5th passage. Ma-4 and Bb-5a isolates showed 40.7% and 26.2% mycosis respectively after 5th passage compared to 30.1% and 20.5% mycosis before passage (Table 65).

D.2.5.2.6 Supply of formulations of entmofungal pathogens (*B. bassiana* Bb5a and *M. anisopliae,* Ma4) for field evaluation against sugarcane woolly aphid

A total quantity of 1.2kg of rice grain formulations of Ma-4 and 1.2kg of Bb-5a were sent to each of the AICRP centers at TNAU, MPKV and UAS, Dharwad for field evaluation against sugarcane woolly aphid during Aug-Sept, 2004.

Ma-4 isolate caused highest per cent mycosis of *C. lanigera* (30.14%), followed by Bb-5a (20.46% mycosis). These two isolates (Ma-4 and Bb-5a) were also found pathogenic on *Dipha* causing 27.62 and 15.32% mycosis respectively and Ma-4 isolate causing 29.14% mycosis of *Micromus* (Table 66).

Table 64. Pathogenicity of different fungal isolates to the Sugarcane woolly aphid (SWA) and its Predators

Fungus	Isolate	*Per cent Mycosis*		
		SWA	*Dipha*	*Micromus*
M. anisopliae	Ma-1	0.0	0.0	0.0
	Ma-2	5.2	0.0	0.0
	Ma-3	13.5	3.9	0.0
	Ma-4	30.1	27.6	29.1
	Ma-5	0.0	0.0	0.0
	Ma-6	4.6	0.0	0.0
	Ma-7	8.5	0.0	0.0
B. bassiana	Bb-3	0.0	0.0	0.0
	Bb-4	12.5	3.8	0.0
	Bb-5a	20.5	15.3	0.0
	Bb-6	9.6	0.0	0.0
V. lecanii	Vl-1	0.0	5.2	20.0
	Vl-2a	0.0	0.0	33.5
	Vl-3a	0.0	0.0	15.7
	Vl-5	0.0	0.0	7.6
	Vl-7	0.0	0.0	17.7
C.D. at 5%		8.3	6.4	8.4

Table 65. Effect of serial passage of Ma-4 and B-5a isolates on SWA on their virulence

Fungal Isolate	Per cent mycosis of SWA after serial passage				
	I	II	III	IV	V
M.anisopliae (Ma-4 isolate)	30.9	30.1	33.5	34.7	40.7
B.bassiana (Bb-5a isolate)	19.3	20.8	22.2	22.6	26.2

Table 66. Effect of different formulations of Ma-4 isolate of *M. anisopliae* on Sugarcane woolly aphid

Formulation	Per cent mycosis of SWA
ULV spray with oil-based formulation (Diesel + Sunflower oil in 7:3 ratio)	37.4
Oil in water emulsion with 0.2% sunflower oil and 0.01% Tween-80	31.9
Oil in water emulsion with 0.2% sunflower oil + 0.01% Tween-80 and 0.2% Glycerin	30.6
Aqueous spore suspension with 0.01% Tween-80	30.1
C.D. at 5%	NS

D.2.5.3 Identification of strains of natural enemies

D.2.5.3.1 Feeding potential of predators of SWA

D.2.5.3.1.2 *Micromus igorotus*

The feeding potential of *M. igorotus* was assessed under laboratory conditions during different seasons (Table 67). During May-June, the total larval duration recorded was 6.14days. While, mean adult longevity was recorded at 15.19 days. The mean number of aphids consumed by each individual throughout its life period was 482.35. Based on these values, per day consumption of aphid by an individual was worked out at 21.33 aphids/day/individual. Similarly, during July-Aug and Sept-Oct, the number of aphids consumed by each individual throughout its life period was 501.34 and 512.34 respectively. Hence, the per day consumption of aphid by an individual was determined at 22.18 and 22.60 aphids /day/individual during July-Aug and Sept-Oct, respectively. Similar trend was noticed during Nov-Dec 05 and Jan-Feb 06, with per day consumption rate of 23.56 and 23.42 aphids/day/individual, respectively.

Table 67. Feeding potential of *Micromus igorotus*

Parameters	May-June
Total larval period (days)	6.140
Adult longevity (days)	15.19
Total	21.33
Total no. of aphids consumed	482.35

D.2.5.3.1.2 *Dipha aphidivora*

The studies on the feeding potential of *Dipha aphidivora* was conducted under laboratory condition during November-December 2004.

Ten freshly hatched first instar larvae were kept in glass vials individually. Each individual was provided with known number of aphids daily and the number was enhanced as the growth of the larvae advanced. The date of each moulting for all individuals was recorded to know the duration of each instar. Finally, the number of aphids consumed by each instar was calculated and per day consumption by each instar was worked out by dividing the total value by the total duration. The data on mean number of aphids consumed by ten individuals is given in table 68.

Table 68. Instar-wise feeding potential of *D. aphidivora* (2004-05)

Larval instars	Mean no. of aphids consumed/day	Duration of each instar	Mean no. of aphids consumed /instar
I	4.23	2.71	11.46^{e}
II	98.01	4.05	396.94^{d}
III	203.01	7.99	1622.04^{b}
IV	278.03	10.25	2849.81^{a}
V	233.61	4.23	988.17^{c}
Total	816.89	29.23	5868.42

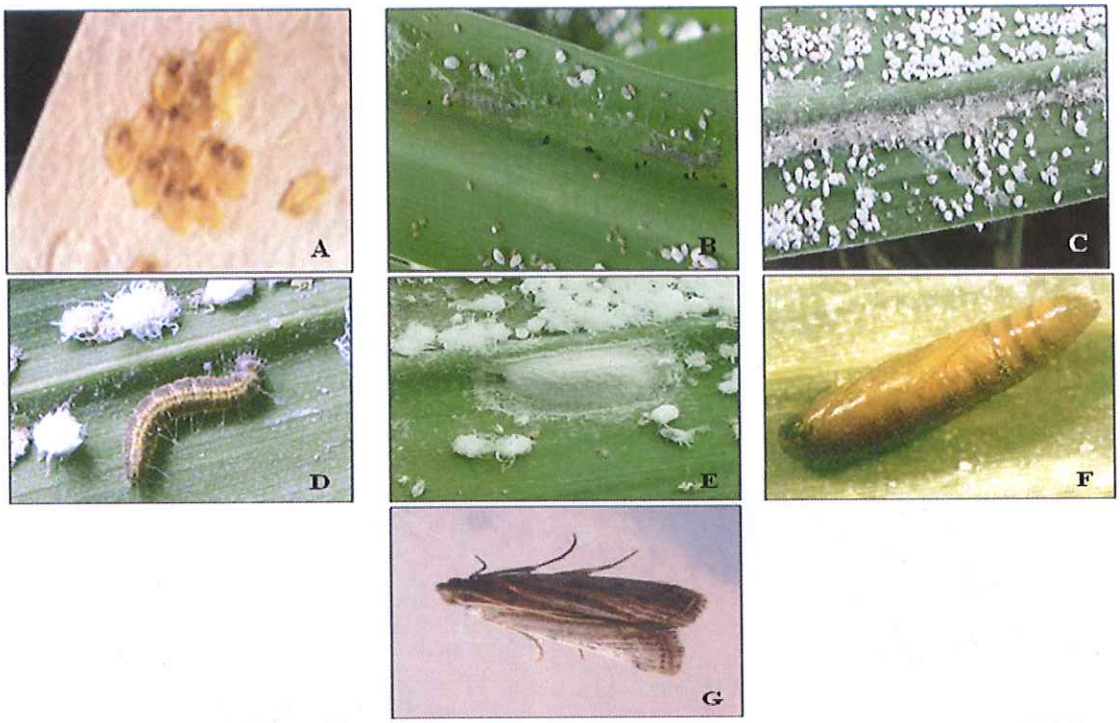


Plate 5. Predator, *Dipha aphidivora* (Meyrick) (Lepidoptera: Pyralidae) A. Eggs, B. Young larva feeding from withing gallery formed by it, C. Gallery formed by the later larval instars, D. Grown up larva, E. Pupa inside silken coccon, F. Naked pupa, G. Adult

Plate 6. Predator, *Micromus igorotus* Banks (Neuroptera: Hemerobiidae) A. Eggs, B. larva feeding on aphid, C. Pupa inside loose silken cocoon, D. Adult

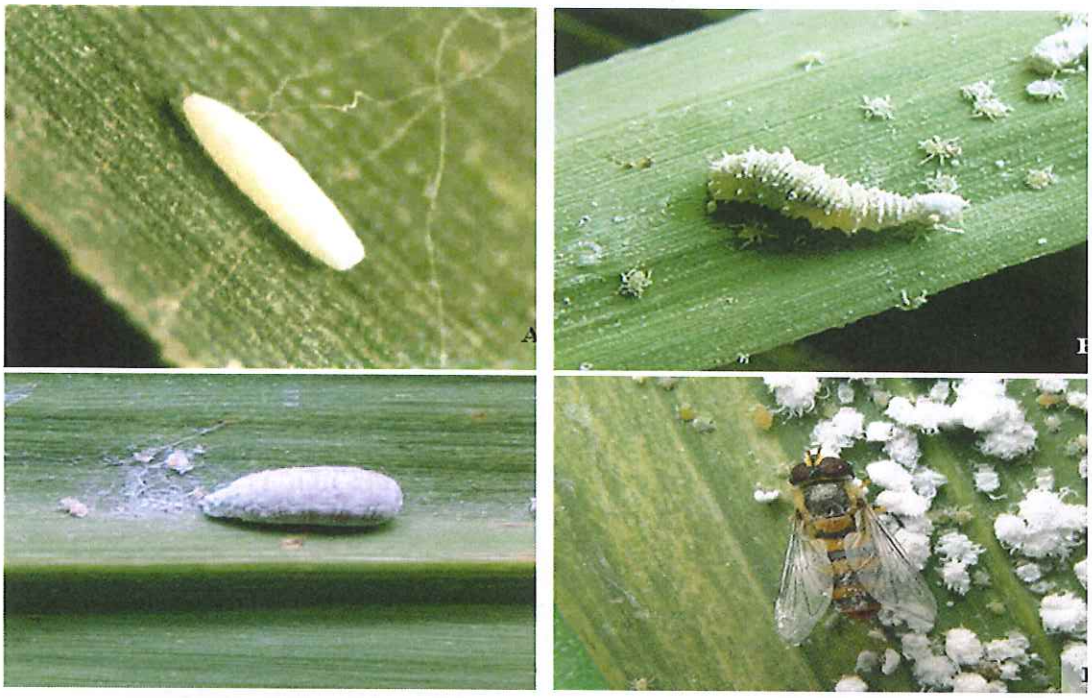


Plate 7. Predator, *Eupeodes confrater* (Wiedemann) (Diptera: Syrphidae) A. Egg, B. larva feeding on aphid, C. Pupa, D. Adult

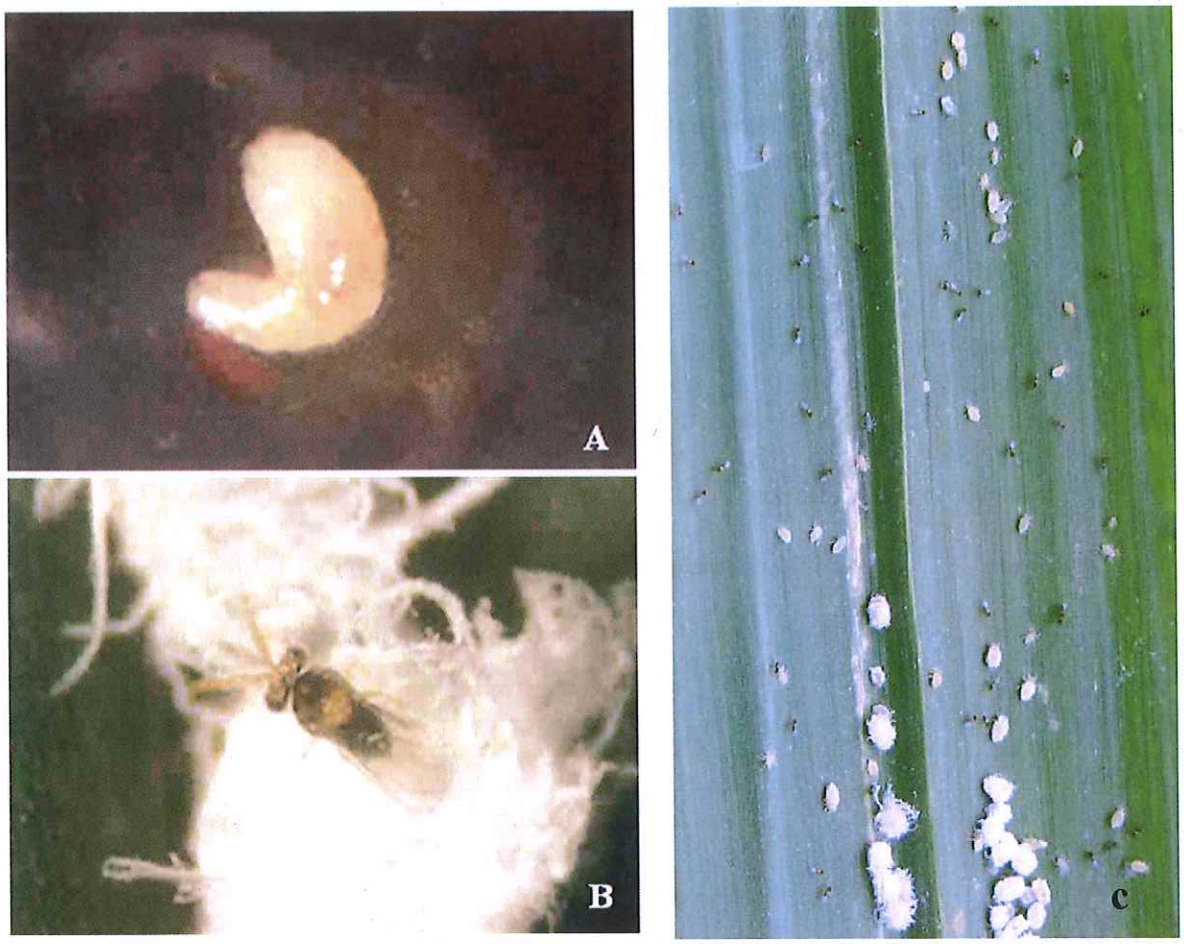


Plate 8. Parasitoid, *Encarsia flavoscutellum* Zehntner (Hymenoptera: Chalcididae) A. Larva, B. Adult, C. Large number of parasitoids parasitizing a colony of aphids

The voracious feeding by *Dipha aphidivora* was observed from second instar onwards and the IV instar larvae consumed maximum number of aphids. However, the consumption rate declined when it entered the fifth instar as the larva reaching full maturity begin to enter the pupal stage. The total number of aphids consumed by an individual during its entire larval period was to the tune of 5868.42.

