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Field efficacy of *Chrysoperla carnea* (Stephens) in combination with biopesticides against *Helicoverpa armigera* (Hübner) on cotton under rainfed condition

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ABSTRACT: The present investigation was carried out to study the field efficacy of *Chrysoperla carnea* (Stephens) in combination with biopesticides against *Helicoverpa armigera* (Hübner). The lowest mean larval population of *H. armigera*, minimum damage on shed squares, squares (intact), bolls and loculi and higher yield were recorded in two releases of *C. carnea* and two sprays of *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*) treated plots followed by *C. carnea* in conjunction with *Ha*NPV and *B.t.k* alone treated plots. The field recovery of *C. carnea*, *Ha*NPV infected, *Bacillus thuringiensis* var. *kurstaki* infected and *Beauveria bassiana* mycosed larvae was more in their respective alone treated plots. The incremental cost benefit ratio was obtained maximum in chlorpyriphos 20 EC alone (1: 3.66) followed by *Ha*NPV alone (1: 3.50), two releases of *C. carnea* with two sprays of *Ha*NPV (1: 2.88) and two releases of *C. carnea* with one spray of *Ha*NPV (1: 2.48).

KEYWORDS: Biopesticides, *Chrysoperla carnea*, cotton, *Helicoverpa armigera*, ICBR

INTRODUCTION

Cotton is an important commercial crop grown in an area of about 9 million hectares in India. Production of cotton is drastically reduced by the incidence of cotton bollworms *viz.*, *Earias* spp., *Helicoverpa armigera* (Hübner) and *Pectinophora gossypiella* Saunders. The insecticide consumption on cotton in India accounts to 52–55 per cent in India (Bhat, 1985). The indiscriminate use of insecticides has caused a number of ecological, economical and social problems in various ecological niches around the globe including India. Hence there is a need to concentrate on the use of biocontrol agents for the management of cotton pests. The green lacewing, *Chrysoperla carnea* (Stephens) is a polyphagous predator of cosmopolitan occurrence on several major insect pests such as *H. armigera*, *Earias* spp., *P. gossypiella* and others. It can be effectively used

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in pest management programmes because of its enhanced searching capacity coupled with voracious feeding habit and tolerance and/or resistance to many pesticides (Tolstova and Yu, 1986). The efficacy of *C. carnea* in cotton ecosystem has been well studied (Brar *et al.*, 1979; Mishra and Mandal, 1995). The reports on field efficacy of *C. carnea* in combination with biopesticides are scanty . The present investigation was carried out to find out the field efficacy of *C. carnea* in combination with biopesticides against the cotton bollworms.

MATERIALS AND METHODS

A field trial was laid out to evaluate the efficacy of *C. carnea* in combination with *Ha*NPV, *Bacillus thuringiensis* var. *kurstaki* and *Beauveria 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 45x30 cm. All recommended agronomic practices were followed. The plot size adopted was 40m^2 and each treatment was replicated thrice. A distance of 100m was maintained between *C. carnea* released plots. To control the early season sucking pests, a spray of dimethoate (0.04%) was given on 30 days after sowing (DAS) uniformly to all the treatments including untreated check. The eggs of *C. carnea* were mixed with the sawdust, and immediately after hatching they were dusted randomly on the plants during evening hours. NPV was sprayed after mixing with jaggery (0.5%) and Triton (0.1%) at monthly interval. The *B. thuringiensis* var. *kurstaki* (Halt® WP) and *B. bassiana* (Bev Bas) were sprayed after mixing with Triton (0.1 %) at monthly interval. The biopesticides and insecticides were applied at the specified dose in 500 litres of water using high volume sprayer (Anonymous, 1991).

Table 1. Treatment details

Sl. no.	Treatment	Dose or no. of releases / ha
1.	*C. carnea*	Four releases @ 50,000 / ha, 45, 70, 95 and 120 DAS
2.	*Helicoverpa armigera* NPV (*Ha*NPV)	Three sprays @ 500 LE/ ha (1.5 x 10^{12} POBs/ml), 70, 95 and 120 DAS
3.	*B. thuringiensis* var. *kurstaki* (*B.t.k.*) (Halt® WP)	Three sprays @ 1 kg/ ha, 70, 95 and 120 DAS
4.	*B. bassiana* (Bev Bas)	Three sprays @ 2 kg/ ha, 70, 95 and 120 DAS
5.	*C. carnea* + *Ha*NPV	Two releases of *C. carnea* @ 50,000/ ha 45 and 70 DAS + two sprays of *Ha*NPV @ 500 LE/ha, 95 and 120 DAS
6.	*C. carnea* + *Ha*NPV	Two releases of *C. carnea* @ 50,000/ ha, 70 and 95 DAS + one spray of *Ha*NPV @ 500 LE @ 120 DAS
7.	*C. carnea* + *B. t. k.*	Two releases of *C. carnea* @ 50,000 / ha at 45 and 70 DAS + two sprays of *B. t. k.* @ 1 kg/ ha, 95 and 120 DAS
8.	*C. carnea* + *B. t. k.*	Two releases of *C. carnea* @ 50,000 / ha, 70 and 95 DAS + one spray of *B. t. k.* @ 1 kg/ ha, 120 DAS
9.	*C. carnea* + *B. bassiana*	Two releases of *C. carnea* @ 50,000 / ha, 45 and 70 DAS + two sprays of *B. bassiana* @ 2 kg / ha, 95 and 120 DAS
10.	*C. carnea* + *B. bassiana*	Two releases of *C. carnea* @ 50,000/ ha, 70 and 95 DAS + one spray of *B. bassiana* @ 2 kg / ha, 120 DAS
11.	Chlorpyriphos 20 EC	Three sprays @ 400g a. i./ ha, 70, 95 and 120 DAS
12.	Untreated check	-

