

Journal of Biological Control, 38(4): 413-419, 2024, DOI: 10.18311/jbc/2024/46321

Research Article

Field evaluation of the delivery system of native predatory bug, *Eocanthecona furcellata* for the management of lepidopteran pests in pulse crops

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ABSTRACT: *Eocanthecona furcellata* (Hemiptera: Pentatomidae) is predatory on most of the lepidopteran insect pests. This bug has been recorded in different regions of India from various crop ecosystems. In Uttarakhand, this predator has been found predating upon different pests of various crops viz. pulses, wheat, rice, soybean, maize, *etc* grown in plains, foothills, mid hills, valleys and high hills. The mass production technology of this predator has also been developed in the laboratory on hosts such as *Spodoptera litura* and *Corcyra cephalonica*. Further, the different release methods in crop fields and rates of release of this insect were studied on pulse crops. Cage experiments were conducted to evaluate the effective predacious stages of this bug and its field release doses in different pulse crop ecosystems. The experiments were carried out in the *tarai* region of Uttarakhand during 2020-2022. The results revealed that 4th and 5th nymphal instars as well as the adults were voracious feeders in the pulse ecosystem. The population of *Maruca vitrata* on mungbean and pigeonpea was reduced significantly by 4th and 5th nymphal instars as compared to other stages of the insect. Thus, the nymphal and adult stages were found to be appropriate to be employed for the management of insect pests in pulse crops. The experiments were also conducted on the dose determination in which different rates as 2, 3, 6, 9, 12 and 15 nymphs and adults per cage were used for the control of *S. litura*. The results revealed a 62.00 and 54.13% reduction of *S. litura* population in soybean, 60.89 and 62.50% in pigeonpea, 63.99 and 60.02% in mungbean in *S. litura* population was found at 10 days after release of the nymphs and adults of the bug respectively at the rate of 9 nymphs and 9 adults per cage. The present results indicate that the releasing rates of 9 nymphs and 9 adults per cage in the pulse ecosystem were satisfactory for suppressing *S. litura* population. This study will be of significant importance in achieving successful management of lepidopterous insect pests through field release of the predator at specified doses.

KEYWORDS: *Eocanthecona furcellata*, field release, lepidopteran pests, predatory bugs

(Article chronicle: Received: 12-10-2024; Revised: 08-12-2024; Accepted: 10-12-2024)

INTRODUCTION

The use of biological control is found to be one of the best eco-friendly alternatives as compared to the use of synthetic insecticides for controlling insect pests in fields. The utilization of natural enemies for the management of insect pests has been growing due to environmental, economic, social and ecological problems encountered with indiscriminate use of insecticides. The chemical control of insect pests seems to be unsuccessful with instances of pest resurgence, resistance to a variety of insecticides and their ill impacts on our environment. Therefore, there is a need to focus our attention on Bio-intensive Integrated Pest Management (BIPM) which is a perfect solution to utilize all the components harmoniously with special reference to the utilization of natural enemies like parasitoids and predators to secure sustainable crop production (Grenier *et al.*, 1995). Several predators of Pentatomidae, Anthocoridae and Reduviidae play a key role in suppressing the pest population in India (Sahayaraj, 2002) and they can be utilized as biological control agents in different crop ecosystems (Sahayaraj & Jeyalekshmi, 2002; Sahayaraj & Martin, 2003). More than sixty species of arthropods prey on *Helicoverpa armigera* in India (Romeis & Shanower, 1996). More than 65 reduviid predators were reported from various ecosystems such as cotton, soybean, rice, sugarcane, groundnut, wheat, sunflower, pigeonpea, *etc*. (Sahayaraj & Balasubramanian, 2016). Hence, there is a better scope for utilizing these predators in the biological control programme in the future.