The studies on the feeding potential of *Dipha aphidivora* were conducted under laboratory conditions during different seasons.

Voracious feeding by *D. aphidivora* was observed from second instar onwards and the IV instar larvae consumed maximum number of aphids. However, the consumption rate declined when it entered the fifth instar as the larva reached its full maturity stage and begin to enter into pupal stage. The total number of aphids consumed by an individual during its entire larval period was to the tune of 5658.26, 5979.85, 6196.11 and 6320.51 during May-June, July-Aug and Sept-Oct and Nov-Dec, respectively (Table 69-72).

Table 69. Instar-wise feeding potential of *D. aphidivora* (May-June 2005)

Larval instars	Mean no. of aphids consumed/day	Duration of each instar (days)	Mean no. of aphids consumed /instar
I	4.25	2.71	11.52 e
II	98.97	3.88	384.00 d
III	200.02	7.85	1570.16 b
IV	279.39	9.75	2724.05 a
V	227.89	4.25	968.53 c
Total		28.44	5658.26

Table 70. Instar-wise feeding potential of *D. aphidivora* (July-August 2005)

Larval instars	Mean no. of aphids consumed/day	Duration of each instar(days)	Mean no. of aphids consumed /instar
I	4.31	2.75	11.85 e
II	100.23	3.96	396.91 d
III	212.35	8.21	1743.39 b
IV	285.39	9.92	2831.06 a
V	231.24	4.31	996.64 c
Total		29.15	5979.85

Table 71. Instar-wise feeding potential of *D. aphidivora* (Sept.-Oct., 2005)

Larval instars	Mean no. of aphids consumed/day	Duration of each instar (days)	Mean no. of aphids consumed /instar
I	4.45	2.82	12.55 e
II	100.85	4.23	426.60 d
III	215.25	8.32	1790.88 b
IV	288.25	10.12	2917.09 a
V	235.20	4.46	1048.99 c
Total		29.95	6196.11

Table 72. Instar-wise feeding potential of *D. aphidivora* (Nov.-Dec., 2005)

Instars	Mean no. of aphids consumed/day	Duration of each instar (days)	Mean no. of aphids consumed /instar
I	4.51	2.89	13.03 e
II	100.96	4.34	438.17 d
III	215.32	8.62	1856.06 b
IV	288.51	10.23	2951.46 a
V	235.43	4.51	1061.79 c
Total		30.59	6320.51

D.2.5.4 Studies on alternate hosts for mass rearing of *Micromus igorotus*

To identify a suitable alternative host for rearing *Micromus igorotus*, the feeding potential of *M. igorotus* was assessed under laboratory conditions using different aphid species. The freshly hatched first instar larvae were kept in glass vials individually. Ten individuals were taken for the study. Each individual was provided with known number of different aphid species daily. The aphid number was increased as the growth of the grub advanced. The total larval duration was recorded on different aphids. The mean number of aphids consumed by each individual throughout its life period was recorded. Based on these values, per day consumption of aphids by an individual was worked out. The results (Table 73) revealed that *Micromus* consumed a maximum of 398.17 cotton aphids as compared to other species of aphids, which may be due to its soft body. Safflower aphid was the least preferred species (75.8 aphids / individual) because of presence of a hard cuticle.

Table 73. Alternate hosts for mass rearing of *Micromus igorotus* larvae

Common name	Scientific name	Total consumption / individual	Total larval period	Mean number of aphids consumed /individual
Cotton aphid	*Aphis gossypii*	398.17	8.06	49.40
Cabbage aphid	*Myzus persicae*	356.63	7.29	48.92
Safflower aphid	*Uroleucon compositae*	75.80	4.26	17.79
Sugarcane woolly aphid	*Ceratovacuna lanigera*	160.00	6.36	25.15

Studies were conducted on the biology and feeding potential of *M. igorotus* on cotton aphid (*Aphis gossipii),* safflower aphid (*Uroleucon compositae)* and cabbage aphid (*Myzus persicae*) in comparison with sugarcane woolly aphid (*Ceratovacuna lanigera*). After hatchin, ten first instar larvae were kept in small petri plates (10 cm diam) along with aphids individually. After every 24 hours, the larvae were transferred to fresh lot of aphids present on fresh leaf. Each individual was provided with known number of aphids daily and the number of aphids was enhanced as the growth of the larvae advanced. Observations on incubation period, total larval period, total number of aphids consumed, pupal period, adult longevity and fecundity were recorded for five generations on cotton aphid, cabbage aphid and SWA and three generations on safflower aphids. The results are presented in tables 74-78.

Table 74. Biology of *Micromus igorotus* on cotton aphid

Parameters	Generation					Mean ± SD
	I	II	III	IV	V	
Incubation period (days)	2.56	2.48	2.43	2.40	2.43	2.46 ± 0.06
Larval period (days)	7.69	7.63	7.65	7.68	7.65	7.67 ± 0.02
Total number of aphids consumed/ grub	230.25	228.00	220.00	218.08	219.00	223.06 ± 5.62
Pupal period (days)	6.70	6.70	6.68	6.58	6.45	6.62 ± 0.01
Adult longevity (days)	12.14	12.10	12.00	11.98	11.89	12.00 ± 0.09
Fecundity (per female)	356.11	342.12	338.26	320.50	312.50	354.50 ± 17.44

Table 75. Biology of *Micromus igorotus* on safflower aphid

Parameters	Generation			Mean ± SD
	I	II	III	
Incubation period (days)	2.90	2.76	2.50	2.72 ± 0.20
Larval period (days)	5.60	5.40	5.21	5.40 ± 0.20
Total number of aphids consumed/grub	58.75	56.25	54.00	56.33 ± 2.37
Pupal period (days)	8.10	7.16	6.81	7.35 ± 0.66
Adult longevity (days)	14.16	13.15	12.00	13.10 ± 1.08
Fecundity (per female)	231.00	228.00	224.50	227.84 ± 3.25

Table 76. Biology of *Micromus igorotus* on cabbage aphid

Parameters	Generation					Mean ± SD
	I	II	III	IV	V	
Incubation period (days)	2.36	2.28	2.22	2.21	2.18	2.25 ± 0.07
Larval period (days)	7.86	7.90	7.95	7.88	7.82	7.89 ± 0.04
Total number of aphids consumed/grub	215.15	211.00	218.25	210.50	200.77	211.14 ± 6.60
Pupal period (days)	7.62	7.29	7.26	7.12	7.09	7.28 ± 0.21
Adult longevity (days)	12.10	12.00	11.98	11.90	11.85	11.96 ± 0.09
Fecundity (per female)	361.25	360.00	358.00	351.20	345.35	355.16 ±6.72

Table 77. Biology and feeding potential of *Micromus igorotus* on sugarcane woolly aphid

Parameters	**Generation**					**Mean ± SD**
	I	**II**	**III**	**IV**	**V**	
Incubation period (days)	3.37	3.25	3.12	3.00	3.00	3.14 ± 0.16
Larval period (days)	6.82	6.69	6.54	6.50	6.45	6.60 ± 0.15
Pupal period (days)	6.98	6.88	6.67	6.54	6.40	6.70 ± 0.23
Adult longevity (days)	14.12	13.25	13.00	12.85	12.47	13.14 ± 0.61
Number of aphids consumed/adult	296.12	294.00	289.36	280.00	268.03	285.50± 1.56
Fecundity (per female)	298.18	293.22	292.00	290.20	287.26	292.18 ± 4.03

Table 78. Biology of *Micromus igorotus* on different aphid species

Parameters	*Aphis gossipii*	*Uroleucon compositae*	*Myzus persicae*	*Ceratovacuna lanigera*
Incubation period (days)	2.46	2.72	2.27	3.14
Larval period (days)	7.67	5.40	7.89	6.60
Total number of aphids consumed/grub	223.06	56.33	211.15	162.83
Pupal period (days)	6.62	7.35	7.28	6.70
Adult longevity (days)	12.00	13.47	11.97	13.14
Fecundity (per female)	354.50	227.84	355.16	292.18

The studies on the biology of *M. igorotus* on cotton aphid for five generations revealed an average of 2.46, 2.67 and 6.62 days of incubation period, larval period and pupal period, respectively. In case of cabbage aphid, incubation, larval and pupal periods occupied an average of 2.27, 7.89 and 7.28 days, respectively. In case of safflower aphid, the average incubation, larval and pupal periods were 2. 72, 5.44 and 7.45 days, respectively.

D.2.5.4.1 Biology of natural enemies of SWA

D.2.5.4.1.1 Biology of *Dipha aphidivora* on natural and alternate laboratory host

The biology of *D. aphidivora* was studied on *C. lanigera* and *Aphis craccivora* Koch. Studies indicated that the larval, pupal and adult periods did not differ significantly, however, the adults resulting from the larvae reared on *A. craccivora* did not lay any eggs. Fecundity of *D. aphidivora* reared on *C. lanigera* was 19.90 eggs per female (Table 79).

Table 79. Biological parameters of *D. aphidivora* on two hosts

Parameter	*Aphis craccivora*	*Ceratovacuna lanigera*
Larval period	11.5 days	12 days
Pupal period	7.25 days	8.19 days
Adult longevity	5.25 days	5.69 days
Fecundity	-	19.90 egg/female

D.2.5.4.1.2 Rearing of *D. aphidivora* on artificial diet

Four artificial diets with different ingredients were formulated for evaluation of survival of larvae of *D. aphidivora*. First instar larvae could not survive on any of the diets evaluated, however second instar larvae could survive on three out of four diets. All the third instar larvae reared on all the diets could pupate and emerge as adults. The larvae fed with other laboratory hosts like *Ferrisia virgata* and *Hemiberlesia lataniae* could not survive.

D.2.5.4.1.3 Rearing of *Micromus igorotus* under laboratory condition at UAS, Dharwad

The studies on biology of *M. igorotus* was carried out under laboratory conditions in two consecutive months of October and November (2004) and also during January – February 2005. The duration of various stages, *viz.* egg, larva, pupa and adult were recorded. The fecundity of the female was also noted. The mean data obtained from 25 individuals has been recorded in table 80.

Table 80. Biology of *Micromus igorotus* (2004-05)

Stage	Duration (days)			
	October	November	Jan - Feb	Mean ± SD
Egg	3.35	3.49	3.38	3.41 ± 0.07
Grub	6.17	6.30	5.97	6.15 ± 0.17
Pupa	6.46	6.78	6.26	6.5 ± 0.26
Adult	15.23	17.36	14.79	15.79 ± 1.37
Fecundity	158.6	161.3	345.25	221.72 ± 106.99
TLC	31.21	33.93	30.40	31.85 ± 1.85

The duration of all the stages of *M. igorotus* was prolonged during November (33.93 days) month as compared to October (31.21days). Comparatively, the life of *M. igorotus* was short (30.40) during January-February. A very high fecundity of 345.25 eggs per female was observed due to change in the methodology of getting eggs laid, *i.e.*, from thread to cotton wad.

2005-06

The study on biology of *M. igorotus* was carried out under laboratory conditions during May-June, July-August, September-October, November – December 2005 and January-February 2006.

The duration of various stages, *viz.* egg, larva, pupa and adult were recorded. The fecundity of the female was also noted. The mean data obtained from 25 individuals has been recorded in table 81.

Table 81. Biology of *Micromus igorotus* in different months (2005-06)

Stage	Duration (days)					
	May-June	July-Aug.	Sept-Oct	Nov-Dec	Jan-Feb	Mean ± SD
Egg	3.32	3.43	3.41	3.47	3.41	3.41 ± 0.05
Grub	6.16	6.30	6.32	6.31	5.94	6.21 ± 0.16
Pupa	6.45	6.52	7.25	6.80	6.28	6.66 ± 0.38
Adult	15.21	16.36	16.41	17.34	14.82	16.03 ± 1.01
Fecundity	301.56	303.24	302.11	361.32	339.36	321.52 ± 27.45
TLC	31.14	32.61	33.39	33.92	30.45	32.3 ± 1.47

The duration of all the stages of *M. igorotus* slightly increased from May-June (31.14 days) to Nov-Dec (33.92). However, slightly less longevity was recorded during Jan-Feb (30.45 days). However, no considerable difference was observed in fecundity during different months.

D.2.5.4.1.4 Biology of *Micromus* sp. studied at MPKV, Pune

A nucleus culture of *Micromus* sp. larvae was collected from nursery plots of the sugarcane variety Co 86032 at Someshwar Co-operative Sugar Factory, Someshwarnagar, Pune, on 8th July, 2004. These larvae were reared in the laboratory on sugarcane woolly aphids. An attempt was also made to rear the larvae on *Corcyra cephalonica* eggs in the laboratory. The durations of the different stages are given in table 82.

Table 82. Durations of different stages of *Micromus* sp. on SWA in Pune, Maharashtra

Stage	Period (days)
Pre-oviposition period	6 - 8
Oviposition period	2 – 7
Incubation period	3 – 5
Larval period	8 – 13
Pupal period	6 – 9
Adult longevity	8 – 10
Total life span	25 – 37
Fecundity	34 eggs/female

D.2.5.4.1.4 Biology of *Dipha aphidivora* studied at MPKV, Pune

The biology of *Dipha aphidivora* was also undertaken under laboratory conditions during November-December, 2004 and January-February, 2005. The mean data obtained from various stages of 25 individuals is presented in table 83.