The bollworm incidence was recorded from 10 randomly selected tagged plants in each replicate, expressed in terms of per cent infestation on green fruiting bodies (squares, flowers and bolls) due to *H. armigera* infestation on open bolls by boll and locule basis at harvest. Data on *C. carnea* stalked eggs and grubs, virosed, *B.t.k.* affected and mycosed larvae were recorded weekly after respective treatments for recovery studies. 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.

RESULTS AND DISCUSSION

H. armigera larval population and damage

The lowest mean larval population was observed in two releases of *C. carnea* and two sprays of *B.t.k.* treated plots with 0.33 per plant against the untreated check with 3.43 per plant. *C. carnea* in conjunction with two sprays of *Ha*NPV and *B.t.k.* alone treated plots recorded 0.37 and 0.50 larvae per plant. The mean larval population was maximum on *B. bassiana* alone treated plots with 2.23 per plant among the treatments (Table 2).

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

Sl. no.	Treatment	Mean larval population of *H. armigera*/ plant	*H. armigera* damage (%)				Yield (kg/ ha)	Increase in yield over untreated check (%)
			Shed square	Square (intact)	Boll	Locule		
1.	*C. carnea*	1.63^{h}	58.15^{g}	18.21^{g}	28.05^{g}	27.10^{g}	638	42.41
2.	*Ha*NPV	0.60^{d}	47.84^{d}	12.17^{d}	19.21^{d}	17.76^{d}	724	61.61
3.	*B. thuringiensis* var. *kurstaki* (*B.t.k.*) (Halt® WP)	0.50^{c}	44.26^{c}	11.15^{c}	17.86^{c}	15.12^{c}	761	69.87
4.	*B. bassiana* (Bev Bas)	2.23^{j}	66.48^{i}	23.78^{i}	36.92^{i}	31.92^{i}	573	27.90
5.	*C. carnea* + *Ha*NPV	0.37^{b}	40.43^{b}	10.25^{b}	15.11^{b}	11.44^{b}	778	73.67
6.	*C. carnea* + *Ha*NPV	1.20^{g}	55.72^{f}	15.78^{f}	24.37^{f}	22.96^{f}	667	48.88
7.	*C. carnea* + *B. t. k.*	0.33^{a}	37.63^{a}	9.01^{a}	13.24^{a}	9.84^{a}	804	79.46
8.	*C. carnea* + *B. t. k*	1.13^{f}	56.27^{f}	15.92^{f}	25.12^{f}	23.21^{f}	674	50.45
9.	*C. carnea* + *B. bassiana*	1.80^{i}	62.36^{h}	21.02^{h}	32.44^{h}	28.87^{h}	603	34.60
10.	*C. carnea* + *B. bassiana*	1.67^{h}	59.40^{g}	18.34^{g}	28.59^{g}	27.35^{g}	626	39.73
11.	Chlorpyriphos 20 EC	0.73^{e}	51.58^{e}	13.84^{e}	21.73^{e}	19.38^{e}	702	56.70
12.	Untreated check	3.43^{k}	72.14^{j}	28.05^{j}	40.95^{j}	37.54^{j}	448	-

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

The damage by *H. armigera* on shed squares, squares (intact), bolls and loculi varied from 37.63 to 66.48, 9.01 to 23.78, 13.24 to 36.92 and 9.84 to 31.92 per cent, respectively. In all the cases, minimum damage was observed in two releases of *C. carnea* with two sprays of *B.t.k.* treated plots and maximum was in *B. bassiana* alone treated plots among the treatments. In untreated plots, 72.14, 28.05, 40.95 and 37.54 per cent of damage on shed squares, squares (intact), bolls and loculi occurred, respectively (Table 2).