Eocanthecona furcellata (Wolff) (Hemiptera: Heteroptera: Pentatomidae: Asopinae) is a predatory Asopine bug and is considered one of the most promising predators of many lepidopteran pests of many economically important crops. It is found worldwide, especially in Southeast Asian countries like India, Japan, Taiwan, the southern part of China and Okinawa (De Clercq, 2000; Yasuda, 2000) in various

crops. It was found associated with *Spodoptera litura* F. and *Chrysodeixis acuta* Walker of soybean (Ahirwar, 2013), crops like paddy (Sharma *et al*., 2015), red gram, chickpea, groundnut, urd bean, mungbean, cotton and vegetable fields preying on larvae of *H. armigera* Hubner, tobacco caterpillar and hairy caterpillars (Yi & Kyi, 2000b; Nyunt, 2008; Nabapure & Agnihotri, 2011), okra lepidopteran pests like *Earias insulana* (Fabricius) and *Earias vitella* (Fabricius) (Bhatt *et al*., 2018), American bollworm in Myanmar (Yi & Kyi, 2000a; Aruna & Devi, 2015) and in forest ecosystems (Aland *et al*., 2010). The mass rearing of *E. furcellata* is possible and cost effective on easily available hosts like *Corcyra cephalonica, Galleria mellonella, Samia cynthia ricini* and *S. litura*. These predators have been established as important biological control agents of the important pests in various crop ecosystems. They have also been released in net houses and fields and have been successful in bringing down the pest populations. Therefore, this study was conducted for the development and standardization of suitable methods of field release of this insect and the determination of the rate of release of predatory bugs for the management of lepidopteran insect pests.

MATERIALS AND METHODS

Predator collection and mass-rearing

The experiments were conducted in the Biological Control Laboratory, Department of Entomology, College of Agriculture, G.B. Pant University Agriculture and Technology, Pantnagar, Uttarakhand, India. The eggs and other biological stages of predatory bug, *E. furcellata* were collected from different crop ecosystems *viz.* rice, wheat, soybean, urd bean, mungbean, pigeonpea, maize, sugarcane, cowpea and poplar through hand picking method. The initial culture was maintained in the laboratory at a temperature of 32±2°C, relative humidity 75±5% and photoperiod 12±1 h. The culture of the predatory bug was maintained in plastic containers (20×20×15 cm) lined with blotting paper and moist cotton was kept to maintain the moisture.

The predator was mass-reared on a tobacco caterpillar, *S. litura* under laboratory conditions. The eggs of the prey, *S. litura* were collected from the field and brought to the laboratory. The eggs were kept in plastic boxes with castor leaves and moist cotton. After hatching more castor leaves were provided as food. The larvae of *S. litura* served as factitious hosts for the predator. The rearing of both the predator and the prey continued during the whole experimental period.

Predator release in the fields

The experiments were initially conducted to know the suitable stages of *E. furcellata* for field release in different crops. The appropriate stage of the predator to be released must be evaluated to release them precisely in the field. The different techniques were evaluated to determine the delivery system of predatory bugs in different pulse crop ecosystems. Experiments were also conducted to determine the rate of release of selected stages of the potential predatory bug under pulse crops based on performances in the fields to keep the insect pest population below an economic threshold level. Experiments were conducted to evaluate different field release methods at N.E.B. Crop Research Centre, Pantnagar against spotted pod borer (*Maruca vitrata*) in pigeonpea and mung bean due to the devastating effect of the pest on these crops. The efficacy of four treatments was compared including control and each treatment was replicated thrice in a randomized block design. The four treatments were as *E. furcellata* eggs placed on the foliage of crops (50 eggs per plot), *E. furcellata* nymphs (2nd to 5th instar) released on the foliage of crops (25 nymphs per plot), *E. furcellata* adults released on the foliage of the crop (25 adults per plot) and control.

For the field experiment, the egg masses were tagged to the foliage of the crops in the field. The nymphs and adults were also released carefully onto the foliage of the plants in the field. One untreated plot was also left as a control for comparison between the treatments. The delivery method experiment was conducted for tall crops and dwarf crops separately. For tall crops, the delivery method of *E. furcellata* was evaluated on pigeonpea crops whereas for dwarf crops same was evaluated on mungbean crops. The observations were taken as to how much control has been achieved. This was done by counting the population of the prey before the release of the predator stage and also after 7 DAR (Day After Release) of the crop, 45 DAR and 60 DAR in mungbean whereas, the population of spotted pod borer was recorded at before release, 75 DAR, 90 DAR and 105 DAR in pigeonpea crop. The average values were calculated and equated with the population of the untreated plots (*i.e.,* plots without any predator stage). The data obtained was subjected to statistical analysis.