Table 83. Biology of *Dipha aphidivora* (2005-06)

Stage	Duration (days)		
	Nov - Dec 2004	Jan - Feb 2005	Mean ± SD
Egg	5.65	4.98	5.32 ± 0.47
Larval instars			
I	2.63	2.41	2.52 ± 0.16
II	3.85	3.75	3.80 ± 0.07
III	8.01	7.02	7.52 ± 0.70
IV	10.33	9.25	9.79 ± 0.76
V	4.15	4.01	4.08 ± 0.10
Total larval period	28.97	26.44	27.71 ± 1.79
Pupal period	9.31	8.02	8.62 ± 0.91
Adult	3.56	3.03	3.30 ± 0.37
Fecundity	113.67	104.04	108.86 ± 6.81
TLC	47.49	42.47	44.98 ± 3.55

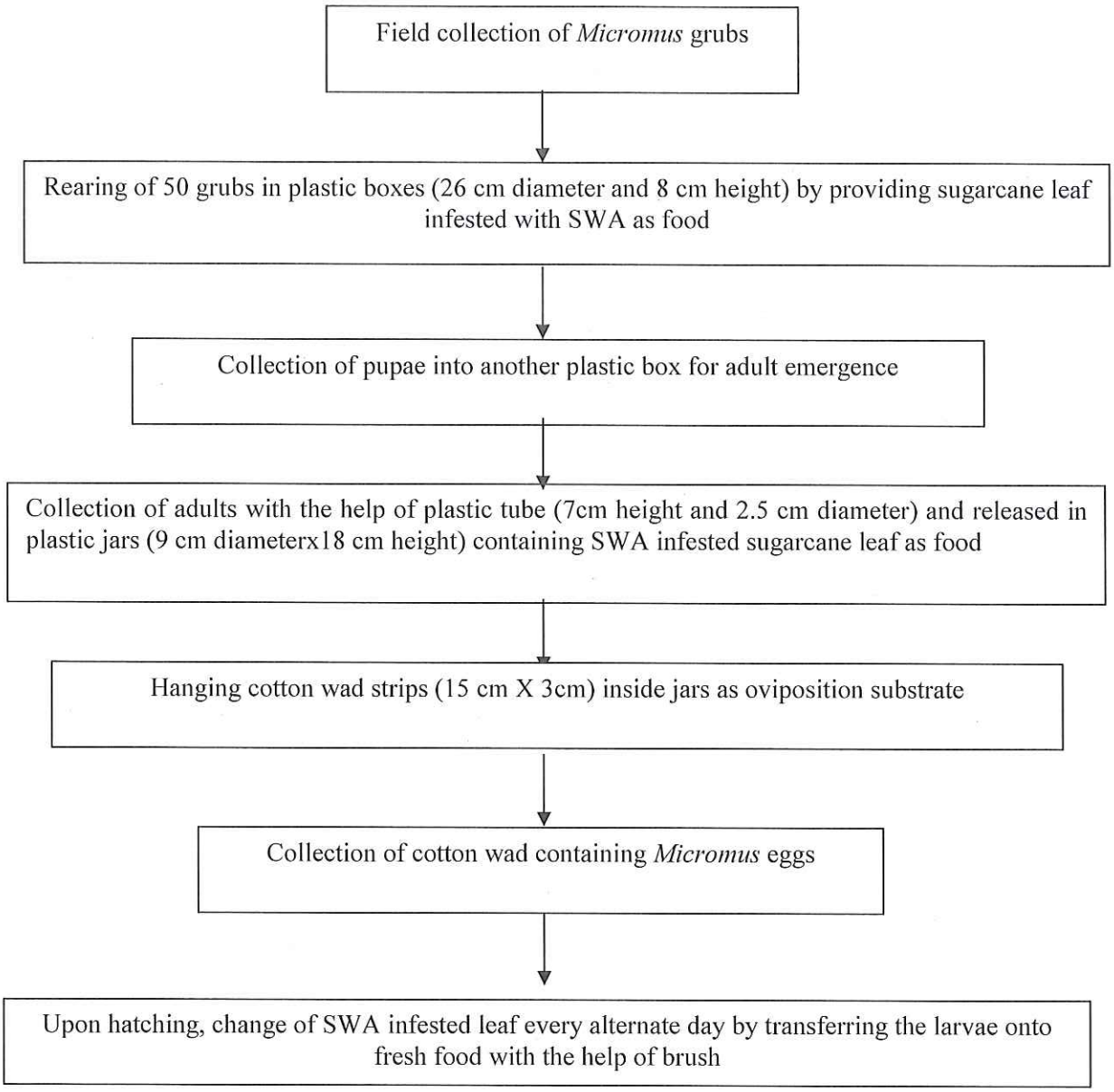
During November-December, the mean egg period was 5.65 days. The duration of different instars *viz.*, I, II, III, IV and V was 2.60, 3.85, 8.01, 10.33 and 4.15 days, respectively. The entire larval period occupied 28.97 days. The pupal period was 9.31 days and the adult survived for 3.56 days. The egg laying capacity of the female was 113.67. The total life cycle occupied about 47.49 days. Whereas,

during January-February 2005, the duration of all the stages was slightly less with the total life cycle of 42.47 days.

D.2.5.5 Mass production of *Micromus igorotus* under laboratory condition

D.2.5.5.1 At UAS, Dharwad

The mass multiplication of *Micromus igorotus* under laboratory condition was carried out throughout the year using the following method.



D.2.5.5.1.1 Production of *Micromus igorotus* during 2005-06

The month wise mass production of *Micromus igorotus* eggs under laboratory condition and their distribution are given in the table 60. The eggs were distributed to the needy farmers (@ 1000 eggs per acre) during the initial stage of aphid infestation in their respective fields (Table 84).

Table 84. Mass production of *M. igorotus* under laboratory conditions (2005-06)

Sl. No.	Month	Eggs Produced (No. in lakhs)	Eggs Distributed to Farmers (No.)
1	April-05	0.37	28,500
2	May-05	0.48	35,000
3	June-05	0.62	54,000
4	July-05	0.69	58,400
5	August-05	1.23	1,08,000
6	September-05	2.14	1,97,800
7	October-05	3.02	2,76,800
8	November- 05	2.52	2,39,000
9	December- 05	2.34	2,19,000
10	January 06	1.65	1,53,000
11	February 06	1.21	1,09,000
12	March 06	0.63	51,000
	Total	16,90,000	15,29,500

D.2.5.5.1.2 Survival of *M. igorotus*

Survival of *M. igorotus* during mass production was studied under laboratory condition during July 2005 and November 2005 (Table 85). Hundred eggs were taken in three replications and the survival rate of predator in different stages was observed. Recovery of eggs was as high as 92.6 and 93.6 per cent during July and November, respectively. The survival of grubs, pupae and adult stages were slightly on lower side (88.5 - 89.0, 84.6-85.0, and 76.0 - 77.1 per cent, respectively).

Table 85. Survivability of *M. igorotus* in mass production condition

Sl. No.	Stage	Survival Rate (%)	
		July 2005	Nov-2006
1	Egg	92.63	93.56
2	Grub	88.52	89.02
3	Pupa	84.67	85.03
4	Adult	76.00	77.12

D.2.5.5.1.3 Laboratory Production of *Micromus igorotus* during 2006-07

Production of *Micromus* eggs under laboratory condition and simultaneous distribution to the needy farmers has been done as per details in Table 86.

Table 86. Mass production of *M. igorotus* under laboratory conditions (2006-07)

Month	Eggs produced	Eggs distributed to Farmers
April	500	-
May	800	-
June	2300	1800
July	19000	17500
August	175000	168000
September	200000	198000
October	169000	165000
November	121000	111000
December	78000	75000
January	40000	35000
February	25000	23000
March	10000	8000
Total	840600	802300

A total of 8,40,600 eggs were produced from April 2006 to March 2007 and total number of eggs distributed to farmers was 8,02,300. The highest number of eggs produced was during September 2006.

D.2.5.5.1.4 Mass Production of *Micromus igorotus* under shade net condition

This experiment was conducted at ARS, Sankeshwar in 2005-2006. The planting of sugarcane variety Co 94012 was undertaken in V shaped ridges and furrows at a spacing of 90 cm between rows in RBD design with 7 replications. The planting was made at thrice at monthly interval to serve as separate treatment. The crop was raised by following the package of practices recommended by UAS, Dharwad except plant protection measures against insect pests. The shade net was erected on 21.05.2005 on different aged crops in different treatments.

Treatment details

T_1: 6-month-old crop; T_2: 7-month-old crop; T_3: 8-month-old crop; Size of the shade net: 5m X 5m, height 4.5 m; Grade of the shade net: 35 %

Artificial inoculation of woolly aphids was made twice in the cage to buildup heavy incidence. Care was taken to eliminate all the predators from the nets. After 25-30 days, when woolly aphid poulation covered the leaves to an extent of 50-60%, the grubs of *Micromus* were released with the help of brush @100 grown up grubs / plot on 20.7.2005 when the aphid infestation was at 4.73, 4.27and 4.37 grades in T_1, T_2 and T_3 respectively. Observation on SWA and predator population was made by following the standard protocol.

D.2.5.5.1.5 Harvest of the predator

Micromus pupae were harvested 33 days after the predator release (Table 27). As the pupation was observed on the under surface of leaves instead of lower dried leaves owing to heavy rains, the pupae were collected along with the leaf bits. The predators thus harvested were used for further field evaluation experiments. Unfortunately, after

the harvest of the pupae, due to continuous heavy rains, the crop was attacked by fungal disease, which could not be controlled even after using fungicidal sprays. Hence, the crop has been cut during October month.

Table 87. Mass production of *Micromus* under shade net (2005-06)

Treatment	SWA grade	SWA density 2.5 cm x 2.5 cm	*Micromus* population
20.7.2005			
T1- 6 months old	4.73	162.67 ± 30.57	100 grubs/plot released
T2-7 months old	4.56	141.03 ± 41.60	100 grubs/plot released
T3- 8 months old	4.32	136.32 ± 37.20	100 grubs/plot released
30.7.2005			
T1- 6 months old	3.94	96.93 ± 16.20	Pupal stage
T2-7 months old	3.71	83.05 ± 12.58	Pupal stage
T3- 8 months old	3.47	76.35 ± 18.50	Pupal stage
10.8.2005			
T1- 6 months old	2.92	45.69 ± 10.20	Adult stage
T2-7 months old	2.64	37.20 ± 6.26	Adult stage
T3- 8 months old	2.28	32.88 ± 9.56	Adult stage
20.8.2005			
T1- 6 months old	2.26	29.42 ±6.53	12.14 grubs/leaf
T2-7 months old	2.41	34.58±9.20	12.54 grubs/leaf
T3- 8 months old	1.94	25.46 ± 8.12	10.88 grubs/leaf
Harvest of pupae from shadenet on 22/24.08.2005			
T1- 6 months old	1.80	17.60 ± 4.30	804.26
T2-7 months old	1.96	20.59 ± 5.42	831.94
T3- 8 months old	1.45	15.29 ± 7.30	723.73

Highest number of pupae was harvested from the seven month old cane. The total number of pupae harvested from 21 plots comprising of 3 treatments replicated 7 times was as high as 16582. Based on these preliminary results, the mass production of *Micromus* under shadenet condition has been once again initiated on 7 months old crop at farmers field in Sankeshwar during April 2006.

D.2.5.5.1.6 Shade net production of *Micromus igorotus* during 2006-07

The experiment was laid out at ARS, Sankeshwar using sugarcane variety Co 86032 in 2006 – 2007. Treatment details were T1- Release of *Micromus* grubs @ 100 grubs/ shade net; T2- No release (Control); Size of the shade net: 5m X 5m, height 5 m; Grade of the shade net: 35 %.

The shade net was installed on 7 months old crop and the artificial release of aphids was made in the cage twice to achieve heavy build up of woolly aphid population. When woolly aphid population covered the leaves to an extent of 50-60 per cent, the release of *Micromus* grubs was made with the help of brush @100 grown up grubs / shade net.

Observations taken were SWA and predator population were recorded once in 7 days on 10 randomly selected canes by observing 2 leaves per cane. The aphid count was made by using 2.5X2.5 cm window at 3 locations on each leaf. While the predators were counted on whole leaf basis.

D.2.5.5.1.6.1 Harvest of the predator:

Micromus grubs were harvested after 35-40 days of predator release (Tables 88-89). The predators were collected along with the leaf bits containing aphids. The predators thus harvested were used for the field evaluation experiments.

Table 88. First harvest of shade net produced *M. igorotus* in 2006–07

Treatment	SWA grade	SWA density (No/ 2.5 cm^2)	Status of *Micromus* population
T1-*Micromus* released	3.92	113.26	100 grubs/plot released
T2- No release	4.36	128.20	No release
T1- *Micromus* released	3.62	83.86	Pupal stage
T2- No release	4.27	129.26	-
T1- *Micromus* released	3.28	86.72	Adults emerged
T2- No release	4.30	137.37	-
T1- *Micromus* released	2.96	42.20	Grubs observed
T2- No release	4.00	117.23	
T1- *Micromus* released	2.17	34.60	Grubs activity
T2- No release	4.93	129.00	-

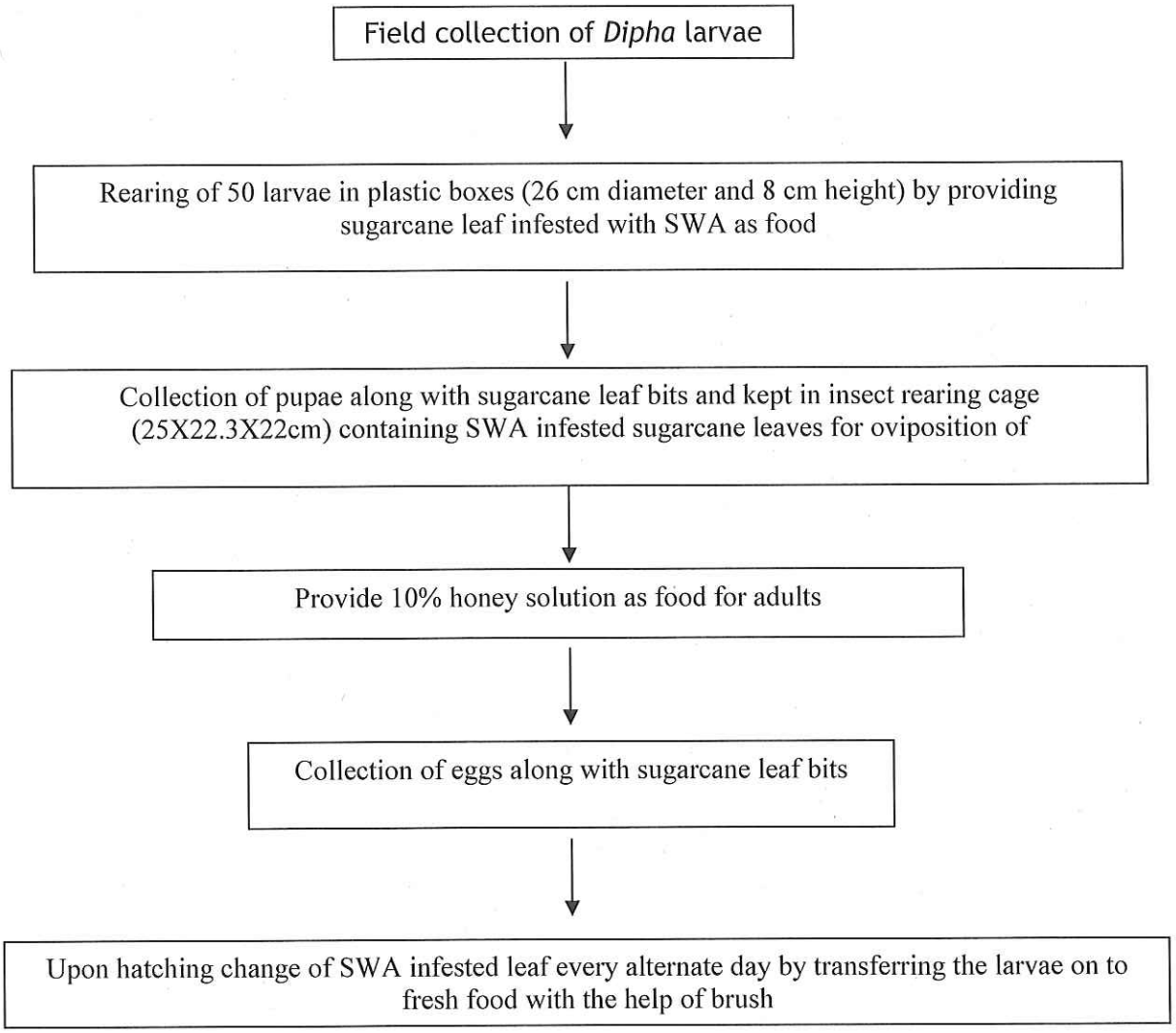
Table 89. Second harvest of shade net produced *M. igorotus* in 2006-07

Treatment	SWA grade	SWA density (No/ 2.5 cm^2)	Status of *Micromus* population
T1-*Micromus* released	3.93	110.06	-
T2- No release	4.36	131.27	No release
T1- *Micromus* released	3.62	73.16	Pupal stage
T2- No release	4.27	110.46	-
T1- *Micromus* released	3.28	69.73	Adults emerged
T2- No release	4.30	109.73	-
T1- *Micromus* released	2.96	53.27	Grubs observed
T2- No release	4.00	99.23	
T1- *Micromus* released	1.80	29.17	Grubs activity
T2- No release	4.86	86.43	-

Within 45 days after release of *Micromus*, as high as 1326 grubs/plot were harvested and the total number of grubs harvested from 14 plots was 18564. The second harvest was made 45 days after first harvest. As high as 745 grubs/ plot were harvested and total number of grubs harvested from 14 plots was 10430.Thus, a total of 28994 of grubs can be harvested with in three months from an area of 350 sq mt.

