J. Biol. Control, 18(2): 121-128, 2004

Efficacy of *Trichogramma chilonis* Ishii in combination with biopesticides against *Helicoverpa armigera* (Hübner) in rainfed cotton ecosystem

N. BALAKRISHNAN[1], R. K. MURALI BASKARAN and N. R. MAHADEVAN
Department of Agricultural Entomology
Agricultural College and Research Institute (TNAU)
Madurai 625 104, Tamil Nadu, India
E-mail: balakrishnanento@yahoo.co.uk

ABSTRACT: A study was undertaken to observe the combined effects of *Trichogramma chilonis* with some biopesticides *viz.*, *Ha*NPV, *Bacillus thuringiensis* var. *kurstaki* (Halt® WP) and *Beauveria bassiana* (Bev Bas). Two releases of *T. chilonis* with two sprays of *B.t.k.* recorded less mean larval population (0.33/plant), less damage on shed squares (42.78%), intact squares (9.12%), bolls (14.20%) and loculi (10.68%) and recorded higher yield (782 kg/ha). Two releases of *T. chilonis* with two sprays of *Ha*NPV was the next best treatment regarding less mean larval population and damage on fruiting parts. Application of *B. bassiana* alone and in conjunction with *T. chilonis* proved less effective compared to other treatments. Two releases of *T. chilonis* with one spray of *B.t.k* or *Ha*NPV and *T. chilonis* alone performed moderately in reducing the larval population and damage on fruiting parts.

KEYWORDS: Biopesticides, efficacy, *Helicoverpa armigera*, *Trichogramma* chilonis

INTRODUCTION

The damage by the American bollworm *Helicoverpa armigera* (Hübner) has become serious on many crops especially on cotton in south India. The future of cotton industry depends very much on the development of suitable alternate methods of controlling *H. armigera* on cotton since resistance in *H. armigera* to several pesticides. Biological control by parasitoids/ predators has been proved to be an excellent alternative to chemical pesticides in number of ecosystems (Singh and Jalali, 1991). With the growing awareness and concern over preservation of environment, biological pest suppression as an ecologically sound alternative to chemical pest control has gained worldwide attention. Hence the study was undertaken to evaluate the efficacy of *Trichogramma chilonis* Ishii in combination with the biopesticides against *H. armigera* in cotton ecosystem.

[1] Present address: Senior Research Fellow, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu

MATERIALS AND METHODS

A field trial was laid out to evaluate the efficacy of *T. chilonis* in combination with *Ha*NPV, *B. thuringiensis* var. *kurstaki* and *B. bassiana* under rainfed condition at Regional Research Station, Aruppukottai during September 2000 to February 2001 by raising a cotton variety MCU 10 with spacing of 45x30cm. All recommended agronomical practices were followed. The plot size adopted was 40m^2 and each treatment was replicated thrice. To control the early season sucking pests, a spray of 0.04 per cent dimethoate was given at 30DAS uniformly to all plots including untreated check. *T. chilonis* parasitized egg card bits were stapled on under-surface of leaves at various places in the treatment plots. NPV was sprayed after mixing with jaggery @ 0.5 per cent and Triton @ 0.1 per cent at monthly interval. The *B. thuringiensis* var. *kurstaki* (Halt^0 WP) and *B. bassiana* (Bev Bas) were sprayed after mixing with Triton @ 0.1 per cent at monthly interval. The biopesticides and insecticides were applied at the specified dose in 500 litres of water using high volume sprayer. The damage by *H. armigera* was recorded on ten randomly selected tagged plants. The *H. armigera* infestation was expressed in terms of per cent infestation on shed squares, squares (intact), bolls and loculi basis.

Four days after every release of *T. chilonis*, the available eggs of *H. armigera* were collected from the released plots and brought to the laboratory for observing the emergence of parasitoid. Virosed, *B.t.k.* affected and mycosed larvae were also recorded weekly after respective treatments. The yield data were recorded and incremental cost benefit ratio (ICBR) was worked out by considering additional income derived over untreated check and total cost incurred on plant protection towards the particular pest.