After the selection of a suitable delivery method and stage of release of the predator for the field release of *E. furcellata*, the rate of release was also evaluated on pulse crops. For carrying out this experiment, the field cage technique was used to evaluate the capabilities of the predator (Barry *et al*., 1974; Richman *et al*., 1980). Nylon net cages (6' long x 4' wide x 6' high) were used to cover different crops like mungbean, and soybean and 6' long x 4' wide x 6' high net cages for pigeonpea. Seven different doses (2, 3, 6, 9, 12 and 15) of both nymphal instars (IV) and adults were evaluated under field cage conditions against *S. litura* including control. In each cage, 10 larvae (3rd instar) of *S. litura* were released.

Each treatment was replicated thrice. The observations were taken by counting the reduction in population of the prey after 3 DAR, 5 DAR, 7 DAR and 10 DAR of the predatory bug. The average values were calculated and compared with the population of the untreated plots (*i.e.*, plots without the predators). The data obtained was subjected to statistical analysis.

Duncan's multiple range test, through one-way ANOVA (OP STAT, 2015), was used to estimate the significance between the infestation rates of both pests. The reduction percentages in *S. litura* populations were calculated per cage as a mean (for each treatment) and compared with the control. These percentages were estimated according to Abbott's (1925) formula because there were no significant differences among the treatments and the control for each pest density on the crops at the beginning of the experiment.

Reduction % = (Control count- Treatment count/Control count) x 100

RESULTS AND DISCUSSION

The results of the field release methods of predatory bug, *E. furcellata* are presented in Table 1 for tall crops. Results on the pigeonpea crop revealed that the *M. vitrata* population at pre-count varied non-significantly from 20.3±1.3 to 21.3±0.9 larvae per 5 pigeonpea plants in the field. After release of the different predator stages at 75 DAS, maximum *M. vitrata* population 19.3±0.88 larvae/5 plants, 11.3±0.9 larvae/5 plants and 12.7±1.2 larvae/5 plants was recorded in the plot with *E. furcellata* eggs releases at 75 DAS, 90 DAS and 105 DAS, respectively, whereas lowest *M. vitrata* population 10.3±0.3 larvae/5 plants, 7.3±0.9 larvae/5 plants and 6.7±0.9 larvae/5 plants at 75, 90 and 105 DAS, respectively was recorded in the plot with *E. furcellata* 5th instar nymphs followed by 11.0±1.5 8.0±0.6 and 7.7±0.9 larvae/5 plants at 75, 90 and 105 DAS, respectively in *E. furcellata* 4th instar nymph released plot. The results revealed that there was no significant difference in the *M. vitrata* population between the treatments with *E. furcellata* 4th instars and *E. furcellata* 5th instars released plots. It is evident from the results that 4th and 5th nymphal instars are voracious feeders and help reduce the population of *M. vitrata* efficiently as compared to *E. furcellata* adults and other nymphal stages. Hence, these nymphal (4th and 5th) stages can be utilised for field releases against pests in tall crops like pigeonpea.

Results on the mungbean crop (Table 2) revealed that *M. vitrata* population at pre-count varied non-significantly from 20.0±1.2 to 22.7±1.5 larvae per 5 mungbean plants in the field. After release of the different predator stages at 7 DAR, maximum *M. vitrata* population 19.3±1.3 larvae/5 plants, 15.7±0.9 larvae/5 plants and 15.7±0.3 larvae/5 plants was recorded in the plot with *E. furcellata* eggs releases at 7 DAR, 15 DAR and 21 DAR, respectively, whereas lowest *M. vitrata* population 10.0±0.6 larvae/5 plants, 7.3±0.9 larvae/5 plants and 4.7±0.3 larvae/5 plants at 7, 15 and 21 DAR, respectively was recorded in the plot with *E. furcellata* 5th instar nymphs followed by 10.0±1.2, 7.7±0.3 and 5.7±0.7 larvae/5 plants at 7, 15 and 21 DAR, respectively in *E. furcellata* 4th instar nymph released plot. Results showed that there is no significant difference among the *M. vitrata* population between the treatment with *E. furcellata* 4th instar and 5th instar released plots. The results revealed that 4th and 5th instar nymphs were better at reducing the population of *M. vitrata* efficiently as compared to *E. furcellata* adults and other nymphal stages. Hence, these nymphal (4th and 5th) stages can be utilised for the field releases against pests in low canopy crops like mungbean, soybean, *etc*.