D.2.5.6 Mass production of *Dipha aphidivora*

The mass multiplication of *Dipha aphidivora* under laboratory condition was carried out throughout the year during 2006-07 using the following method.



The *Dipha* larvae were mass produced under laboratory condition by following the steps as shown in the following chart. The number of larve produced in different months is furnished in Fig. 8. The larvae produced were distributed among the needy farmers.

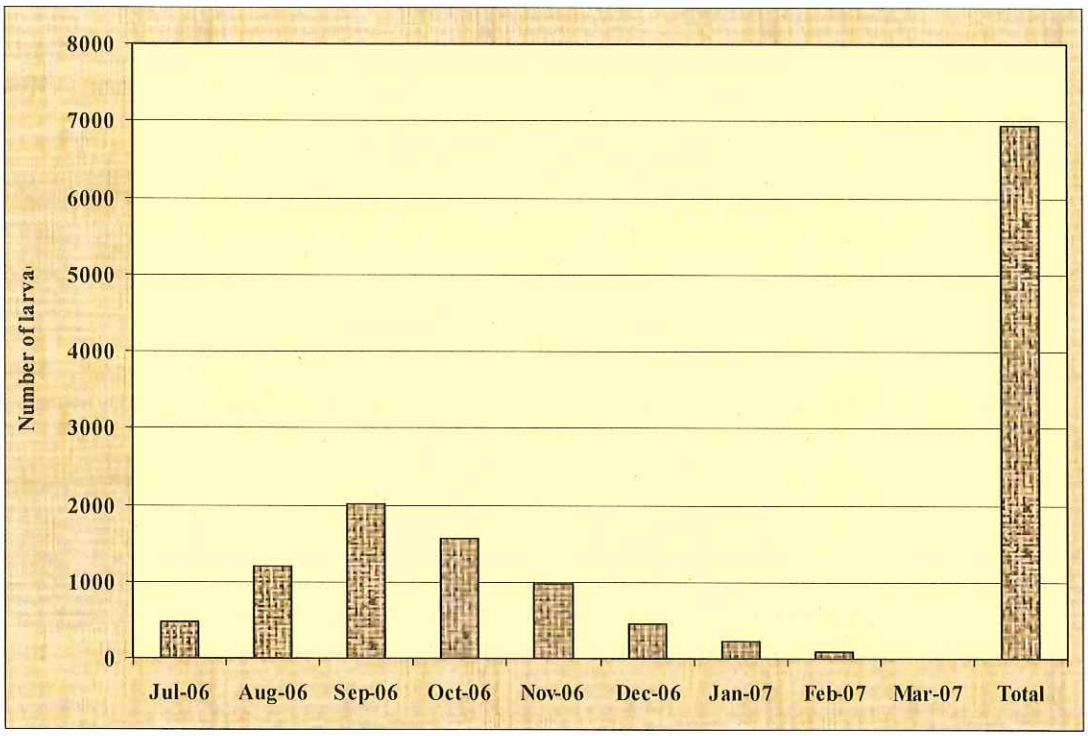


Fig. 8. Mass production of *Dipha aphidivora* in the laboratory

D.2.5.7 Evaluation of suitable stage of *Micromus* for release

The experiment was carried out at MARS, Dharwad under caged condition.Four field cages (6.25x5 m) were installed on seven month old crop (Co 86032) in the month of August. When woolly aphid population covered the leaves to an extent of 50-70 per cent, a total of 100 numbers of either eggs (2 days old), grubs (first instars), pupae or adults (2 days old) were released at four spots in each cage. Before release, all the natural enemies were removed from cages. The observations on pest grade, number of aphids per 2.5 sq.cm and number of *Micromus* grubs per leaf were recorded on weekly interval basis upto 55 days after release by selecting 2 leaves from each 20 canes selected randomly in each cage (Fig. 9 and 10).

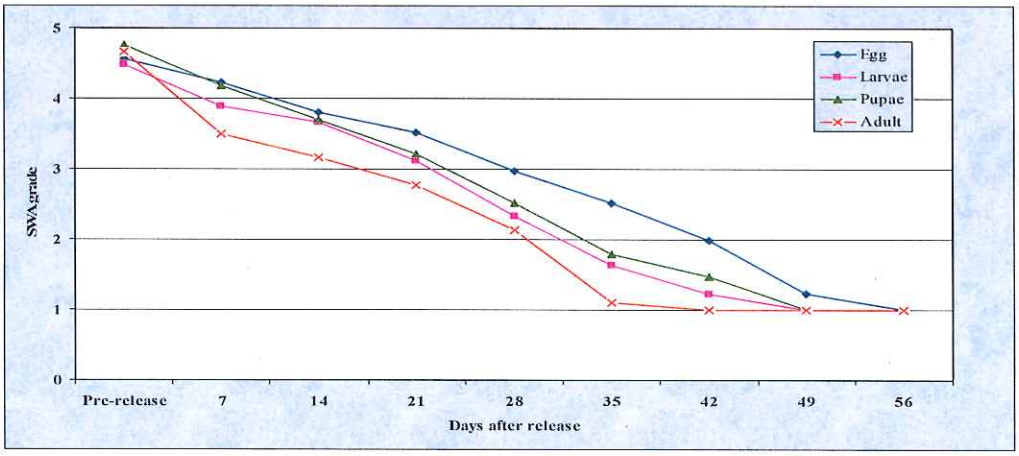


Fig. 9. Impact of release of different stages of *Micromus igorotus* on SWA grade

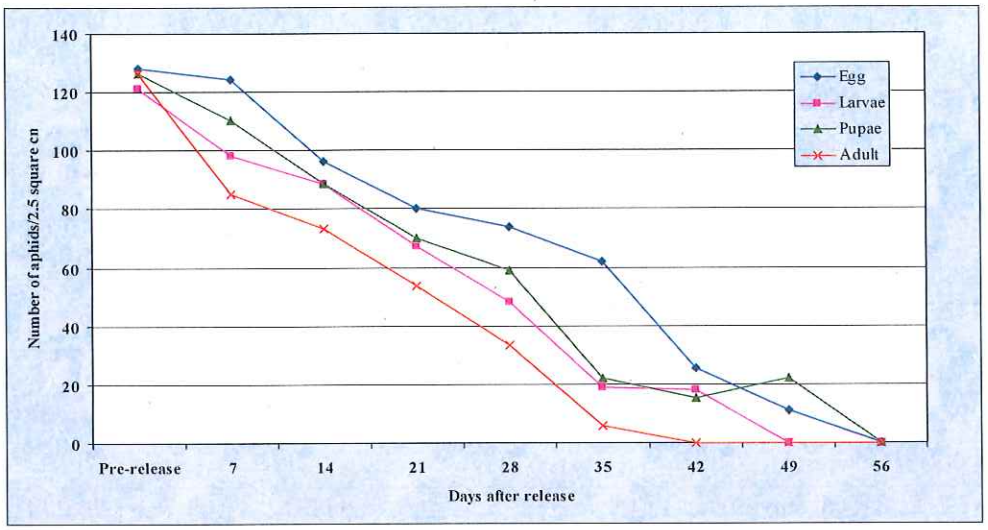


Fig. 10. Impact of release of different stages of *Micromus igorotus* on number of aphids per 6.25 square cm.

It is evident from the figures that the release of adults showed highest reduction in the pest population followed by release of grubs and pupae. The least reduction in the population was noticed in the eggs released cage.

D.2.5.7.1 Evaluation of different containers for transportation of *Micromus* grubs

The study was conducted using four methods of transporting *Micromus* grubs as mentioned below.

1. Cardboard box of size 13 x 14 x 16 cm
2. Plastic jar of size 9 cm diameter and 19 cm height
3. Plastic box of size 21.5cm diameter and 7 cm height
4. Polythene bag of size 31x 25 cm

Table 90. Development of suitable methods for transportation of *Micromus* grubs (2006-07)

Container	Per cent survival after 350 Km.	Per cent survival after 550 Km.	Rate per unit (Rs.)
Cardboard box (13x14x16cm)	100.0	96.0	4.00
Plastic jar (9cm dx 19cm h)	85.0	80.0	20.00
Plastic box (21.5 d x 7 cm h)	87.0	82.0	35.00
Polythene bag (31 x 25 cm)	56.4	42.0	1.00

The results indicated that cardboard boxes were the best containers for the transport of *Micromus* larvae (Table 90).

Table 91. Cost of production of *Micromus* under laboratory condition

Sl. No	Particulars	Number	Rate in Rs.	Amount in Rs.
Non-recurring items				
1	Room (Rent/year)	1	50,000	50,000
2	Collection cost		50,000	50,000
3	Test tubes	500	10	5000
Total				1,05,000
Recurring Costs				
1	Technical supervisor	1	8000	96,000
2	Contract Labourers*	52	2000	1,04,000
3	Consumables		20,000	20,000
Total				3,20,000

* From January to May: 2 labourers/month (2X5=10) and From June to December: 6 labourers/month (6X7=42); Total labourers per year 10+42=52

Depreciation of fixed assets was calculated at the rate of 17% interest on the capital and depreciating 20% of the capital each year
(17850 + 14280 + 1942.08 + 246.12 + 33.47 = 34351.67)
For five years 34351.67/5 = 6870.33
Labour for seven months = 52 x 2000 = 1,04,000
Supervision = 12 x 8000 = 96, 000
Consumables = 20,000
Total operational cost = 1,05,000 + 6870.33 + 1,04,000 + 96,000 + 20,000 = 3,31,870
Cost of producing one *Micromus* larva = 3,31,870/25,00,000 = 13 paise

D.2.5.8 Field evaluation and demonstration

D.2.5.8.1 PDBC, Bangalore

A total of 350 larvae of *D. aphidivora* were released on six months old crop on four clumps of sugarcane (var. Co 86032) (Fig. 11). The mean initial population of SWA was 93 aphids/6.25 cm^2 of leaf. Five weeks after release the mean aphid population on released clumps was 7.6 aphids/6.25 cm^2 of leaf, whereas in control plots the aphid population was 43.4 aphids/2.5 cm^2 of leaf. Even though there was considerable reduction in aphid population on canes after the release of *Dipha* , there were no significant differences in cane yield, cane height, internode length, brix, pol, and recovery per cent .

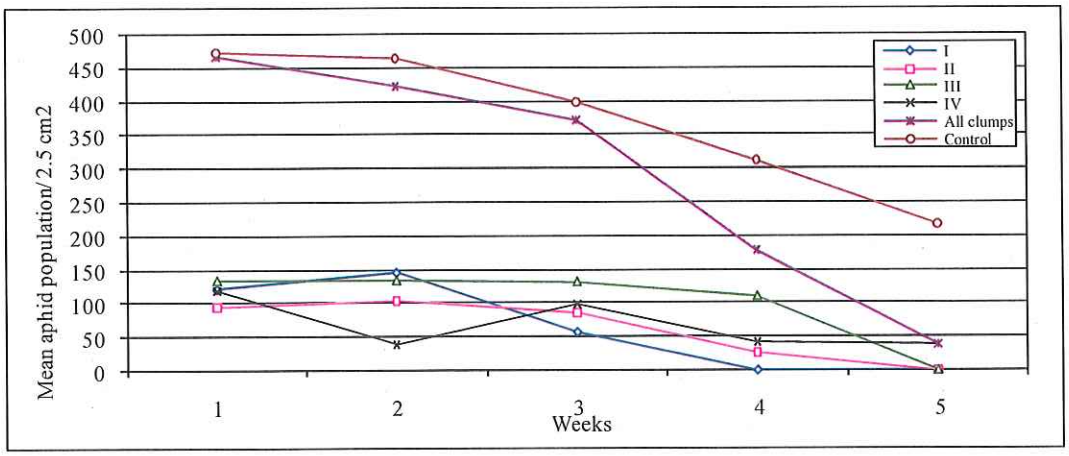


Fig. 11. Impact of release of *Dipha aphidivora* on SWA populations in K.M.Doddi, Karnataka

D.2.5.8.2 UAS, Dharwar

The field release of natural enemies *viz. Micromus igorotus* (@ 2500 larvae/hectare) and *Dipha aphidivora* (@1000 larvae/hectare) was undertaken at three locations in 2004-2005. The sugarcane field with 7-8 month old crop (one acre each) and infested with SWA was selected at each location for release of the natural enemies. The adjacent field which received insecticidal application served as a check. Details of the experiment are given below (Tables 92).

Table 92. Field release and evaluation of SWA at different locations

Location	Name of the farmer	Village	Date of release of predators	
			Micromus igorotus	*Dipha aphidivora*
1	Venkanna Ganachari	Ugarakod	13.09.2004 & 23.09.2004	23.10.2004 & 3.11.2004
2	Tippanna Sheelavanthar	Narendra	14.10.2004 & 24.10.2004	24.11.2004 & 04.12.2004

Chemical treated plot received two sprays of chlorpyriphos @ 2ml/l during experimental period. Observations were made on pre release count- one day before release of predators and post release count -10 days after the last release of predators.