Table 1. Treatment details

Sl. no.	Treatment	Dose or number of releases / ha
1.	*T. chilonis*	Six releases @ 100000/ha, 45, 60, 75, 90, 105 and 120 DAS
2.	*Helicoverpa armigera* NPV (*Ha*NPV)	Three sprays @ 500LE/ ha ($1.5x10^{12}$ POBs/ml), 60, 90 and 120 DAS
3.	*B. thuringiensis* var. *kurstaki (B.t.k.)* (Halt® WP)	Three sprays @ 1 kg / ha, 60, 90 and 120 DAS
4.	*B. bassiana* (Bev Bas)	Three sprays @ 2 kg / ha, 60, 90 and 120 DAS
5.	*T. chilonis* + *Ha*NPV	Two releases of *T. chilonis* @ 1,00,000/ha, 45 and 60 DAS + two sprays of *Ha*NPV @ 500 LE/ha, 90 and 120 DAS
6.	*T. chilonis* + *Ha*NPV	Two releases of *T. chilonis* @ 1,00,000/ha, 60 and 90 DAS + one spray of *Ha*NPV @ 500 LE/ha 120 DAS
7.	*T. chilonis* + *B.t.k.*	Two releases of *T. chilonis* @ 1,00,000/ha, 45 and 60 DAS + two sprays of *B. t. k.* @ 1kg / ha, 90 and 120 DAS
8.	*T. chilonis* + *B. t. k.*	Two releases of *T. chilonis* @ 1,00,000/ha, 60 and 90 DAS + one spray of *B. t. k.* @ 1kg/ ha, 120 DAS
9.	*T. chilonis* + *B. bassiana*	Two releases of *T. chilonis* @ 1,00,000/ha, 45 and 60 DAS+ two sprays of *B. bassiana* @ 2 kg / ha, 90 and 120 DAS
10.	*T. chilonis* + *B. bassiana*	Two releases of *T. chilonis* @ 1,00,000/ha, 60 and 90 DAS + one spray of *B. bassiana* @ 2 kg / ha, 120 DAS
11.	Chlorpyriphos 20EC alone	Three sprays @ 400g a.i./ ha, 60, 90, 120 DAS
12.	Untreated check	-

RESULTS AND DISCUSSION

H. armigera larval population, damage and yield

The mean larval population in treatments ranged from 0.33 to 2.47 per plant against the untreated check 3.60 per plant. The minimum larval population was observed in treatment having two releases of *T. chilonis* with two sprays of *B.t.k.* (0.33 / plant) followed by two releases of *T. chilonis* along with two sprays of *Ha*NPV (0.43/plant). Application of *B. bassiana* alone and in conjunction with *T. chilonis* proved less effective in minimizing *H. armigera* larvae compared to other treatments. Two releases of *T. chilonis* with one spray of *B.t.k.* or *Ha*NPV and *T. chilonis* alone performed moderately in reducing the larval population (Table 2).

Two releases of *T. chilonis* with two sprays of *B.t.k.* recorded 42.78, 9.12, 14.20 and 10.68 per cent damage on shed squares, squares (intact), bolls and loculi, respectively. Two releases of *T. chilonis* with two sprays of *Ha*NPV was the next best in having less damage on shed squares, squares (intact), bolls and loculi with 45.61, 10.16, 16.44 and 13.53 per cent, respectively. *B. bassiana* alone treated plots performed poorly and the damage by *H. armigera* was higher compared to all other treatments. *B.t.k.* alone and *Ha*NPV alone treated plots moderately recorded the damage by *H. armigera* (Table 2).

The kapas yield ranged from 515 to 782 kg/ha against the untreated check 435 kg/ha. The maximum yield was obtained in two releases of *T. chilonis* and two sprays of *B.t.k.* treated plots with 79.77 per cent yield increase over check. The minimum yield was on *B. bassiana* alone treated plots with yield increase over check of 18.39 per cent. Application of *B.t.k.* alone and *Ha*NPV alone treated plots yielded about 754 and 708 kg/ha with yield increase of 73.33 and 62.76 per cent over untreated check (Table 2).