From the results, it is clear that egg-released methods required some time to give control against the pest. In the case of the egg method, eggs were placed onto the leaves, nymphs did not find a suitable site for shelter and feeding immediately.

Table 1. Effect of different field release methods of *E. furcellata* in tall crops, *i.e.,* pigeonpea

Treatments	Population of prey				
	Pre-population	75 DAS	90 DAS	105 DAS	Mean no. of *Maruca* per 5 plants after release
Eggs on foliage	20.7±1.2	19.3±0.9	11.3±0.9	12.7±1.2	14.4
Nymphs 2nd instar	20.3±1.3	14.0±1.2	10.0±0.6	12.3±1.3	12.1
Nymphs 3rd instar	22.7±1.5	12.3±1.5	8.7±0.9	9.3±0.9	10.1
Nymphs 4th instar	22.7±0.9	11.0±1.5	8.0±0.6	7.7±0.9	8.9
Nymphs 5th instar	20.3±1.9	10.3±0.9	7.3±0.9	6.7±0.9	8.1
Adults	21.3±0.9	10.3±0. 3	10.3±0.9	11.7±0.9	10.7
Control	21.3±0.9	21.0±1.2	20.7±0.9	21.7±0.9	21.1
CD @ 5%	2.4 ns	3.5	2.6	3.2	-

Table 2. Effect of different field release methods of *E. furcellata* in dwarf crop, mung bean

Treatments	Population of prey				Mean no. of *Maruca* per 5 plants after release
	Pre-population	7 DAR	15 DAR	21 DAR	
Eggs on foliage	20.3±0.9	19.3±1.3	15.7±0.9	15.7±0.3	16.9
Nymphs 2nd instar	21.7±1.7	18.3±1.2	12.0±0.6	9.0±0.6	13.1
Nymphs 3rd instar	20.0±1.2	14.7±0.7	11.0±1.7	10.0±2.0	11.9
Nymphs 4th instar	22.7±1.5	10.0±1.2	7.7±0.3	5.7±0.7	7.9
Nymphs 5th instar	20.3±1.9	10.0±0.6	7.3±0.9	4.7±0.3	7.3
Adults	20.3±0.9	10.3±0.6	10.0±0.6	9.7±0.3	9.9
Control	21.3±1.2	21.0±1.2	19.7±0.9	20.7±0.3	20.5
CD @ 5%	3.3 ns	3.0	3.0	2.7	-

As the nymphs of this predator are zoophytophagous in nature, so, immediately after hatching they need plant sap to feed. Hence, there might be high mortality of the eggs and hatched nymphs in both cases and hence low control of the pest. In the nymph release method, a high number of predations was reported in the plot because there was no waiting period for the predation. Nymphs started predating on the prey just after the release and continued feeding up to the adult stage. In the instance of adult release, an average level of predation was reported from the time of release to the end of the trial. The adults' active flying character accounted for the average predation. They flew around in the cage after a while; however, they provided good predation compared to the initial nymphal stages.

It is, therefore, concluded that the nymph release method of *E. furcellata* in the field had an added advantage and provided good control of insect pests for a longer period when compared to other ways of field release.

As per the results of the previous experiment, 4th instar nymphs and adults of the predatory bug, *E. furcellata* provided maximum predation on the prey. So they were further utilised to determine the rate of release of the same in the field conditions in mungbean, soybean and pigeonpea plants. Results of same has been presented in Tables 3, 4 and 5. Results in mungbean revealed a progressive decline in prey population in all the treatments at 3 DAR, 5 DAR, 7 DAR and 10 DAR of predatory nymphs. At 10 DAR maximum reduction (63.99%) of prey population was found at dose 9 nymphs/cage which was at par with the reduced population reported in the treatments of doses 6, 12 and 15 nymphs/cage at 10 DAR. Similarly, in the case of adult releases, a significant reduction in prey population was reported in all the treatments at 3 DAR, 5 DAR, 7 DAR and 10 DAR of predatory adults. At 10 DAR maximum reduction (60.02 %) of the prey population was found at dose 9 adults/cage which was at par with the prey population reported in the treatments of doses 6, 12 and 15 adults/cage at 10 DAR (Table 3).