Table 93. Field evaluation of natural enemies of SWA

Village	Predator plot					Chemical plot				
	SWA grade		NE's			SWA grade		NE's		
	Pre release	Post release	Post release (No/leaf)			Pre release	Post release	Post release (No/leaf)		
			M i	*D a*	Syrphids			*M I*	*D a*	Syrphids
Ugarkode (Mean)	4.02	1.26	5.57	1.76	0.78	4.15	3.96	1.87	0.70	0.48
Narendra (Mean)	3.89	1.91	4.90	2.28	0.21	3.84	3.94	2.04	1.03	0.30

The data from both the locations (Ugarcode and Narendra, Table 33) indicated significant reduction in aphid population in predator released plot as compared to

insecticide treated plot. On the contrary, significantly higher population of both Micromus and Dipha predators was observed in predator released treatment over chemical treatment. However, there was statistical variation in the population of syrphids. From the field trials it is clear that the predators play a very important role in checking the pest buildup over a period of time.

D.2.5.8.2.1 2005-06

The field release of natural enemies, *viz.*, *Micromus igorotus* (@ 2500 larvae / ha) and *Dipha aphidivora* (1000 larvae / ha) was undertaken at four locations. The sugarcane field with 7-8 month old crop (one acre each) and well infested with SWA was selected at each location for release of the natural enemies. The adjacent field which received insecticidal application served as a check. Details of the experiment are given below (Table 94).

Table 94. Field release and evaluation predators of SWA at different locations

Name of the farmer	Village	Date of release of predators	
		Micromus igorotus	*Dipha aphidivora*
G.S.Nerli	Gurlapur	13.3.2005 and 23.3.2005	14.04.2005 and 24.04.2005
Ashok Meti	Kalaginakoppa	05.08.2005 and 15.08.2005	05.09.2005 and 15.09.2005
Chandrashekhar Shettennavar	Gandhigawad	10.08.2005 and 20.08.2005	10.09.2005 and 20.09.2005
Ashok Hurali	Marewad	15.08.2005 and 25.08.2005	15.09.2005 and 25.09.2005
N. S. Galagali	Ghatnatti	9.11.05 and 19.11.2005	9.12.2005 and 19.12.2005
Veerbasayya Pujari	Belavadi	25.11.2005 and 05.12.2005	25.12.2005 and 05.01.2006

Table 95. Field efficacy of natural enemies against SWA (2005-06)

Village	Predator released plot					Chemical treated plot				
	SWA grade		NE's			SWA grade		NE's		
	Pre release	Post release	Post release count (No/leaf)			Pre release	Post release	Post release count (No/leaf)		
			M i	D a	Syr			M i	D a	Syr
Gurlapur	1.85	1.11	2.84	1.58	0.00	1.80	1.83	0.72	0.38	0.00
T values between two plots						-	2.75	2.33	NS	-
Kalaginakoppa	2.47	1.38	1.59	0.73	0.27	2.10	1.98	0.70	0.39	0.18
T values between two plots						-	3.02*	7.66**	2.43	NS
Gandigawad	2.68	1.59	1.76	0.81	0.22	2.51	2.27	0.68	0.19	0.15
T values between two plots						-	4.10*	2.86	2.31	NS
Marewad	2.55	1.38	1.58	0.89	0.00	2.56	2.52	0.82	0.30	0.00
T values between two plots						-	2.29	3.12	5.8	-
Gatnatti	2.20	1.14	2.75	1.68	0.09	2.33	1.87	0.62	0.22	0.00
T values between two plots						-	2.87	7.41**	6.10**	2.66
Belavadi	2.27	1.32	1.90	0.71	0.50	2.13	1.90	0.26	0.24	0.04
T values between two plots						-	4.03*	8.25**	4.24*	3.02

Table 96. Field efficacy and evaluation of natural enemies (2006-07)

Village	Predator released plot						Chemical treated plot					
	SWA grade		NE's			Cane yield (t/ac)	SWA grade		NE's			Cane yield (t/ac)
	Prerelease	Post release	Post release (No./leaf)				Pre release	Post release	Post release (No./leaf)			
	No/6.25 cm^2		*M i*	*D a*	Syrphids		No/6.25 cm^2		*M i*	*D a*	Syrphids	
Gurlapur	30.25	16.17	2.67	1.68	0.00	59.65	27.03	26.94	0.76	0.45	0.00	53.93
T values between two plots							-	2.53	2.60	NS	-	3.60
Narendra	26.05	16.18	2.75	1.73	0.94	59.13	25.45	24.91	0.22	0.21	0.00	55.50
T values between two plots							-	3.02	2.52	NS	-	3.45
Hiremalligawad	30.58	16.46	1.79	0.81	0.22	55.77	28.55	28.28	0.68	0.19	0.15	52.00
T values between two plots							-	3.20	2.80	NS	-	3.40

The data from different locations (I- VI) indicated significant reduction in aphid population in predator-released plot as compared to insecticide treated plot (Tables 95-96). On the contrary, significantly higher population of predators viz. *Micromus, Dipha* and Syrphids predators was observed in predator released treatment over chemical treatment. From the field release trials it was clear that the predators play a very important role in checking the pest buildup over a period of time as compared to chemical insecticides.

D.2.5.8.2.2 2006-07

The field release of natural enemies *viz. Micromus igorotus* (2500 larvae / ha) and *Dipha aphidivora* (1000 larvae / ha) was undertaken at three locations. The sugarcane field with 8-10 month old crop (one each) and well infested with SWA was selected at each location for release of the natural enemies. The adjacent field which received insecticidal application served as a check. Details of the experiment are given in table 97.

Table 97. Field release and evaluation of SWA at different locations

Name of the farmer	Village	Variety	Crop Stage (months)	Total Area (Acres)	Date of release of predators	
					Micromus igorotus	*Dipha aphidivora*
Ashok Hurali	Marewad	Co-86032	8	6	23.8.2006	3.9.2006
Channamalla Morab	Narendra	Co- 671	9	2	5.9.2006	15.9.2006
Basavaraj Sutagatti	Hire malliagawad	Co- 86032	9	3	14.09.2006	24.09.2006

The data from different locations indicated significant reduction in aphid population and increase in yield in predator released plot as compared to insecticide treated plot. Similar trend in the aphid population and yield was observed in all the three locations *viz.*, Marewad, Narendra and Hiremalligawad.

D.2.5.9 Field Demonstration

Field demonstration on the efficacy of SWA natural enemies *viz. Micromus igorotus* and *Dipha aphidivora* was undertaken in different sugarcane growing areas by selecting heavily infested fields during 2005-06. The farmer's participation was quite encouraging. The details of the demonstrations conducted at various places are furnished in table 98.

Table 98. Field demonstration of predator release in sugarcane eco system (2005-06)

Village	No. of Demonstrations	Area (Ac) covered	No. of Farmers Participated	Per cent Reduction in pest load over control
Gandigawad	5	8	54	86.55
Marewad	3	6	32	88 .75
Narendra	4	5	25	81.56
Sankeshwar	6	12	38	91.23
Ambolli	3	4	21	82.25
Sameerwadi	2	6	45	86.35
Kesarkoppa	7	9	48	78.63
Mangalagatti	4	7	42	83.52
Hukkeri	3	6	36	86.32
Godur	4	11	41	87.35
Mudhol	5	6	24	83.66
Mahalingpur	5	4	56	83.52

The demonstrations on the method of release of natural enemies and subsequent impact on the aphid population were made at two fields in each village. To compare the effectiveness of the predator release, half of the field was treated with chemical insecticides.

The results clearly indicated that there was effective control of aphids in predator released plots over a long period of time as compared to chemical treated fields which results comparatively higher cane yield in predator released fields. The farmers who participated in each demonstration were well convinced and appreciated the role of predators in the management of SWA.

D.2.5.10 Genetic characterization of different populations of SWA and its natural enemies

D.2.5.10.1 PDBC, Bangalore

The spread of the SWA to different regions of our country has thrown up the challenge of determining the location from where the aphid might have spread to other regions. The main objective of this work is to find out whether these woolly aphids have migrated to the southern parts of the country from West Bengal and to determine if there has been a gradual divergence within the species.

The SWA populations and its natural enemies *Dipha, Micromus and Encarsia* were collected from PDBC, Bangalore, Assam, Coimbatore, Pune, Dharwad. In order to determine the intraspecific variation of geographically distributed populations of *Ceratovacuna lanigera* Zehnter and its natural enemies and and internal transcribed

spacer 2 DNA characterization and Random Amplified Polymorphic DNA Polymerase Chain Reaction (RAPD-PCR) techniques were carried out.

The ITS region between 18s and 28s rRNA usually has higher degree of polymorphism than the coding region (Hoy, 1994). The ITS region has been used intensively to infer phylogenetic relationships. Random Amplified Polymorphic DNA Polymerase Chain Reaction (RAPD-PCR) technique was used to detect DNA polymorphisms among different populations of SWA.

Collection of samples: The aphids were collected from sugarcane plants at PDBC, Bangalore. During the general survey, SWA and its natural enemies were collected on sugarcane plants from Coimbatore, Pune, Dharwad and Assam. Insects were washed in sterile water and the wax layer was removed from the body. The adults were freezed in liquid nitrogen and stored in deep freezer till further extraction of DNA.

Isolation of DNA from SWA populations and their natural enemies

Two methods that are widely used to isolate DNA from insects were followed. The DNA extraction was carried out with samples weighing 1 to 5mg.

Protocol I: Lysis method

1. Individual insects frozen at –70°C were transferred to a 1.5ml microfuge tube with 20µl lysis buffer (200mM Tris – HCl, pH8.0; 70mM EDTA; 2M sodium chloride; 20mM sodium metabisulphite).
2. A plastic micro pestle was used to crush the insects for a few minutes till a clear homogenate was observed. Volume of the homogenate was made up to100µl with lysis buffer.
3. 35µl of 5% sodium lauryl sarcosine was added, mixed well by inverting and then incubated at 55°C for 2hr.
4. The tubes were centrifuged at15000rpm for 15min and to the supernatant 1\10th volume 10mM Ammonium acetate and equal volume of isopropanol were added.
5. The tubes were left at –20° C. The DNA was pelleted by centrifugation at 20000 rpm for 20min at 4 °C.
6. The DNA was given 70% ethanol wash. Tubes were allowed to dry at room temperature for 1hr. DNA was dissolved in 30 µl TE buffer.
7. The DNA samples were analyzed by electrophoresis in 0.8%agarose gel.

Protocol II: Chelex Method

1. 20µl of 5% chelex (5% weight to volume chelating resin in ultra pure water) to 0.01mg of sample placed in a 1.5ml microfuge tube and was crushed using micropestle.
2. After homogenization, the samples were incubated at 55°C for 3hrs followed by 100°C for 5minutes
3. The tubes were vortexed and centrifuged at maximum speed for 2 minutes.
4. The chelex supernatant containing DNA was used for PCR or stored at –20°C

Protocol III: CTAB method of DNA extraction :

1. The sample collected in a 2ml vial, was placed in a mortar with 20-30ml of liquid nitrogen and immediately the sample was ground to a fine powder.
2. 500µl of CTAB lysis buffer preheated to 65°C was added to the vial and homogenized with the pestle.
3. Immediately 5µl of 2-mercaptoethanol was added and incubated at 65°C for 30min in a water bath by inverting the tube every 10 min to ensure adequate mixing.
4. After incubation, 500µl of Chloroform: Isoamylalcohol was added and incubated on a shaking platform for 20 min at 60rpm.
5. Then centrifugation was carried out at 10,000 rpm for 20min at 4°C.
6. The aqueous top phase was removed carefully without disturbing the interface
7. Again 500µl of Chloroform: Isoamylalcohol was added, the tubes were shaken gently and centrifugation was repeated.
8. To the aqueous phase, 6µl of Isopropanol was added and kept at –20°C for overnight incubation.
9. The tubes were then centrifuged at 10,000 rpm for 20 min and the pellet was collected.
10. The pellet was washed with 1.5ml of 70% ethanol by centrifuging for 5 mins.
11. The pellets were then left for 30mins to 1hr. on a bench for drying.
12. The dried pellets were resuspended in 12.5µl of TE buffer and stored at -20°C.

DNA Quantification

DNA concentration in the sample was estimated by recording absorbance at 260nm in an UV/Vis spectrometer.

Protocol

1) Take 5 µl of DNA sample in a quartz cuvette. Make up the volume to 1ml with distilled water
2) Measure the absorbance at 260nm and 280nm
3) Calculate the ratios A_{260}/A_{280}
4) A good DNA preparation exhibits the following spectral properties
5) A_{260}/A_{280} >2 OD units
6) A_{260}/A_{280} < 0.55 OD units
7) Calculate the DNA concentration using the relationship for double stranded

DNA 1OD at A_{260} = 50 µg/ml

T

otal quantity of DNA (µg/µl) = $\frac{\text{OD at 260nm x 50 x Dilution Factor}}{1000}$

Dilution Factor = $\frac{\text{volume made}}{\text{volume of the aliquot}}$

Polymerase Chain Reaction amplification of ITS-2 region

With the PCR it is possible to specifically address a particular DNA sequence and to amplify this sequence to extremely high copy numbers. PCR is a technique that

enables multiple copies of DNA to be generated by enzymatic amplification of target DNA sequence.

Table 99. Components of ITS-2 PCR reaction

Component	Volume	Concentration
10X Reaction Buffer, MgCl2-Free	5µl	1.0X
MgCl2, 25mM Solution	3µl	1.5mM
PCR Nucleotide Mix, 10mM each	1µl	200µM each
Upstream Control Primer	5–50pmol	0.1–1.0µM
Downstream Control Primer	5–50pmol	0.1–1.0µM
TaqDNA Polymerase, 5u/µl	0.25µl	1.25u/50µl
Template DNA	variable	<0.5µg/50µl
Nuclease-Free Water to a final volume of	50µl	
ITS-2 Primer sequence (Forward)	5'-TGTGAACTGCAGGACACATG- 3'	
ITS-2 Primer sequence (Reverse)	5'-GTCTTGCCTGCTCTGAG-3'	

PCR cycling reactions

The thermal cycling condition for PCR consisted of 30cycles (Den: 94°C for 1min, Ann: 55°C for 1min, Ext: 72°C for 2min, with an initial Den: 95°C for 5 min and final extension at 72°Cfor 10 minutes).

Sequencing

ITS-2 PCR product of SWA and *Encarsia* was gel eluted using Qiagen Gel Extraction kit (cat. no 28604). Sequencing was done in an ABI Prism Auto Med Sequencing Analyzer. To check the accuracy of the sequencer, sequencing of the PCR product was done twice with both forward and reverse primers.

Results

The 260/280-adsorption ratio of DNA was 1.9-2.0 suggesting that the isolated DNA was fairly pure with minimum protein impurities. Electrophoresis of the isolated DNA revealed that the DNA was intact.