Table 2. Incidence of *H. armigera* in cotton in different treatments

Treatment	Mean larval population / plant	*H. armigera* damage (%)				Yield (kg/ha)	Yield increase over untreated check (%)
		Shed square	Square (intact)	Boll	Locule		
1. *T. chilonis*	1.93^{h}	61.34^{g}	18.26^{g}	29.10^{h}	27.92^{g}	598	37.47
2. *Ha*NPV	0.67^{d}	52.28^{d}	13.14^{d}	20.52^{d}	18.42^{d}	708	62.76
3. *B. thuringiensis* var. *kurstaki* (Halt® WP)	0.53^{c}	48.76^{c}	12.04^{c}	18.08^{c}	16.94^{c}	754	73.33
4. *B. bassiana* (Bev Bas)	2.47^{j}	67.50^{i}	24.65^{i}	37.87^{k}	34.38^{i}	515	18.39
5. *T. chilonis* + *Ha*NPV	0.43^{b}	45.61^{b}	10.16^{b}	16.44^{b}	13.53^{b}	770	77.01
6. *T. chilonis* + *Ha*NPV	1.23^{f}	58.92^{f}	16.97^{f}	26.73^{g}	24.98^{f}	652	49.89
7. *T. chilonis* + *B. t. k.*	0.33^{a}	42.78^{a}	9.12^{a}	14.20^{a}	10.68^{a}	782	79.77
8. *T. chilonis* + *B. t. k.*	1.27^{g}	58.58^{f}	16.53^{f}	25.46^{f}	24.57^{f}	642	47.59
9. *T. chilonis* + *B. bassiana*	2.03^{i}	64.44^{h}	21.18^{h}	34.33^{j}	31.46^{h}	538	23.64
10. *T. chilonis* + *B. bassiana*	1.97^{h}	62.17^{g}	18.72^{g}	30.82^{i}	28.64^{g}	545	25.29
11. Chlorpyriphos 20 EC	0.80^{e}	54.41^{e}	15.03^{e}	23.78^{e}	21.25^{e}	689	58.39
12. Untreated check	3.60^{k}	71.32^{j}	28.82^{j}	41.64^{l}	37.18^{j}	435	-

Means in a column followed by same letter is not significantly different (P = 0.05) by DMRT.

The study on efficacy of *T. chilonis* in combination with biopesticides revealed that two releases of *T. chilonis* (6.25 cc/ha) at 45 and 60 DAS with two sprays of *B.t.k.* @ 1 kg/ha, 90 and 120 DAS recorded highest yield with least damage (on squares, bolls and loculi) followed by two releases of *T. chilonis* (6.25 cc/ha) at 45 and 60 DAS with two sprays of *Ha*NPV @ 500 LE/ha (1.5×10^{12} POBs/ml) at 90 and 120 DAS. In general, it is easily understood from the study that integration of *T. chilonis* and biopesticides gave higher yields than their respective sole treatments, only if *T. chilonis* was released in time at 45 and 60 DAS with two sprays of the respective biopesticides. This could be due to parasitisation of *T. chilonis* on *H. armigera* eggs resulting in reduction in larval population. In addition, though some of the eggs of *H. armigera* escaped from parasitism by *T. chilonis* and hatched to larvae, they would be killed by application of the biopesticides. This is in consonance with the findings of Dhandapani *et al.* (1992), Kalyanasundaram *et al.* (1991) and Mishra and Mandal (1995). *B. bassiana* proved least effective in controlling *H. armigera*. This is probably because of unfavourable conditions prevailed in that situation might have affected the fungus in causing mortality to *H. armigera*. Moreover, *H. armigera* normally causes damage to buds, flowers and bolls, thus making it difficult for *B. bassiana* to have contact on *H. armigera*. Similar findings were reported by Hazarika and Puzari (1997) in case of rice leaf miners as they remain inside the tunnels. In contrary to this *B. bassiana* was reported effective to bring down the *H. armigera* pod damage in redgram (Saxena and Ahmad, 1997), *Sylepta derogata* Fabr. in cotton (Ramesh *et al.*, 1999) and boll weevils in cotton (Wright and Chandler, 1992). Reduction in bollworm damage due to bioagents effectiveness resulted in increased the yield. Utilization of biocontrol agents increased the seed cotton yield, which is in line with the reports of Sangwan *et al.* (1972) and King *et al.* (1985).