In soybean also both 4th instar nymphs and adults were evaluated for the determination of doses. Results of the same has been presented in Table 4. Results revealed a significant reduction in prey population in all the treatments at 3 DAR, 5 DAR, 7 DAR and 10 DAR of predatory nymphs. At 10 DAR maximum reduction (62.00 %) in prey population was found at dose7 nymphs/cage which is at par with the reduction of prey population reported in the treatments of doses 6, 12 and 15 nymphs/cage. Similarly, in the case of adult releases a significant reduction in prey population was reported in all the treatments at 3 DAR, 5 DAR 7 DAR and 10 DAR of the adult bugs. At 10 DAR maximum reduction (54.13%) of the prey population was found at dose 9 adults/cage which is at par with the prey population reported in the treatments of doses 6, 7, 12 and 15 adults/cage at 10 DAR.

Similarly in pigeonpea, also both 4th instar nymphs and adults were evaluated for the determination of doses. Results of the same has been presented in Table 5. Results revealed a significant reduction in prey population in all the treatments at 3 DAR, 5 DAR, 7 DAR and 10 DAR of predatory nymphs. At 10 DAR maximum reduction (60.89%) in prey population was found at dose 9 nymphs/cage which is at par with the reduction of prey population reported in the treatments of doses 6, 7, 12 and 15 nymphs/cage. Similarly, in the case of adult releases a significant reduction in prey population was reported in all the treatments at 3 DAR, 5 DAR 7 DAR and 10 DAR of the adult bugs. At 10 DAR maximum reduction (62.50%) of the prey population was found at dose 9 adults/cage which is at par with the prey population reported in the treatments of doses 6, 7, 12 and 15 adults/cage at 10 DAR.

The results aligned with the experiments conducted by Montemayor and Cave (2012) where the predation capacity of the spined soldier bug, *Podisus maculiventris* (Say) (Hemiptera: Pentatomidae), was evaluated at three release rates in field cages containing larvae of the yellow margined leaf beetle, *Microtheca ochroloma* Stål (Coleoptera: Chrysomelidae), a pest of organic crucifer (Brassicaceae)

Table 3. Evaluation of different release rates of *E. furcellata* nymphs on Mung bean

Treatments	Population of prey/cage in mung bean															
	3 DAR				5 DAR				7 DAR				10 DAR			
	Nymphs	Reduction %	Adults	Reduction %	Nymphs	Reduction %	Adults	Reduction %	Nymphs	Reduction %	Adults	Reduction %	Nymphs	Reduction %	Adults	Reduction %
2/cage	8.7±0.3	7.0	8.3±0.3	10.7	7.0±0.6	22.2	7.0±1.0	19.2	6.7±0.9	23.0	6.6±1.3	19.9	6.3±0.9	24.0	6.3±1.2	24.0
3 /cage	7.0±0.6	24.9	8.0±0.6	14.2	6.7±0.7	25.8	6.6±0.8	23.0	5.7±0.3	34.6	5.6±0.6	31.9	5.0±0.6	39.9	5.3±0.9	36.0
6/cage	5.7±0.3	39.2	7.3±0.3	21.4	5.3±0.3	40.7	5.3±0.3	38.5	4.7±0.3	46.1	4.6±0.3	43.9	3.6±0.3	55.9	3.6±0.3	55.9
9/cage	5.3±0.3	42.8	7.0±0.6	24.9	4.7±0.3	48.1	4.6±0.3	46.1	4.0±0.6	53.8	4.3±0.3	48.0	3.0±0.6	63.9	3.3±0.3	60.0
12/cage	7.3±0.3	21.4	8.3±0.3	10.7	5.3±0.3	40.7	4.6±0.3	46.1	4.3±0.3	50.0	4.3±0.3	48.0	4.0±0.6	51.9	4.0±0.6	51.9
15/cage	7.3±0.7	21.4	9.0±0.0	3.5	4.7±0.3	48.1	4.6±0.3	46.1	4.3±0.7	50.0	4.6±0.3	43.9	4.0±0.6	51.9	4.3±0.3	48.0
Control	9.3±0.3	0.0	9.3±0.3	0.0	9.0±0.6	0.0	8.6±0.3	0.0	8.7±0.3	0.0	8.3±0.3	0.0	8.3±0.3	0.0	8.3±0.3	0.0
CD @ 5%	**1.3	-	*1.3	-	**1.4	-	**1.8	-	**1.2	-	*2.0	-	*2.4	-	*2.0	-