The ITS-2 region of rDNA of SWA consisted of 448bp with 37.05% GC content (Fig. 12). ITS-2 sequence has been deposited in GeneBank, Accession no DQ825651.

The nucleotide sequence of ITS- region of rDNA of SWA is being reported for the first time (Table 100). A 370 bp DNA of ITS-2 region of rDNA of *Encarsia* was amplified in PCR (Table 101).

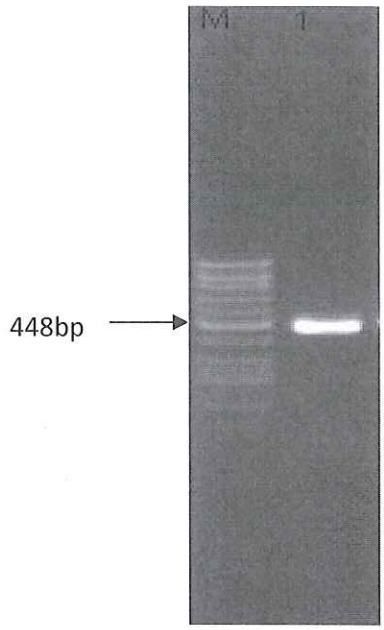


Fig. 12. PCR amplified ITS-2 region of SWA, Bangalore (Lane M 50 bp DNA ladder, Lane 1 - ITS-2 region of SWA, Bangalore)

Table 100. ITS-2 sequence of *Ceratovacuna lanigera* Zehntner (PDBC Strain)

CATTTCAAGCACATTGTTGCCCACGGAGATGTCTCCCGGACCACGCCTGGCTGAG
GGTCGTTCAACAAACAAAATCAGACTGCTCGTATTTTATGCGAGCGAATTTACTG
AGCGTTCGCTTTGGTTAATGCTCTTCTCTGAGCATTGCCTCTCGTCGCTTTAAATG
ATAGAAACAATTTTTATTTTTTTTATTTCAAATTTTTGAAAGATAAAAATAAATAT
CAAGGGTCTGCTATCGAAAGTTTTTGAGAATTAAAAAGAAAAATTCCAAAGCTCT
TTGATCGTCAGTCGAGTCCCGGAGCCTATTTGCACGCCGATCGAAGATCACAGTG
CACCGGGCGGACCGATCGTACGAAAATGAGAGTTTTTTTTTTTTTTTCTCTCAGC
ATGATCAATTTTGAAAGTATTAATATTTATTTAAATGCGAAATAGAAAAGAATAA
AATTA

(Assam SWA)

CTAGCTTCGACGCCATTGCGGTCCCGGTATCGTCTCCCGGAcCACGCCTGGCTGAG
GGTCGTTCAACAAACAAAATCAGACTGCTCGTATTTTATGCGAGCGAATTTACTG
AGCGTTCGCTTTGGTTAATGCTCTTCTCTGAGCATTGCCTCTCGTCGCTTTAAATG
ATAGAAACAATTTTTATTTTTTTTATTTCAAATTTTTGAAAGATAAAAATAAATAT
CAAGGGTCTGCTATCGAAAGTTTTTGAGAATTAAAAAGAAAAATTCCAAAGCTCT
TTGATCGTCAGTCGAGTCCCGGAGCCTATTTGCACGCCGATCGAAGATCACAGTG
CACCGGGCGGACCGATCGTACGAAAATGAGAGTTTTTTTTTTTTTTTCCCCCC

(Coimbatore SWA)

CGTTGCGGTCCCGCGCCTGGTCTCCCGGCCCACGCCTGGCTGAGGGtCGTTCAACA
TGGCAAATCAGACTGCTCGTATTTTATGCGAGCGAATTTACTGAGCGtTCGCTTTG
GTTAATGCTCTTCTCTGAGCATTGCCTCTCGTCGCTTTAAATGATAGAAACAATTT
TTATTTTTTTTATTTCAAATTTTTGAAAGATAAAAATAAATATCAAGGGTCTGCTA
TCGAAAGTTTTTGAGAATTAAAAAGAAAAATTCCAAAGCTCTTTGATCGTCAGTC
GAGTCCCGGAGCCTATTTGCACGCCGATCGAAGATCACAGTGCACCGGGCGGAC
CGATCGTACGAAAATGAGAGTTTTTTTTTTTTTTCCC

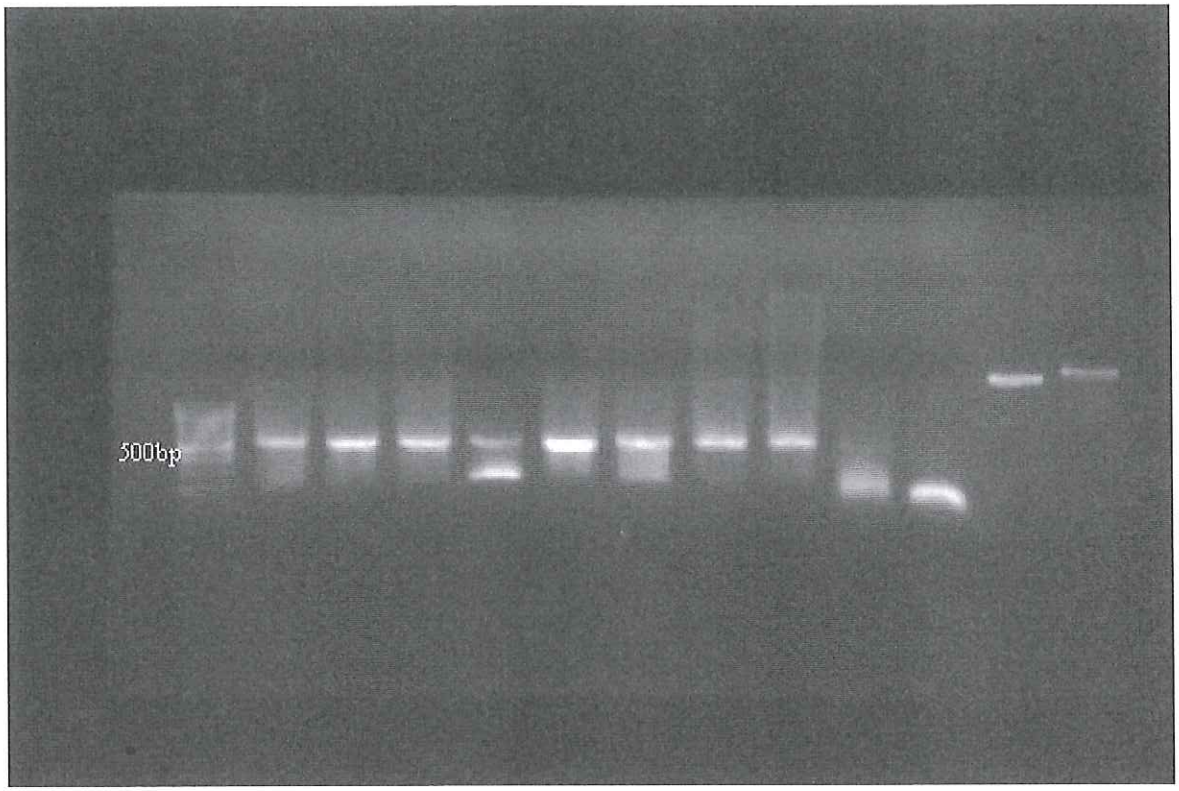


Fig. 13. ITS-2 PCR of different populations of SWA (Lane 1: 1kb ladder, Lane 2: SWA Coimbatore, Lane 3: SWA Pune, Lane 4: SWA Assam, Lane 6: SWA PDBC, Lane 7: SWA Dharwad, Lane 8: SWA Mandya)

Table 101. ITS-2 sequence of *Encarsia*

Encarsia (Coimbatore)

GTTGTGCGtgCAAACTTTGGTCTGCGGACAAAAAGCCTGGTTTCTCCTCGTTCAAC
ATAAAAAATCAGACTGCTCGTATTTTATGCGAGCGAATTTATTGagCgtTCGCTTTG
GTtAATGCTCTTCTCTGAGCATTGCCTCTCGTCGCTTTAAATGATAGAAACAATTTT
TATTTTTTTTATTTCAAATTTTTGAAAGATAAAAATAAATATCAAGGGTCTGCTAT
CGAAAGTTTTTGAGAATTAAAAAGAATAATTCCGAAGCTCTTTGATCGTCTGTCG
AGTCCCGGAGCCTATTTGCTAGTCGATCGGCCATCTCGGTGCCCCGGGCGGACCG
NTCGTA

Encarsia (Assam)

TGTCTCCCGGCCCACGCCTGGCTGATGGTCGTTCAACAAACAAAATCAGACTGCT
CGTATTTTATGCGAGCGAATTTACTGAGCGTTCGCTTTGGTTAATGCTCTTCTCTG
AGCATTGCCTCTCGTCGCTTTAAATGATAGAAACAATTTTTATTTTTTTTATTTCA
AATTTTTGAAAGATAAAAATAAATATCaAGGGTCTGCTATCGAAAGTTTTTGAGA
ATTAAAAAGAAAAATTCCAAAGCTCTTTGATCGTCAGTCGAGTCCCGGAGCCTAT
TTGCACGCCGATCGAAGATCACAGTGCACCGGGCGGACCGATCGTACGAAAATG
AGAGTTTTTTTTTTTTTTTNCCCCCNGCGGGANCA

D.2.5.10.2 UAS, Dharwad

The studies on genetic diversity of SWA and its natural enemies was made through molecular characterization under laboratory condition. The samples of SWA and its natural enemies (*Dipha* and *Micromus*) were collected from different locations across the country.

The larval samples were freezed in liquid nitrogen and ground using mortar and pestle and the fine powder was transferred to a sterile 1.5ml eppendrof tube containing 750 ml of lysis buffer [1% Cetyl Trimethyl Ammonium Bromide (CTAB), 5% polyvinyl pyrrolidone (PVP), 1.4 M Nacl, 20 MM 2-mercaptoethanol] and mixed gently. An equal volume (750 ml) of phenol: chloroform: isoamyl alcohol,(25:24:1) were added and mixed well by inversion. It was then centrifuged at 8000 rpm for 10 min at 4^0C. The aqueous layer containing the DNA was collected and placed in a new 1.5 ml centrifuge tube. Two volumes of cold isopropanol was added and mixed well by inversion to pricipitate DNA. The sample was centrifuged at 8000 rpm for 5 minutes and the supernatant was removed. The pellet was rinsed with 500 ml of 70% ethanol and dried. The pellet was resuspended in appropriate quantity of $T_{10}E_1$ buffer [10mm Tris Hcl (p^H 8.0) + 1mm E DTA] and store at -20^0C. Amplification of DNA was done through PCR by using A1 to A10 primers and analyzed through NTSYS software.

Genetic diversity in SWA populations

The dendrogram constructed via clustering analysis indicated that the SWA population has been grouped into two major clusters A and B. Cluster A comprised of Dharwad, Sameerwadi and Assam whereas, cluster B comprised of Pune and Bangalore. Both cluster A and B separated at the similarity co-efficient of 0.28. The second major cluster constituted two populations *viz.*, Pune and Bangalore which separated from first major cluster at the highest genetic similarity index of around 0.6. Whereas, minimum genetic similarity of 0.20 was observed between Pune and Sameerwadi and, Pune and Dharwad populations followed by 0.22 between Pune and Assam populations.

Genetic diversity in *Micromus igorotus* populations

The dendrogram of *Micromus igorotus* resulted into two major clusters. The first cluster included Pune and Bangalore and second cluster was Bangalore and, Pune strains with a similarity index of 0.8 followed by Dharwad and Bangalore and Bangalore and Sameerwadi with a similarity index of 0.6. The minimum genetic similarity of 0.5 was recorded between Dharwad & Pune and Sameerwadi & Pune.

Genetic diversity in *Dipha aphidivora* populations

The studies on genetic diversity of *Dipha aphidivora* indicated that there existed variation in the DNA profiling of different samples. The dendrogram constructed using symmetric matrix resulted into two major clusters. The first cluster consisted of Dharwad, Sameerwadi and Bangalore populations whereas, the second cluster consisted of Pune and Assam populations. The highest genetic similarity index of 0.8 was observed among Assam and Pune strains.

The variation in the genome level may be due to the difference in the sequence of nucleotides. All these strains were from different cropping patterns with diverse weather conditions interms temperature, relative humidity and rainfall. Perhaps these factors might have strong bearing on their evolution and hence might be sharing more nucleotide similarity.

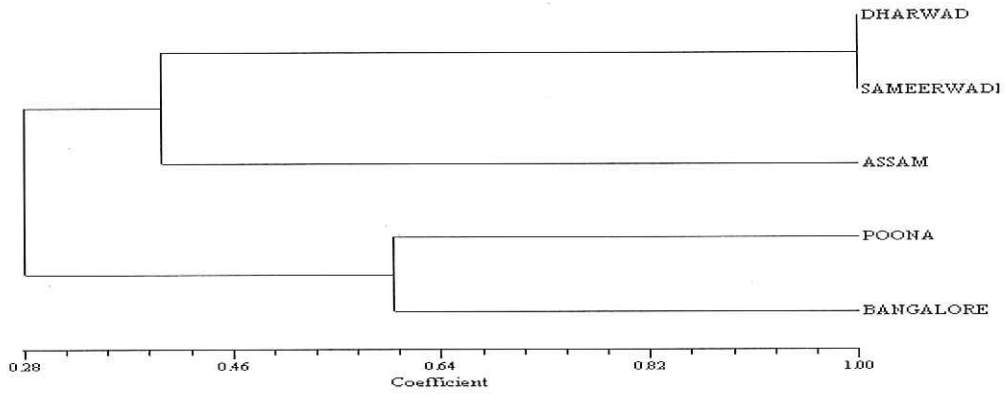


Fig. 14. Dendrogram showing genetic relatedness among different geographical strains of Sugarcane woolly aphid

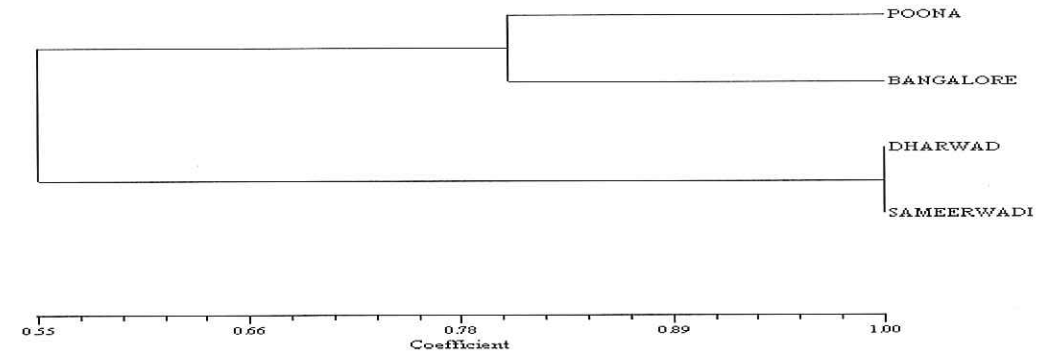


Fig. 15. Dendrogram showing genetic relatedness among different geographical strains of *Micromus igorotus*

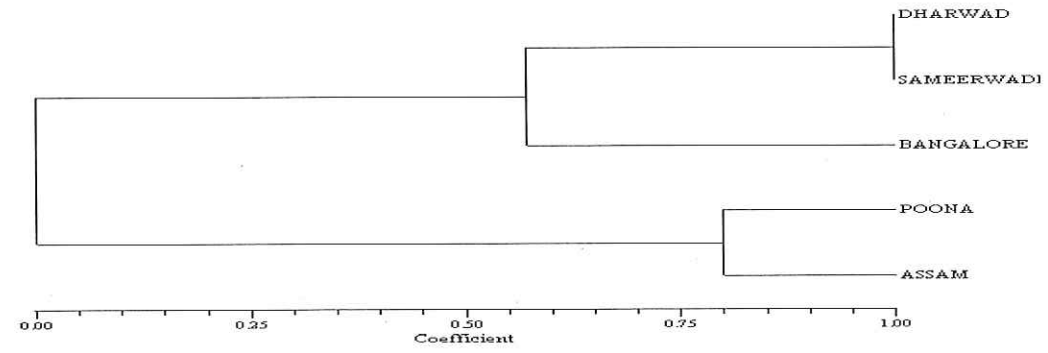


Fig. 16. Dendrogram showing genetic relatedness among different geographical strains of *Dipha aphidivora*

E. Other sucking pests

E.1 Sugarcane leafhopper *Pyrilla perpusilla* Walker (Homoptera, Lophopidae)

Sugarcane pyrilla or leafhopper *P. perpusilla* has often assumed a pest status in many parts of the country. Its sporadic and large scale outbreaks have been recorded from Uttar Pradesh, North Bihar and Karnataka. Most of these outbreaks precede long spells of drought in these areas. It is essentially a pest of sugarcane but in case of pest outbreaks it has been observed on several graminaceous and other crops.