Field recovery

The maximum per cent (43.64 %) parasitised eggs was observed in *T. chilonis* alone treated plots followed by two releases of *T. chilonis* and two sprays of *B. bassiana* applied plots with 40.56 per cent. Two releases of *T. chilonis* in conjunction with one spray of *Ha*NPV and two releases of *T. chilonis* + one spray of *B.t.k.* were on par with each other by recording 40.51 and 40.12 per cent parasitism, respectively. The field recovery of *T. chilonis* was 6.40 per cent in chlorpyriphos treated plots which was lower than the parasitism observed in untreated plots (8.96 %) (Table 3). The recovery of NPV infected larvae ranged from 0.03 to 0.85 per plant in insecticide and *Ha*NPV alone treated plots. The recovery of *B.t.k.* infected and mycosed larvae was observed only in the respective treated plots. The field recovery ranged from 0.48 to 0.66 and 0.14 to 0.31 for *B.t.k.* infected and mycosed larvae (Table 3).

By and large, parasitism by *T. chilonis* was observed more in *T. chilonis* released plots (43.64 %). The recovery of *Trichogramma* from parasitoid colonised areas has also been reported by Varma and Maninder (1983) and Awate *et al.* (1997). Mani and Krishnamoorthy (1983) recovered *T. brasiliense* to the extent of 34.6 to 51.3 per cent parasitism in tomato. Dhandapani *et al.* (1992) observed that 32.0 per cent egg parasitism in biocontrol plots as compared to 0.0 and 3.0 per cent in insecticide treated and untreated plots, respectively. It is probably due to the toxic effect of insecticide, which might have reduced the occurrence of parasitoids. Similarly, *Ha*NPV infected larvae were found more in *Ha*NPV treated plots and natural incidence of *Ha*NPV on *H. armigera* was noticed in a meager range in other treatments also. However, *B.t.k.* and *B. bassiana* infected larvae were found only in their respective treated plots.

Incremental Cost Benefit Ratio (ICBR)

The cost incurred on treatment varied from Rs. 716 (two releases of *T. chilonis* with one spray of *B. bassiana*) to Rs. 2520 (*B.t.k.* alone) in different treatments (Table 4). Highest additional gross income over untreated check was obtained in *T. chilonis* + *B.t.k.* + *B.t.k.* with Rs. 6593/ha and lowest in *B. bassiana* alone treated plots with Rs. 1520 / ha. Two releases of *T. chilonis* with two sprays of *Ha*NPV recorded highest ICBR (1:4.84) followed

Table 3. Field recovery of *T. chilonis*, *Ha*NPV and B. t. k. infected and mycosed larvae