Table 4. Evaluation of different release rates of *E. furcellata* nymphs on soybean

Treatments	Population of prey/cage in soybean															
	3 DAR				5 DAR				7 DAR				10 DAR			
	Nymphs	Reduction %	Adults	Reduction%	Nymphs	Reduction %	Adults	Reduction%	Nymphs	Reduction %	Adults	Reduction%	Nymphs	Reduction%	Adults	Reduction%
2/cage	8.7±0.3	7.0	8.7±0.8	3.6	7.7±0.3	11.5	7.7±0.3	7.9	6.7±0.8	23.0	7.0±0.5	12.5	6.3±0.9	26.9	6.6±0.3	16.6
3/cage	8.3±0.3	10.7	8.0±0.5	11.1	6.7±0.8	23.0	7.3±0.6	12.0	6.3±0.6	26.9	6.7±0.8	16.6	6.0±1.0	30.8	6.3±0.7	20.8
6/cage	7.0±0.0	24.9	7.3±1.2	18.5	5.0±0.5	42.3	5.7±0.6	31.9	4.3±0.6	50.0	5.0±0.0	37.5	3.3±0.7	61.5	4.3±0.3	45.8
9/cage	6.7±0.3	28.5	7.3±0.3	18.5	4.7±1.2	46.1	5.3±0.6	36.0	4.3±1.4	50.0	4.3±0.3	45.8	3.3±1.4	62.0	3.6±0.3	54.1
12/cage	7.7±0.8	17.7	7.7±0.8	14.7	4.7±0.3	46.1	5.7±0.3	31.9	4.7±0.8	46.1	5.0±0.5	37.5	4.3±1.2	50.0	4.6±0.7	41.6
15/cage	8.7±0.3	7.0	7.7±0.3	14.7	4.3±0.6	50.0	7.3±0.3	12.0	4.3±0.6	50.0	5.0±0.5	37.5	4.0±0.6	53.8	4.6±0.8	41.6
Control	9.3±0.3	0.0	9.0±0.0	0.0	8.7±0.3	0.0	8.3±0.3	0.0	8.7±0.3	0.0	8.0±0.0	0.0	8.6±0.3	0.0	8.0±0.0	0.0
CD @ 5%	**1.3	-	2.3 ns	-	**2.1	-	**1.6	-	**2.7	-	**1.7	-	**1.8	-	**2.0	-

Table 5. Evaluation of different release rates of *E. furcellata* nymphs on pigeonpea

Treatments	Population of prey/cage in pigeonpea															
	3 DAR				5 DAR				7 DAR				10 DAR			
	Nymphs	Reduction %	Adults	Reduction %	Nymphs	Reduction %	Adults	Reduction %	Nymphs	Reduction %	Adults	Reduction %	Nymphs	Reduction %	Adults	Reduction %
2/cage	8.0±0.0	14.2	8.3±0.3	7.4	7.7±0.3	4.1	7.0±1.0	15.9	7.3±0.3	4.4	6.3±0.8	20.8	7.0±0.6	8.7	6.0±1.0	25.0
3/cage	8.3±0.3	10.7	8.7±0.3	3.67	7.7±0.3	4.1	6.7±0.6	19.9	7.0±0.0	8.7	6.0±0.5	25.0	6.6±0.3	13.0	5.6±0.7	29.1
6/cage	7.3±0.3	21.4	7.0±0.5	22.2	6.7±0.3	16.6	6.0±1.0	39.9	6.0±0.3	21.7	5.7±0.5	50.0	4.6±0.3	39.1	3.0±0.6	62.5
9/cage	5.7±0.3	39.2	6.3±0.6	29.6	4.7±0.3	41.6	5.0±1.0	39.9	4.3±0.3	43.5	4.0±1.0	50.0	3.0±0.6	60.8	3.0±1.0	62.5
12/cage	8.7±0.3	7.0	8.0±0.5	11.1	6.7±0.7	16.6	7.3±1.2	12.0	5.3±1.3	30.5	6.7±0.8	16.6	5.0±1.0	34.8	6.3±0.7	20.8
15/cage	9.3±0.3	0.0	8.0±1.0	11.1	7.3±1.2	8.3	8.0±1.0	3.9	6.0±1.0	21.7	7.7±0.8	4.1	5.6±1.2	26.0	7.3±0.9	8.3
Control	9.3±0.3	0.0	9.0±0.0	0.0	8.0±0.0	0.0	8.3±0.3	0.0	7.7±0.3	0.0	8.0±0.5	0.0	7.6±0.3	0.0	8.0±0.6	0.0
CD @ 5%	**0.9	-	*1.4	-	1.6**	-	**1.6	-	2.0 *	-	**1.4	-	**2.1	-	*1.4	-