Whitish or brownish nymphs with their forked tail and straw coloured adults with prominent rostrum suck sap from the affected canes. In case of heavy infestation yellowing of leaves and development of black sooty mould on honey dew secreted on leaves are the common symptoms of attack of pyrilla.

Native natural enemies

Information on native natural enemies is provided in the table 102.

Table 102. Natural enemies of *Pyrilla perpusilla*

Natural enemy	Host stage attacked	Place
1	2	3
Ooencyrtus papilionis	Eggs	Punjab
Cheilonecurus pyrillae	Nymph	Gola Gokarannath (UP)
Lestodryinus pyrillae	Nymph	Punjab
Richardsidrynius pyrillae		Dimapur (Nagaland) Shakar Nagar(AP)
Dryinus pyrillae	Nymph	Punjab
Tetrastichus pyrillae	Eggs	Gola Gokarannath (UP) Shakar Nagar(AP) Dimapur (Nagaland) Captainganj(UP)
Euderomphale sp.	Eggs	Gola Gokarannath (UP)
Epiricania melanoleuca	Nymphs and adults	Punjab Dimapur (Nagaland) Gola Gokarannath (UP) Captainganj(UP)
Nimboa basipunctata	Eggs	Punjab Dimapur (Nagaland)
Chrysoperla sp	Eggs and nymphs	Punjab
Brumoides suturalis	Eggs and nymphs	Punjab Dimapur (Nagaland) Captainganj(UP)
Verania allordi	Eggs	Punjab
Chielomenes sexmaculata	Eggs	Punjab, UP
Coccinella septempunctata	Eggs	Punjab
Clubiona drassodes	Nymphs and adults	Punjab
Erythracid mite	Nymphs	Punjab
Metarhizium anisopliae	Nymphs and adults	Punjab and UP
Hirsutella sp.	Nymphs and adults	Mandya (Karnataka)
Fusarium sp.	Nymphs and adults	Mandya (Karnataka)

At Shakar Nagar (AP), biology of *Richardsidrynius pyrillae* was studied in detail. This parasitoid has been observed to be acting at low key in the area. Maximum parasitisation of egg parasitoid *Tetrastichus pyrillae* (90%) was recorded in September in several areas of Uttar Pradesh. But the parasitoid can prove effective only if cultural practices like trash burning are not followed indiscriminately. At least a part of the trash should be conserved so that the parasitoid starts emerging early and parasitizes the first available population in the field. Such trials conducted in the farmers field in Punjab have given encouraging results.

Dendrocenus sp. (Megspilidae) parasitised the pupae of chrysopid at Pravaranagar (Maharashtra).

E.1.1 *Epiricania melanoleuca* (Fletcher) (Lepidoptera, Epipyropidae)

E. melanoleuca is the most important nymphal and adult parasitoid of *Pyrilla perpusilla*. The parasitoid keeps the population of *P. perpusilla* under check in several places monitored through laborastories at Lucknow, Captainganj and Gola Gokarannath and at Dinapur (Nagalnd).

Repeated releases of *Epiricania melanoleuca* (obtained from IISR, Pyrilla research Centre at Muzaffarnagar and IISR, Lucknow have helped in establishing the parasitoid on pyrilla in the released areas (Manon, Dadh, Kopergaon, Ravalgaon and Melunji villages).

It was observed that even a small number of (200) cocoons released in the areas was sufficient for establishment of the parasitoids. However, several thousand cocoons and egg masses have been colononized in sugarcane fields at Pravaranagar (Maharashtra) and Shakar Nagar (AP) between July and October in different years. The parasitoid has successfully established in all the colonized areas. The parasitoid was less active in months with low temperature and its potentiality is reduced in drought years. The failure of monsoon rains in Uttar Pradseh in 1985 resulted in the build up of *P. perpusilla* due to delecterious effect of drought on *E. melanoleuca* and other natural enemies. With the advent of rains in September, the population of *E. melanoleuca* could build up resulting in suppression of *P. perpusilla* population. The parasitoid is capable of suppression of *P. perpusilla* in most monsoon period.

Some of the cultural practices like keeping the trash containing eggs and cocoons of parasitoids of *P. perpussila* conserved the parasitoid.

E.1.1.1 Pesticide screening against *Epiricania melanoleuca* and *Tetrastichus pyrillae*

The results of the pesticide screening against *Epiricania melanoleuca* and *Tetrastichus pyrillae* are presented in following tables 103 and 104.

Table 103. Pesticide screened against *Epiricania melanoleuca*

Stage tested	Pesticides tested	Safe pesticides identified	Remarks
Nymphs	Malathion, dimethoate, endosulfan, vamidothion, BHC and sevidol	All safe, dimethoate ranks high	Field and laboratory assay

Table 104. Pesticide screened against *Tetrastichus pyrillae*

Stage tested	Pesticides tested	Safe pesticides identified	Remarks
Immature	Edosulfan, dimethoate, vamidothion, BHC and sevidol	None, emergence considerable	Field spray

E.1.1.2 *Metarhizium anisopliae* (Metchnikoff) Sorokin (Moniliaceae)

M. anisopliae is an important fungal pathogen of *P. perpusilla*. It takes a heavy toll of *P. perpusilla* during humid months. In 1985, *M. anisopliae* was multiplied in the laboratory and its spore suspension was sprayed in July. By end of October the fungus was recordwd from a wide area around the spraed field.

In field trials at Shakar Nagar, Muzaffarnagar, Daurala, and Mawana, introduction of fungus through *M. anisopliae* inoculated pyrilla adults @ 300-600 per hectare increased the field infection of *M. anisopliae* from 4 percent at the start to 98.4 percent after 60 days.

E.2 Sugarcane scale insect *Melanaspis glomerata* (Green) (Homoptera, Diaspididae)

Among several species of scale insects damaging sugarcane *M. glomerata* is highly destructive in most of the sugarcane growing areas of the country. It has not yet reached the state of Punjab.

The scale insect is a greyish black insect and infests 5-6 month old sugarcane crop. Due to continuous desaping, the canes start shrivelling up resulting in stunted growth. In severe cases of infestation in susceptible varities, the canes show tip drying, yellowing and ultimately drying up of the crop.

E.2.1 Native natural enemies

Information collected on natural enemies of scale insect in different parts of the country reveal that about 26 species of natural enemies attack scale insect. The important ones were *Azotus fumipennis, Azotus* sp., *A. delhiensis, Coccobius* sp., *Encarsia* sp., *Botryoideclava bharatiya, Tetrastichus* sp. nr. *purpureus, Adelencyrtus* sp., *A. mayurai, A. moderatus, Astymachus japonicas, Microterys* sp., *Neastymachus* sp., *Phanertoma* sp., *Chilocorus nigrita, Cebocephatus* sp., *Aprostocetus* sp., *Eutopus benefices, Microterys* sp., *Pharoscymnus horni* and *Sanioslus nudus*.

E.2.1.1 Studies on natural enemies *Neococcidencyrtus* sp. (Hymenoptera, Encyrtidae)

Out of seven exotic parasitoids introduced only *Neococcidencyrtus* sp. collected from *Melanaspis smilacis* in Brazil accepted *M. glomerata*. Life cycle of *Neococcidencyrtus* sp. was studied by exposing six pairs of adults to separate canes fully infested with *M. glomerata* in plastic jars. Longevity of females was 21.2 and that of males 17.2 days. Total developmental period lasted 35.2 days. Fecundity was found to be 31.7 and sex ratio (Females: males) 1:2.64. 25-45 day old scales were preferred to 5-25 days.

E.2.1.2 *Signiphora lutea* Rast (Hymenoptera, Signiphoridae)

Shipments of exotic parasitoid *Signiphora* spp. Attacking *Melanaspis smilacis* on sugarcane and *M. indigaspis* on *Ligustrum lucidum* were received during December 1981 and March – April 1983. Even though all stages of laboratory reared *M. glomerata* were provided, the scale was not accepted and no parasitism occurred.

E.2.1.3 *Aphytis mytilaspidis* (Le Baron) (Hymenoptera, Aphilinidae)

This parasitoid of *Aulacaspis tegalensis* was obtained from Mauritius in 1983 and tried against *M. glomerata*, which was rejected by the scale insect.

E.2.1.4 *Adelencyrtus mayurai* Subba Rao (Hymenoptera, Encyrtidae)

A. mayurai is the most common indigenous parasitoid of sugarcane scale insect *Melanaspis glomerata* at Shakarnagar, Rudrur, Vuyyuru (Andhra Pradesh), Pravaranagar (Maharashtra), Gola Gokarannath (Uttar Pradesh) and many other places surveyed. At Rudrur the parasitoidis most active from 2nd half of July to September, at Vuyyuru from 2nd half of July to October and at Pravaranagar from August to November.

In general it can be inferred that the optimum temperature range of mean maximum from 29 to 31^{0}C and mean minimum of 21 to 25^{0}C combined with relative humidity range of 79-94 percent are favourable for the development of the parasitoid of sugarcane scale, *A. mayurai* as well as *Azotus* sp.

The biology of the encyrtid endoparasitoid *A. mayurai* was studied in the laboratory on *M. glomerata* which was multiplied as follows.

Good canes with intact buds were cut into pieces retaining two or three nodes. The tips were treated with 2% benlate solution and were dipped in molten paraffin wax. Rooting and sprouting were obtained and the canes remained in good conditions for more than 4 months. Canes were infested by keeping fresh ones in contact with fully infested canes where crawler production had started. It was possible to rear two generations of the scales on the same cane without difficulty.

Only female scales were found to be parasitized and those between 25-45 days old were preferred. Reproduction was by thelytokous parthenogenesis and the average number of progeny per female was 68.6. high humidity and a carbohydrate source were found to prolong survival. Maximum longevity of 23 days was obtained when 100% honey was provided along with 80% R.H.

At Coimbatore, *A. mayurai* could complete its life cycle in 15.1 days laying 35.75 eggs. 40 days old scale insects were more suitable for this parasitoid. Longevity of the parasitoid is increased at low temperature and by providing 100 percent honey and water.

The parasitoid was multiplied and evaluated at Pravaranagar. Although the experiments were conducted on a small scale, the results were quite encouraging.

E.2.1.4.1 Pesticide screening against *Adelencyrtus mayurai*

The results of pesticide screening against *A. mayurai* are presented in table 105.

Table 105. Pesticide screened against *Adelencyrtus mayurai*

Stage tested	Pesticides tested	Safe pesticides identified	Remarks
Adult, Immature	Malathion, dimethoate, edosulfan	Malathion, edosulfan	Field, laboratory assay

E.2.1.5 *Cryptognatha nodiceps* Marshall (Coleoptera, Coccinellidae)

This coccinellid predator of *Aspidiotus destructor* was imported from Trinidad for trials against *M. glomerata*. They readily fed on young *M. glomerata* scales but did not breed on the same.

E.2.1.6 *Chilocorus cacti* Linnacus (Coleoptera, Coccinellidae)

The culture of this predator was obtained from Trinidad but could not be multiplied in the laboratory.

E.2.1.7 *Rhyzobius* (=*Lindorus*) *lophanthae* (Blaisdell) (Coleoptera, Coccinellidae)

A small culture of exotic predator *R. Lophanthae* was obtained at Lucknow in 1979. Efforts were made to multiply these on a biotype of *Melanaspis glomerata* infesting 'Munja leaves' *Erianthus cillaris*, *R. Lophanthae* could not be successfully reared on 'Munja' scale. This scale also could not be multiplied on pumpkins. This predator was subsequently multiplied in the laboratory on *Melanaspis glomerata* infesting sugarcane and other diaspine scales.

E.2.1.8 *Stichilotis madagassa* Weise (Coleoptera, Coccinellidae)

Exotic predator *Stichilotis madagassa* (Origin : East Africa) was initially multiplied on diaspine scale insect (a biotype of *Melanaspis glomerata*) infesting mid-ribs of 'Munja' (*Erianthus cilaiaris*) leaves at Lucknow. Adults bred on this scale insect mated successfully and oviposition commenced 3 days later, continuing for 21 days. However, fecundity per female was low. Duration of incubation, larval and pupal periods at 30^{+}- 2^{0}C and 50^{+}- 50% RH was 6.5, 20 and 5 days, respectively. But subsequently the predator was multiplied on sugarcane scale insect at Pravaranagar and Shakar Nagar and Gola Gokarannath. Maximum releases were made at Pravaranagar.