The seed cotton yield varied from 573 to 804 kg/ ha among the treatments against the untreated check (448 kg/ha). Two releases of *C. carnea* in conjunction with two sprays of *B.t.k.* or two sprays of *Ha*NPV treated plots recorded the higher yields of 804 and 778 kg / ha, respectively. Minimum yield was obtained in plots treated with *B. bassiana* alone. The yield increase over untreated check ranged from 27.90 to 79.46 per cent. The minimum yield was in *B. bassiana* alone treated plots and maximum was in two releases of *C. carnea* with two sprays of *B.t.k.* treated plots (Table 2).

The lowest damage (on squares, bolls and loculi) and highest yield with highest gross income were recorded in two releases of *C. carnea* (50,000/ ha) at 45 and 70 DAS with two sprays of *B.t.k.* (1kg/ ha) at 95 and 120 DAS, followed by two releases of *C. carnea* (50,000/ ha) with two sprays of *Ha*NPV (500 LE/ha (i.e.,1.5 x 10^{12} POBs/ml) at 95 and 120 DAS three sprays of *B.t.k.* alone at 70, 95 and 120 DAS, three sprays of *Ha*NPV alone at 70, 95 and 120 DAS and three sprays of chlorpyriphos (400g a. i./ha) at 70, 95 and 120 DAS. However, highest yield was recorded in insecticide treated plots compared to biocontrol agents and microbial insecticides used plots (Dhandapani *et al.*, 1992; Panchabhavi *et al.*, 1995).

The yield reduction in insecticide treated plots of the present investigation may be due to the manifold resistance developed by *H. armigera* to insecticides. In addition, the behavioural pattern of larvae of *H. armigera* feeding on squares, flowers and bolls in a hidden manner and thus escapes from the exposure to the application of insecticides. In case of application of NPV and *B.t.k.*, addition of jaggery as phagostimulant played an important role in causing highest mortality compared to insecticides in the present study. Among the microbial pesticides used, the mean larval population of *H. armigera* and damage were in the decreasing order of *B.t.k.*, *Ha*NPV and *B. bassiana*. Jayanthi (1992) and Manjula and Padmavathamma (1999) proved the efficacy in decreasing order of *B.t.k.*, *Ha*NPV and *B. bassiana* against *H. armigera* under laboratory conditions.

The integration of *C. carnea* and biopesticides resulted in higher yields compared to their respective sole treatments, only if *C. carnea* was released in time, (at 45 and 70 DAS) with two sprays of respective biopesticides. It could be explained that *C. carnea* feeds on *H. armigera* eggs and neonate larvae. The larvae escaped from *C. carnea* may develop as grown up instars, which will be checked by application of biopesticides.

Field recovery

Field recovery of *C. carnea* was observed in two ways through number of eggs per plant and number of grubs per plant. Maximum number of *C. carnea* eggs per plant was observed in *C. carnea* alone released plots (8.60 per plant) and minimum in insecticide treated plots with 1.67 per plant. The untreated plots recorded *C. carnea* eggs of 3.00 per plant. Number of *C. carnea* grubs recovered ranged from 0.03 to 5.67 per plant and the maximum number was observed in *C. carnea* alone treated plots. The NPV infected larvae were recovered more from *Ha*NPV alone treated plots (1.15 per plant) and it was low (0.03/ plant) in insecticide treated plots. The *B. t. k.* infected (1.13 to 1.40/plant) and mycosed larvae (0.14 to 0.33/plant) were recovered, respectively from their treated plots (Table 3).

In general, more number of *C. carnea* was recovered from *C. carnea* released plots compared to unreleased plots. *C. carnea* recovered in insecticide treated plots were even lesser than untreated check plots because of the toxic effect of insecticide on *C. carnea*. *Ha*NPV infected larvae were found more in *Ha*NPV treated plots and less in untreated plots. The *B.t.k.* and mycosed larvae

Table 3. Field recovery of *C. carnea*, *Ha*NPV, *B.t.k.* infected and mycosed larvae in different treatments