Treatment	* Field recovery			
	Parasitised eggs (%)	NPV infected larvae (No. / plant)	*B.t.k.* infected larvae (No. / plant)	Mycosed larvae (No. / plant)
1. *T. chilonis*	43.64^{d}	0.07^{de}	0.00^{d}	0.00^{d}
2. *Ha*NPV	9.21^{e}	0.85^{a}	0.00^{d}	0.00^{d}
3. *B. thuringiensis* var. *kurstaki*(B. t. k.) (Halt® WP)	9.05^{e}	0.06^{e}	0.66^{a}	0.00^{d}
4. *B. bassiana* (Bev Bas)	9.14^{e}	0.06^{e}	0.00^{d}	0.31^{a}
5. *T. chilonis* + *Ha*NPV	39.28^{bc}	0.56^{b}	0.00^{d}	0.00^{d}
6. *T. chilonis* + *Ha*NPV	40.51^{bc}	0.43^{c}	0.00^{d}	0.00^{d}
7. *T. chilonis* + *B. t. k.*	37.39^{d}	0.07^{de}	0.53^{b}	0.00^{d}
8. *T. chilonis* + *B. t. k.*	40.12^{bc}	0.06^{e}	0.48^{c}	0.00^{d}
9. *T.chilonis* + *B. bassiana*	40.56^{b}	0.07^{de}	0.00^{d}	0.26^{b}
10. *T. chilonis* + *B. bassiana*	38.93^{c}	0.08^{d}	0.00^{d}	0.14^{c}
11. Chlorpyriphos	6.40^{f}	0.03^{g}	0.00^{d}	0.00^{d}
12. Untreated check	8.96^{e}	0.05^{f}	0.00^{d}	0.00^{d}

* Mean of three observations based on three replications

Means in a column followed by same letter is not significantly different (P = 0.05) by DMRT

Table 4. Effect of *T. chilonis* in combination with other biopesticides on seed cotton yield and cost benefit ratio

Treatment	Cost of treatment (Rs./ha)	Seed cotton yield	Gross income (Rs./ha)	Additional income over untreated	Incremental cost benefit ratio (ICBR)
1. *T. chilonis*	948	598	11362	3097	1: 3.27
2. *Ha*NPV	1500	708	13452	5187	1: 3.46
3. *B. thuringiensis* var. *kurstaki* (B. t. k.) (Halt® WP)	2520	754	14326	6061	1: 2.41
4. *B. bassiana* (Bev Bas)	1200	515	9785	1520	1: 1.27
5. *T. chilonis* + *Ha*NPV	1316	770	14630	6365	1: 4.84
6. *T. chilonis* + *Ha*NPV	1158	652	12388	4123	1: 3.56
7. *T. chilonis* + *B. t. k.*	1996	782	14858	6593	1: 3.30
8. *T. chilonis* + *B. t. k.*	1156	642	12198	3933	1: 3.40
9. *T.chilonis* + *B. bassiana*	1116	538	10222	1957	1: 1.75
10. *T. chilonis* + *B. bassiana*	716	545	10355	2090	1: 2.92
11. Chlorpyriphos	1320	689	13091	4826	1: 3.66
12. Untreated check	-	435	8265	-	-

* Mean of three observations based on three replications

Means in a column followed by same letter is not significantly different (P = 0.05) by DMRT

by chlorpyriphos 20EC alone (1: 3.66), two releases of *T. chilonis* with one spray of *Ha*NPV (1: 3.56), *Ha*NPV alone (1: 3.46) and two releases of *T. chilonis* with one spray of *B.t.k.* (1: 3.40). *B. bassiana* alone recorded lowest ICBR of 1: 1.27. The other treatments performed moderately regarding ICBR.

The gross income obtained was high in two releases of *T. chilonis* (6.25 cc/ha) at 45 and 60 DAS with two sprays of *B.t.k.* (1 kg/ha) at 90 and 120 DAS followed by two releases of *T. chilonis* (6.25 cc/ha) at 45 and 60 DAS with two sprays of *Ha*NPV @ 500 LE/ha at 90 and 120 DAS, three sprays of *B.t.k.* (1 kg/ha) alone at 60, 90 and 120 DAS and three sprays of *Ha*NPV alone at 60, 90 and 120 DAS. However, highest ICBR was observed in two releases of *T. chillonis* (6.25cc/ha) at 45 and 60 DAS with two sprays of *Ha*NPV (500 LE/ha) at 90 and 120 DAS followed by three sprays of chlorpyriphos (400g a. i./ha) at 60, 90 and 120 DAS and two releases of *T. chilonis* (6.25 cc/ha) at 60 and 90 DAS with one spray of *Ha*NPV (500 LE/ha i.e., 1.5 x 10^{12} POBs/ml), 120 DAS. This indicates that though gross income obtained was higher in some treatments, the ICBRs were lower because of higher cost incurred on the treatments. This is in line with Nagrare and More (1998).