Storage technology for *S. madagassa* was developed- 5^{0}C and 10^{0}C were found to be lethal for storage as 100% mortality was observed within 7 and 10 days, respectively. At 15^{0}C , the predator could be stored effectively upto 60 days while at room temperature (27^{0}C), it could be stored only upto 20 days. Adults inside container were provided with corrugated paper sheets and honey + agar to feed . Storage at 15^{0}C did not reduce fecundity upto 45 days and at 27^{0}C upto 15 days. Longevity at 15^{0}C and 27^{0}C remained unaffected till 60 and 15 days, respectively. Development time was increased with longer storage. Results indicate that the predator could be staored at 15^{0}C upto 60 days in advance months without affecting their biotic potential.

Studies on combined action of *Adelencyrtus mayurai* and *Stichilotis madagassa* on *Melanaspis glomerata* indicated that *A. mayurai* alone is capable of parasitizing 78.8% and *S. madagassa* alone predated on 53.4% of the host. Among 8 various combinations tried with various day gaps, release of *A. mayurai* followed by grubs of *S. madagassa* resulted in 90.4% parasitism. However, in all multiple release combinations individual efficacy of natural enemies was drastically reduced. In all multiple release combinations fecundity and longevity were also redyced mainly due to heavy parasitism/predation causing non availability of host. Developmental time of predator increased in combinations. *S. madagassa* could not distinguish between parasitism and non-parasitism host in its earlier stage of development.

Laboratory bred beetles of *S. madagassa* have been released on scale infested canes under field conditions. Recovery of beetles has been made from the 'release' area, within a period of three months. This has perhaps been possible because of the cultivators habit of keeping their sugarcane fields clean from dry foliage as also creepers which grow luxuriantly if not weeded out at periodic interval. Dispersal of the beetles, however, was almost negligible at this center (Pravaranagar) also. The activity of beetles was observed upto 90 days after the releases. During summer, beetles migrate to the lower portion of canes, dry leaves and soil cracks.

At Captainganj (Uttar Pradesh) an ant *Camponotus* sp. was observed carrying away beetles in the released plots, hampering colonisation of the predator. No recovery of pupae or beetle was observed in the area.

At shaker Nagar (Andhra Pradesh) release of *S. madagassa* adults and grubs were recoveredfrom released fields. Several attempts to colonise in several sugarcane growing areas in the country not only by the centre of this project in Uttar Pradesh, Andhra Pradesh, Maharashtra and Nagaland, but also in collaboration with other oraganisations were made. But, it has failed to establish permanently in the colonised areas.

E.2.1.9 *Pharoscymnus horni* (Weise) (Coleoptera, Coccinellidae)

P. horni is a common indigenous predator of diaspine scale insects. It has been recorded on sugarcane scale insect *M. glomerata* from Shakr Nagar (Andhra Pradesh) and Pravaranagar (Maharashtra). As both adults and grubsare voracious feeders on scale insect, the need for conservation is stressed. The egg, grub, prepupal and pupal stages are completed in 4.4^{+}-0.48, 14.4^{+}-0.48, 1.2^{+}-0.40 and 5.4^{+}-0.48 days, respectively. Continuous laboratory rearing for about 10 months resulted in prolonging of developmental period of different stages. The egg, grub, prepupal and pupal stages was completed in 6.0^{+}-1.0, 20.2^{+}-1.03, 1.6^{+}-0.48 and 6.4^{+}-1.01 days, respectively. Field collected predators lived longer and the females produced 36.6^{+}-5.91 eggs compared to 22.2^{+}-3.86 of laboratory reared. Based on these results a regular replacement of part of the laboratory stocks with wild individuals collected from the file is suggested. Due to insufficient availability of the predators in the country only limited field trials were conducted by releasing the adults and grubs. The placement of about-to-hatch eggs in the field is advocated so that hatching grubs start feeding and the progeny multiplies in the field.

E.2.1.10 *Chilocorus nigrita* Fabricius (Coleoptera, Coccinellidae)

C. nigrita has almost similar status as that of *P. horni.* This indigenous predator completes the egg, grub and pupal stage in 3-6, 13-16, 5-6 days, respectively. The

adult males were short lived (15 days) but the females lived for one to two months. This predator has been utilised through inundative release, not only in sugarcane ecosystem but also on several other diaspine scales including red scale of citrus.

E.2.1.11 *Fusarium subglutinans* (Moniliales, Moniliaceae)

F. subglutinans has been isolated from *Melanaspis glomerata*, *Chilo sacchariphagus indicus*, *Scirpophaga excerptalis*, *Pyrilla perpusilla* and *Pulvinaria elongate*. *F. subglutinans* has been successfully cultured at Coiambatore on carrot medium. The radial growth, biomass production and mycelia dry weight was quite satisfactory on this medium.

The pathogenicity of the fungus has been tested on *M. glomerata*. The mortality range varied from 36.7 to 60.8% in 1st- 2nd instars but it was low in 3rd and 4th instars varying from 9.6 to 26.6%. The mortality was higher at low temperature (15 and 20^{0}C) compared to high temperature (35^{0}C). Moderate mortality 33.58 to 62.12% was observed at 25 and 30^{0}C. 90% RH was found to be congenial for inflicting high mortality of scale insects.

Stubble treatment with *F. subglutinans* was effective in reducing the sugarcane scale population in ratoon stubbles at Coimbatore to the extent of 63 to 98%.

F. subglutinans was highly pathogenic to *Pulvinaria elongate*, *Aleurolobus barodensis*, nymphs of white fly and *S. excerptalis*.

E.2.1.12 Sugarcane aphid *Melanaphis indosacchari* (Zehntner) David (Homoptera, Aphididae)

M. indosacchari feeds on young growth. It is not a serious pest but some times in certain pockets it creates problem due to desaping. The plants become weak and the honey dew secreted by the aphids attreacts sooty mould causing fungus.

E.2.2 Native natural enemies

Among the natural enemies, mainly polyphagous coccinellid predators have been recorded which shift to aphids in case good infestation is available. *Cheilomenes sexmaculata* has often been associated with *M. indosacchari* at Coimbatore and other places.

E.2.2.1 Studies on natural enemies

C. sexmaculata takes 10 days to complete the life cycle and the adults lived for 21.8 days.

A single predatory grub can consume 142.8 (127-155) *Melanaphis indosacchari* during its development period. A single adult can consume 992.4 (465-1256) aphids during its life span. Food consumption by grubs increased with increase in age, wheras in adult, it decresed with increase in age. The grubs of *C. sexmaculata* consumed 122 to 385 (Mean 197.6) aphids in 4-6 days and adults consumed 1130 to 1540 (Mean 1397.6) aphids in 16 to 30 days when *M. indosacchari* was offered as pray.

E.2.3 Black bug *Cavelerius sweeti* Slater and Mugomoto (Homoptera, Lygaeidae)

Both nymphs and adults are found in leaf whorls and sheathing bases of the leaves whereas they breed and desap the plant. In due course of time the infested plant turn yellow with brown patches and under severe infestation they wither or dry up.

E.2.3.1 Native natural enemies

Of the different entomogenous funji collected from sugarcane agro-ecosystem, release of inoculated adults of *Cavelerius sweeti* @ 500/ha with Beuveria bassian culd induce sizeable mortality to over wintering population of *C. sweeti.*

F. Biological Control of Sugarcane Pests with Entomopathogenic Nematodes – NBAII and AICRP Biological control

The impressive attributes of EPN have stimulated strong commercial interest in nematodes as biological insecticides. These include their wide spectrum of insecticidal activity, ability to kill most hosts within short periods, efficient mass culturing techniques and exemption by EPA for registration in west. Nevertheless these insecticidal nematodes are perceived as viable alternatives to chemical. EPN possess impressive attributes of parasitoids/predators and pathogens *viz.*, quick kill, broad host range, high virulence, presence of chemoreceptors, amenability for in vitro production, presence of numerical but no functional response, safety to vertebrates, plants and non-targets, amenability for application using standard application equipments, compatibility with many chemical pesticides and genetic diversity. As the control potential of EPN is not affected by agrochemicals, they can be integrated into standard chemical control practice. Today nematodes are mainly used in the environment where chemical compounds fail *viz.*, in the soil, in the galleries of boring insects, or in cases where resistance to insecticides has developed.

There has been heightened interest among University, Governmental and industrial scientists in augmentative biological control of insects using EPN throughout the world. Nematodes have been successfully applied to control agricultural and horticultural pests in many countries. Nematode based products are available in international market for the control of a wide spectrum of insects. Improvements in formulations have resulted in nematode products that have longer shelf-life and stability and are easier to mix and apply. Many medically important insects and invertebrate pests are found susceptible to EPN. Development of local markets will be a challenging task. EPN are generally more expensive to produce than are chemical larvicides and the quantities required for efficacy and require more training to use. Growers will be willing to pay the extra price and learn to use a nematode-based product instead of an alternative chemical pesticide only if the nematode products have comparable efficacy. A final opportunity worthy of development is to incorporate EPN in to IPM program.

In India the work on insect parasitic nematodes started early as 1027 with mermithids from *Anopheles* mosquitoes. The VCRC, Puducherry was engaged in the use of *Romenomermis*. Reports of mermithids on different hosts have continuously appeared since then. A few species of rhabdtid nematodes, other than Steinernematids and Heterorhqabditids were reported from the house fly, maize stem borer, paddy stem borer, red palm weevil, rhinoceros beetles and ragi pink borer

(Mathur *et al.*, 1996). Heterorhabditidae and Steinernematidae have widely been perceived as continuing biological control agents (GAugler and Kaya, 1990). Rao and Manjunath (1966) discussed the use of DD136 in the control of insect pests of rice, sugarcane and apple. Different workers have studies the use of EPN against cutworms, ragi pink borer, rice leaf folder and stem borers, paddy gall midge, sugarcane borer, whitegrubs, red hairy caterpillars etc., in lab and field.

In India, work on EPN for control of sugarcane pests has been initiated during 90's and the contribution from Sugarcane Breeding Institute, Coimbatore is appreciable. *Heterorhabditis indica* (Pionar *et al.*, 1992) the first EPN reported from India was originally isolated and described from the Sugarcane Breeding Institute, Coimbatore.

NBAII, Bengaluru, has made significant progress in cataloguing EPN diversity, genetic and molecular identity, genomics, mass production, formulation, shelf-life studies, field testing, commercialization for the management of whitegrubs and termites in sugarcane in hot spot area of whitegrubs in Assam, Karnataka, Maharashtra, Gujarat and UP.

F.1 NBAII

F.1.1 Survey and reports on EPN

NBAII conducted surveys in root-grub endemic sugarcane areas of Assam, North Karnataka, AP and Maharashtra for grubs, eggs and infested cadavers. The endemicity of *Holotrichia serrata*, *H. consanguinea* and *Leucopholis lepidophora* in Belagum and Kolhpur and *Anomala bengalensis*, *Cosmopolites* spp. (on banana) and *L. burmestrii* and *Holotrichia* spp. in Ananthpur and Chittor areas of AP, was recorded.

Two new isolates of *Heterorhabditis* spp. were isolated from diseased grubs collected from north Karnataka-Maharashtra and added to NBAII collections.

Analysis of soil samples from whitegrub endemic sugarcane fields of Maharashtra and vegetable fields of Srinagar (J & K) yielded 2 isolates of *Heterorhabditis* from Maharashtra and one isolates each of *Heterorhabditis* and *Steinernema* species. They were screened *in vitro* for efficiency against second and third instar grubs of *Anomala bengalensis*. Results indicated that all the four nematodes caused mortality.

F.1.2 Pathogenicity of EPN against sugarcane white grubs

Young grubs (2^{nd} – 3^{rd} instar) of *Leucopholis*, *Anomala* and *Cosmopolites* were examined for LD_{90} and LT_{90} at 10, 20 and 30cm depth with 3 preparations (aqueous, talc and sponge). The LD values did not different significantly between 3 preparations for the grubs in same instar and same species. However, the LCD values were significantly different among EPN populations for each instar and species of the grub.

LD_{50} and LT_{50} values for 7 isolates of EPN were worked out against sugarcane white grubs (*Phyllophaga calciata* in Maharashtra and *Lepidiota mansueta* in Assam).

Integration of talc and cadaver formulations of *H. indica*, *H. bacteriophora*, *S. abbasi* with cocopeat, vermiculite or vermicompost significantly improved field persistence, infectivity and shelf-life.

Effect of field soil moisture on the behavior of root grubs, EPN persistence and infectivity have been successfully studied for one season for developing guideline data. Soil moisture was recorded at 7-10, 17-20 and 27-30cm depth at monthly intervals between August and February at a predetermined EPN- treated sugarcane plot in North Karnataka. Root grubs of different sizes 1cm to 2.5sm were predominant in top 20cm from August to October with intermittent large sized grubs, while grubs of more than 2.5cm were predominant between 10 and 30cm from Oct to January.

F.2 AICRP trials

F.2.1 IISR, Lucknow

A field experiment was conducted at IISR, research with variety CoLk 8102. The talk-based formulations of entomopathogenic nematodes (*Heterohabditis indica* and *Steinernema carpocapsae*) supplied by PDBC Bangalore, was dissolved in water and applied with a rose can in furrow at time of planting. The six treatments were arranged in RBD having three replications. The experimental plots were separated from each other by bunds having a distance of 90 cm. All agronomic practices were followed to raise a good crop. Observations on termite infestation were recorded by digging the sets before monsoon and at harvest. Cane yield was recorded at harvest.

Table 106. Effect of EPN on incidence of termite and yield (year)

Treatment	% incidence of termite		Yield (t ha^{-1})
	Cane damage* (May)	Cane damage* (at harvest)	
T1- Soil application of *Heterohabditis indica* PDBCEN 13.31@2.5b ha^{-1}	14.27 (22.19)	27.10 (31.30)	33.33
T2- Soil application of *Heterohabditis indica* PDBCEN 13.31@5b ha^{-1}	10.82 (19.18)	29.60 (32.96)	51.29
T3- Soil application of *Steinernema carpocapsae* PDBCEN 11@2.5b ha^{-1}	16.49 (23.95)	31.40 (34.08)	34.25
T4- Soil application of *Steinernema carpocapsae* PDBCEN 11@5b ha^{-1}	12.17 (20.71)	25.70 (30.45)	36.29
T5- Soil application of chlorpyriphos 20EC @ 1kg a.i. ha^{-1}	10.47 (18.87)	22.40 (28.25)	37.37
T6- control	23.33 (28.65)	32.33 (34.65)	31.29
CD ($P - 0.05$)	1.63	2.29	3.97

* Figures in parentheses are sine transformation

The cane damage during May was minimum in chemical treatment (chlorpyriphos 20EC @1 kg a.i. ha^{-1}) and entomopathogenic nematode (*Heterohabditis indica* PDBCEN 13.31@5b ha^{-1}) as compared to other treatment than EPN treatment (Table 106).

The maximum cane yield (51.29t ha^{-1}) was observed in EPN treatment (*Heterohabditis indica* PDBCEN 13.31@5b ha^{-1}) than other treatment.