Sl. no.	Treatment	* Field recovery				
		C. carnea		NPV infected larvae (No./ plant)	*B. t. k.* infected larvae (No./ plant)	Mycosed larvae (No./plant)
		No. of eggs / plant	No. grubs/ plant			
1.	*C. carnea*	8.60[a]	5.67[a]	0.07[d]	0.00[d]	0.00[d]
2.	*Ha*NPV	3.27[g]	0.07[e]	1.15[a]	0.00[d]	0.00[d]
3.	*B. thuringiensis* var. *kurstaki* (*B.t.k.*) (Halt® WP)	3.33[g]	0.03[f]	0.06[f]	1.40[a]	0.00[d]
4.	*B. bassiana* alone (Bev Bas)	4.00[f]	0.07[e]	0.07[d]	0.00[d]	0.33[a]
5.	*C. carnea* + NPV	4.67[e]	2.23[d]	0.91[b]	0.00[d]	0.00[d]
6.	*C. carnea* + NPV	2.87[c]	4.47[c]	0.82[c]	0.00[d]	0.00[d]
7.	*C. carnea* + *B. t. k.*	4.00[f]	2.33[d]	0.07[d]	1.23[b]	0.00[d]
8.	*C. carnea* + *B. t. k.*	6.43[b]	4.87[b]	0.07[d]	1.13[c]	0.00[d]
9.	*C. carnea* + *B. bassiana*	5.23[d]	2.30[d]	0.07[d]	0.00[d]	0.21[b]
10.	*C. carnea* + *B. bassiana*	5.67[c]	4.40[c]	0.08[d]	0.00[d]	0.14[c]
11.	Chlorpyriphos 20 EC	1.67[i]	0.03[f]	0.03[g]	0.00[d]	0.00[d]
12.	Untreated check	3.00[h]	0.07[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 (s) are not significantly different (P = 0.05) by DMRT.

were found only in their respective treated plots and not occurred naturally.

Incremental Cost Benefit Ratio (ICBR)

The cost incurred on different treatments varied from Rs. 1200/ha (*B. bassiana* alone) to Rs. 2950/ha (*C. carnea* alone). Highest additional gross income was recorded in two releases of *C. carnea* with two sprays of *B.t.k.* (Rs. 6764/ha) followed by two releases of *C. carnea* with two sprays of *Ha* NPV (Rs. 6270/ha) *B.t.k.* alone (Rs. 5947/ha) and *Ha*NPV alone (Rs. 5244/ha). *B. bassiana* alone recorded lowest additional gross income over untreated check (Rs. 2375/ha). The incremental cost benefit ratio (ICBR) was in the order of chlorpyriphos 20 EC alone (1 : 3.66) > *Ha*NPV alone (1: 3.50) > two releases of *C. carnea* with two sprays of *Ha*NPV (1 : 2.88) > two releases of *C. carnea* with one spray of *Ha*NPV (1: 2.48) and others remained below. ICBR was equal (1: 2.36) for *B.t.k.* alone and two releases of *C. carnea* with two sprays of *B. t. k.* Lowest ICBR (1:1.22) was observed with *C. carnea* alone treatment because of its higher cost (Table 4).

The ICBR calculated were not in proportionate to the gross income obtained in some treatments. This is because of the higher cost incurred on the treatments. The highest ICBR was obtained in insecticide treated plots followed by *Ha*NPV alone treated plots, two releases of *C. carnea* (50,000/ ha) 45 and 70 DAS with two sprays of *Ha*NPV (500 LE/ ha *i.e.*, 1.5 x 10^{12} POBs/ml), 95 and 120 DAS and two releases of *C. carnea* (50,000/ha), 70 and 95 DAS with one spray of *Ha*NPV, 120 DAS. Lowest

Table 4. Effect of *C. carnea* in combination with biopesticides on seed cotton yield and cost benefit ratio

Sl. no.	Treatment	Cost of treatment (including application charges) (Rs./ha)	Seed cotton yield kg/ha	Gross income (Rs. / ha)	Additional income over untreated check (Rs./ha)	Incremental cost benefit ratio (ICBR)
1.	*C. carnea*	2950	638	12122	3610	1: 1.22
2.	*Ha*NPV	1500	724	13756	5244	1:3.50
3.	*B. thuringiensis* var. *kurstaki* (*B.t.k.*) (Halt® WP)	2520	761	14459	5947	1:2.36
4.	*B. bassiana* alone (Bev Bas)	1200	573	10887	2375	1:1.98
5.	*C. carnea* + NPV	2180	778	14782	6270	1:2.88
6.	*C. carnea* + NPV	1680	667	12673	4161	1:2.48
7.	*C. carnea* + *B. t. k.*	2860	804	15276	6764	1:2.36
8.	*C. carnea* + *B. t. k.*	2020	674	12806	4294	1:2.13
9.	*C. carnea* + *B. bassiana*	1980	603	11457	2945	1:1.48
10.	*C. carnea* + *B. bassiana*	1580	626	11894	3382	1:2.14
11.	Chlorpyriphos 20 EC alone	1320	702	13338	4826	1:3.66
12.	Untreated check	-	448	8512	-	-

Market price value of seed cotton = Rs. 1900/quintal

ICBR (1:1.22) was obtained in *C. carnea* alone released plots, which corroborate with the report of Praveen and Dhandapani (2001) who calculated it as 1:1.94 on tomato. This may be due to the higher cost of the biocontrol agent *C. carnea*.

Looking to the principles of pest management and to avoid negative effects on biocoenosis of cotton and possible development of resistance (Chari *et al.*, 1981), it is necessary to follow release of biocontrol agent alternately with biopesticides and restricted insecticide application to reduce the damage caused by bollworms.

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