ACKNOWLEDGEMENT

The first author expresses his gratitude to Indian Council of Agricultural Research, New Delhi for the financial help rendered through Senior Research Fellowship.

REFERENCES

Awate, B. G., Naik, L. M. and Parlkar, G. Y. 1997. Possibility of introducing exotic parasite, *Trichogramma brasiliensis* Ashmead in the integrated control of cotton bollworms. *Cotton Development*, **7**: 21 - 22.

Dhandapani, N., Kalyanasundaram, M., Swamiappan, M., Sundarababu, P. C. and Jayaraj, S. 1992. Experiments on management of major pests of cotton with biological control agents in India. *Journal of Applied Entomology*, **114**: 52 - 56.

Hazarika, L. K. and Puzari, K. C. 1997. Field efficacy of white muscardine fungus (*Beauveria bassiana*) on rice hispa (*Dicladispa armigera*). *Indian Journal of Agricultural Sciences*, **67**: 463-465.

Kalyanasundaram, M., Dhandapani, M., Swamiappan, M., Sundara Babu, P. C. and Jayaraj, S. 1991. Efficacy of *Trichogramma chilonis* Ishii, *Brinkochrysa scelestes* (Banks) and NPV of *Spodoptera litura* (Fabr.) against major pests of groundnut in India, pp. 60 - 66. In: *Midterm report: Biological control of insect pests through biotechnology*. Tamil Nadu Agricultural University, Coimbatore.

King, E. G., Bull, D. L., Bouse, L. F. and Phillips, J. R. 1985. Biological control of bollworm and tobacco cutworm in cotton by augmentative releases of *Trichogramma*. In: *Supplement to the South Western Entomologist*. No. **8**. Texas: Harring Printing Co. 198 pp.

Mani, M. and Krishnamoorthy, A. 1983. Recovery of two exotic parasites, *Trichogramma brasiliensis* and *Eucelatoria bryani* from *Heliothis armigera* in tomato fields. *Entomophaga*, **28**: 401 - 406.

Mishra, B. K. and Mandal, S. M. A. 1995. Integrated management of cotton pests with emphasis on bollworms. *Indian Journal of Plant Protection*, **23**: 135 - 138.

Nagrare, V. S. and More, G. D. 1998. Economics in using bioagents against *Helicoverpa armigera* on pigeonpea. *Indian Journal of Entomology*, **60**: 203 - 206.

Ramesh, K., Murali Mohan, C., Arunalakshmi, K., Padmavathi, J. and Umadevi, K. 1999. *Beauveria bassiana* Vuill. in cotton pest management: A field trial on the cotton leaf roller *Sylepta derogata* Fabr. (Lepidoptera: Pyraustidae). *Journal of Entomological Research*, **23**: 267 - 271.

Sangwan, H. S., Verma, S. N. and Sharma, V. K. 1972. Possibilities of exotic parasite *Trichogramma brasiliensis* Ashmead for the control of cotton bollworm. *Indian Journal of Entomology*, **34**: 360 - 361.

Saxena, H. and Ahmad, R. 1997. Field evaluation of *Beauveria bassiana* (Balsamo) Vuillemin against *Helicoverpa armigera* (Hübner) infesting chickpea. *Journal of Biological Control*, **11**: 93-96.

Singh, S. P. and Jalali, S. K. 1991. Chrysopid predators: their production and use. *Extra Bulletin No.* **2.** National Centre for Integrated Pest Management, 12 pp.

Varma, G. C. and Maninder, T. 1983. Establishment of *Trhichogramma brasiliensis* Ashmead (Trichogrammatidae, Hymenoptera) in the Punjab. *Cotton Development,* **13**: 31 - 32.

Wright, J. E. and Chandler, L. D. 1992. Development of an international myco-insecticide: *Beauveria bassiana* conidial formulation and its application against boll weevil populations (Celeoptera: Curculionidae). *Journal of Economic Entomology,* **85**: 1130-1135.