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Research Article

Bio-efficacy of different biocontrol agents against shoot and fruit borer, *Earias vittella* (Fabricius) (Lepidoptera: Noctuidae) in okra

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ABSTRACT: Experiments were conducted to evaluate the efficacy of different biocontrol agents against shoot and fruit borer, *Earias vittella* (Fabricius) infesting okra at Biological Control farm, Anand Agricultural University, Anand (Gujarat) during two successive years, *kharif*, 2018 and 2019. Among the different biocontrol agents evaluated, the plots sprayed with *Bacillus thuringiensis* @ 5 g/litre for three times at fortnightly interval witnessed lowest larval population (0.52 larva(e)/plant)and fruit damage (7.00%-number basis, 8.09%-weight basis). The treatment comprising six releases of egg parasitoid *Trichogramma chilonis* @ 50,000 parasitoids/ha was found next effective treatment with lower larval population (0.67larva(e)/plant) and fruit damage (8.19%-number basis, 9.97%-weight basis). This bio-efficacy of egg parasitoid *T. chilonis* was statistically at par with the efficacy of treatments *viz.,* Neem Seed Kernel Extract (NSKE) @ 5% and *Beauveria bassiana*@ 5 g/litre. The highest fruit yield was documented in the treatment *B. thuringiensis* @ 5 g/litre (111.02 q/ha, CB ratio 1:2.79) followed by the treatments *T. chilonis* @ 50,000 parasitoids/ha (105.10 q/ha, CB ratio 1:2.77) and NSKE @ 5% (104.64 q/ha, CB ratio 1:2.76). The significant findings of this study could be used to frame BIPM strategy for the management of shoot and fruit borer, *E. vittella* in okra.

KEY WORDS: *Bacillus thuringiensis*, biocontrol agents, okra, shoot and fruit borer, *Trichogrmma chilonis*

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INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is the only vegetable crop of significance in the Malvaceae family, and it is an economically important vegetable crop grown in tropical and sub-tropical regions around the world. One of the major impediments in successful production of okra is insect pests. Among several insects infesting okra, shoot and fruit borer, *Earias vittella* (Fabricius) is the major pest causing severe fruit and shoot damage resulting economic yield loss up to 91.60 per cent (Pareek and Bhargava, 2003). The pest has been noted to cause 24.6 to 26.0 per cent shoot damage (Zala et al., 1999) and 40 to 100 per cent fruit damage in okra (Shinde *et al*., 2005).

In the recent years, the keen concern on chemical residue free food by the consumers and environment safety has necessitated the use of eco-friendly methods in insect pest management. The bio-products are safe to natural enemies with no harmful toxic residues in food commodities and easily biodegradable in the environment. The universal egg parasitoid of the various lepidopteran insect pests *Trichogramma* spp. is recommended as one of the crucial components of Integrated Pest Management strategies against *Earias* spp. in okra (Anonymous, 2001). The bio-agents and microbial biopesticides offer ecologically feasible and compatible alternatives to synthetic chemical pesticides for the management of insect pests. Evaluation of field efficacy of biocontrol agents is inevitable to establish the non-chemical strategies for insect pest management. With this view, field experiments were carried outunder All India Coordinated Research Project on Biological Control of Crop Pests (AICRP-BC) to assess the field efficacy of different biocontrol agents against shoot and fruit borer, *Earias vittella* infesting okra during *kharif* season of the year 2018 and 2019.

MATERIAL AND METHODS

Experiments were carried out at Biological Control farm (GPS coordinates: 22.538524, 72.984704) Anand Agricultural University, Anand, Gujarat during the year *Kharif*, 2018 and 2019. The bio-efficacy of various biocontrol agents was assessed against shoot and fruit borer, *E. vittella* infesting okra. Anand belongs to Agro-climatic Zone III of

Gujarat with average *kharif* temperature of 25.8-31.5°C. The majority of rainfall occurs during June to September.

The experiment was comprised of eight different treatments of biocontrol agents. All the treatments were laid out in Randomized Block Design (RBD) with three replications. The three different entomofungal pathogens *viz*., *Lecanicillium lecanii*, *Metarhizium anisopliae, Beauveria bassiana,* egg parasitoid *Trichogramma chilonis*, entomotoxic bacteria *Bacillus thuringiensis,* botanical biopesticide Neem Seed Kernel Extract (NSKE) 5% and one recommended chemical insecticide Emamectin benzoate 5 SG was used as chemical check. The ready to use formulations of entomopathogens *viz*., *Lecanicillium lecanii*, *Metarhizium anisopliae, Beauveria bassiana* and entomotoxic bacteria *Bacillus thuringiensis* were received from ICAR-National Bureau of Agricultural Insect Resources, Bengaluru under AICRP on Biological Control of crop pests. The plots treated with egg parasitoid *T. chilonis* were maintained at an isolation distance of 200m. The details of treatments have been presented in the Table 1. The seeds of okra variety GAO-5 were sown with the spacing of 60 x 30 cm in a plot of size 7.8 x 4.8 m (Net plot size: 7.2 x 3.6 m). All the standard package of practices was followed except the plant protection measures against shoot and fruit borer *E. vittella.*

With the initiation of the pest, the egg parasitoid *T. chilonis* was released for six times at weekly interval and different entomopathogens, NSKE and chemical insecticide were sprayed three times at fortnightly interval. For recording observations, five plants were randomly selected in each plot. The larval population of *E. vittella* was recorded before the spray and at 5th, 10th and 15th day after each spray in each treatment. At each picking, the fruit damage caused by *E. vittella* was documented on number and weight basis from the fruits harvested from the net plot area of each treatment. The weight of healthy marketable fruits (kg/plot) was recorded.