DAR - Days after release of the predator, *E. furcellata*

crops in the United States. 132 first instars of *M. ochroloma* were put into the cages and four (=low), 10 (=medium), or 16 (=high) first instars of *P. maculiventris* were released evenly among six turnip (*Brassica rapa* L.) plants in cages. Control treatment cages received no predators. The mean number of *M. ochroloma* larvae declined progressively during the first four sampling dates. On the final (seventh) sampling date, the mean numbers of total *M. ochroloma* in the two higher release-rate treatments were significantly lower than in the low release-rate and control treatments.

Similar studies were conducted by Ridgway and Jones (1968) where the inundative releases of larvae and eggs of green lacewing, *Chrysopa carnea* Stephens, were tested in field cages to determine effects on the bollworm, *Heliothis zea* (Boddie), and the tobacco budworm, *H. virescens* (F.), the predator reduced larval populations from 73.8 to 99.5% (a minimum of 266 larvae/acre).

Similar studies were done by Grundy (2004) to examine post-release survival and biological control efficacy of the assassin bug, *Pristhesancus plagipennis* (Walker) released in cotton at rates of 1.0, 0.75, 0.5 and 0.25 nymphs per metre crop row. These releases resulted in >72% survival of nymphs with respective field populations of 0.75, 0.54, 0.41 and 0.25 nymphs m^{-1} 4 weeks postrelease. Each of the *P. plagipennis* nymph release treatments gave significant reductions in *Helicoverpa* spp. larval densities, whilst only the higher nymph release rates of 1.0 and 0.75m^{-1} decreased densities of mirids, *Creontiades* spp.

The results of this study indicated that the release of 9 nymphs/cage and 9 adults/cage were sufficient in achieving a good suppression of *S. litura* (lepidopteran pest) after 7 to 10 days of release of the predator. In India, *E. furcellata* has been identified as an important predator on *Pericallia ricini* (Lepidoptera: Arctiidae) on cotton (Shophiya & Sahayaraj, 2014), *Latoia lepida* (Lepidoptera: Limacodidae) (Senrayan, 1988), *M. vitrata* (Fabricius) (Lepidoptera: Pyralidae), and *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae) (Tiwari *et al*., 2017).

CONCLUSION

The utilization of biocontrol agents has emerged as a highly promising and cost-effective strategy for managing lepidopteran pests, representing a significant breakthrough in agricultural pest management. In India, where agriculture plays a pivotal role in the economy, the presence of a diverse array of natural enemies targeting lepidopteran pests, such as parasitoids, arthropod predators, and entomopathogens, has been documented. The research findings outlined in the study demonstrated the efficacy of employing *E. furcellata* as an eco-friendly approach to effectively mitigate the populations of lepidopteran pests, specifically *S. litura* and *M. vitrata*, on pulse crops cultivated in open fields. The significance of these findings lies in the demonstrated potential of this insect to serve as a successful bioagent in IPM programs. By harnessing the natural enemies of pests, such as *E. furcellata*, farmers can reduce reliance on chemical pesticides, thereby promoting sustainable agriculture and safeguarding ecosystem health. Furthermore, the adoption of *E. furcellata* in IPM programs holds promise for enhancing agricultural productivity and reducing economic losses associated with lepidopteran pest damage. As such, the results of this study offer a valuable understanding of the practical application of biocontrol agents in sustainable pest management practices, thereby contributing to the advancement of agricultural sustainability and food security in India and beyond.

ACKNOWLEDGEMENT

The authors are grateful to the Uttarakhand Council for Biotechnology, Haldi, Uttarakhand for financial assistance and the Department of Entomology, G.B.P.U.A.T., Pantnagar for providing the necessary facilities to carry out this study.

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