Statistical analysis

The data obtained from the experiments was subjected to square root transformation and the data on fruit damage caused by the pest was converted into per cent values and subjected to arc sine transformation, followed by ANOVA analysis with Web Agri Stat Package (WASP-2) developed by ICAR-Central Agricultural Research Institute, Goa. Significant differences among the means of different treatments were tested using Duncan New Multiple Range Test (DNMRT).

RESULTS AND DISCUSSION

The results of the experiment on bio-efficacy of different biocontrol agents against shoot and fruit borer *E. vittella* in okra conducted during *kharif* 2018 and 2019 are presented here under. The significant level of pest infestation was noticed during the fruit initiation stage (Plate 1). During the experiment, the highest efficacy in reducing the pest infestation was documented in the chemical check treatment T7 - Emamectin benzoate 5 SG. As the objective of the experiment was to evaluate different biocontrol agents, the results are discussed by comparing the efficacy of biocontrol treatments with untreated control treatment.

First Year (*Kharif*, 2018)

Larval population

Among the different biocontrol agents evaluated, the data on larval population after first spray (Table 2) depicted the lowest larval population of 0.60 larva(e)/plant in the

Table 1. The details of biological control agents used in the study

Treatments		Concentration/ spore load/g of product	Quantity (ml or g)/10 L
T_1	*Lecanicillium lecanii* - 1% WP (ICAR-NBAIR strain Vl-8)	2x10^{8}cfu	50 g
T_2	*Metarhizium anisopliae* -1% WP (ICAR-NBAIR strain Ma-4)	2x10^{8}cfu	50 g
T_3	*Beauveria bassiana* -1% WP (ICAR-NBAIR strain Bb-5a)	2x10^{8}cfu	50 g
T_4	*Trichogramma chilonis* (Native isolate)	50,000 parasitoids*	6 releases*
T_5	*Bacillus thuringiensis* -1% WP (ICAR-NBAIR strain *Bt*G-4)	2x10^{8}cfu	50 g
T_6	Neem Seed Kernel Extract	5%	500 g
T_7	Emamectin benzoate 5 SG(12.5 ga.i./ha)	0.0025%	5 g
T_8	Untreated control	-	-
*Egg parasitoid *T. chilonis* 50,000/ ha – Total 6 releases at weekly interval			

treatment T5–*B. thuringiensis* @ 5 g/litre. This treatment was followed by the next effective treatment comprising egg parasitoid T4 – *T. chilonis* @ 50,000 parasitoids/ha (0.85 larva(e)/plant) and treatment T6 - NSKE 5%(0.87 larva(e)/plant)and T3 - *B. bassiana* @ 5 g/litre (0.87 larva(e)/plant). After second spray, the data pertaining to larval population indicated that the treatment T5 – *B. thuringiensis* @ 5 g/litre was effective in reducing the larval population (0.54 larva(e)/plant), which was followed by the treatments T_4 - *T. chilonis* @ 50,000 parasitoids/ha (0.67 larva(e)/plant) and T_6 - NSKE 5% (0.73 larva(e)/plant). All these three treatments found effective during the second spray were statistically at par with each other. Similarly, after third spray, the treatment T_5 - *B. thuringiensis* @ 5 g/litre showed the lowest larval population (0.31 larva(e)/plant) in comparison to the larval population recorded in other treatments. This treatments was followed by T_4 - *T. chilonis*@ 50,000 parasitoids/ha (0.40 larva(e)/plant) and T_6 - NSKE 5% (0.48 larva(e)/plant. All these three superior treatments were foundstatistically at par with each other.

The pooled data of larval population over periods and sprays showed the highest efficacy of the treatment T_5 - *B. thuringiensis* @ 5 g/litre (0.48 larva(e)/plant) with lowest larval population followed by T_4 - *T. chilonis* @ 50,000 parasitoids/ha (0.64 larva(e)/plant). These two treatments showing highest efficacy were found statistically at par with each other. Further, the treatment T_6 - NSKE 5% (0.69 larva(e)/plant) found next effective in reducing the larval population of *E. vittella*. The highest larval population was witnessed in untreated control treatment with the population of 2.67 larva(e)/plant.

Fruit damage and yield

The efficacy of biocontrol agents in reducing the larval population of *E. vittella* was affirmed with the observations on fruit damage and yield of the crop (Table 3). The lowest fruit damage was recorded in the treatment T_5 - *B. thuringiensis* @ 5 g/litre (7.29% - number basis, 8.53% - weight basis). This microbial biopesticide was found statistically at par with the fruit damage recorded in chemical check treatment T7 - Emamectin benzoate 5 SG (3.84% – number basis). Further, this effective biocontrol treatment was followed by the treatment T_4 - *T. chilonis* @ 50,000 parasitoids/ha (8.27% - number basis, 10.27% - weight basis), and the fruit damage recorded in the treatment of egg parasitoid *T. chilonis* was statistically at par with the fruit damage recorded in T_6 - NSKE 5% (8.81% - number basis, 10.12% - weight basis). The untreated control treatment T_8 showed the highest fruit damage (29.54% - number basis, 31.90% - weight basis). Similar trend was observed in fruit yield also. Among the biocontrol treatments, T_5 - *B. thuringiensis* @ 5 g/litre recorded the highest fruit yield (109.10 q/ha) which was statistically at par with the yield recorded in the treatments T_4 - *T. chilonis* @ 50,000 parasitoids/ha (104.55 q/ha) and T_6 - NSKE 5% (104.14 q/ha). The lowest fruit yield was recorded in untreated control treatment (59.44 q/ha).

Table 2. Bio-efficacy of different biocontrol agents against larval population of *Earias vittella* infesting okra (*Kharif* 2018)

Treatments		No. of larva(e)/plant			Pooled over periods over sprays
		1st spray	2nd spray	3rd spray	
		Pooled	Pooled	Pooled	
T1	*Lecanicillium lecanii* @ 5 g/litre	1.39d (1.43)	1.46d (1.63)	1.44d (1.57)	1.43e (1.54)
T2	*Metarhizium anisopliae* @ 5 g/litre	1.23cd (1.01)	1.28c (1.14)	1.18c (0.89)	1.23d (1.01)
T3	*Beauveria bassiana* @ 5 g/litre	1.17bc (0.87)	1.13b (0.78)	1.02b (0.54)	1.11c (0.73)
T4	*Trichogramma chilonis* @ 50,000 parasitoids/ha	1.16bc (0.85)	1.08b (0.67)	0.95b (0.40)	1.07bc (0.64)
T5	*Bacillus thuringiensis* @ 5 g/litre	1.05ab (0.60)	1.02b (0.54)	0.90b (0.31)	0.99b (0.48)
T6	NSKE 5%	1.17bc (0.87)	1.11b (0.73)	0.99b (0.48)	1.09c (0.69)
T7	Emamectin benzoate 5 SG @ 0.0025%	0.96a (0.42)	0.80a (0.14)	0.73a (0.03)	0.83a (0.19)
T8	Untreated control	1.66e (2.26)	1.83e (2.85)	1.84e (2.89)	1.78f (2.67)
S. Em. ±		0.05	0.04	0.04	0.03
C. D. at 5%		0.13	0.11	0.12	0.07
C. V. (%)		11.14	9.82	10.84	10.75

Note: *Figures are $\sqrt{x + 0.5}$ transformed values whereas those in parentheses are retransformed values Treatment means with the letter/letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance

Table 3. Bio-efficacy of different biocontrol agents against *Earias vittella* fruit damage and its influence on yield of okra (*Kharif* 2018)

Treatments Number basis		**Fruit damage (%)**		**Yield (q/ha)**
		Weight basis		
T1	*Lecanicillium lecanii* @ 5 g/litre	24.06d (16.62)	24.76d (17.54)	80.50d
T2	*Metarhizium anisopliae* @ 5 g/litre	21.79cd (13.78)	21.82cd (13.82)	90.93cd
T3	*Beauveria bassiana* @ 5 g/litre	18.64bc (10.22)	20.44bc (12.20)	101.33bc
T4	*Trichogramma chilonis* @ 50,000 parasitoids/ha	16.71bc (8.27)	18.69bc (10.27)	104.55bc
T5	*Bacillus thuringiensis* @ 5 g/litre	15.66ab (7.29)	16.98b (8.53)	109.10b
T6	NSKE 5%	17.27bc (8.81)	18.55bc (10.12)	104.14bc
T7	Emamectin benzoate 5 SG @ 0.0025%	11.30a (3.84)	12.02a (4.34)	122.45a
T8	Untreated control	32.92e (29.54)	34.39e (31.90)	59.44e
S. Em. ±		1.51	1.13	4.13
C. D. at 5%		4.57	3.44	12.54
CV%		13.17	9.37	7.42

Note: Figures outside the parentheses are arcsine transformed values, those inside are retransformed values. Treatment means with the letter/letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance

Second Year (*Kharif*, 2019)

Larval population

During the second year, the efficacy of biocontrol agents in reducing the larval population and fruit damage of *E. vittella* was evaluated and observations were documented (Table 4). The consistent efficacy of treatments was observed in the year *kharif,* 2019 and the results were in conformity with the bio-efficacy data recorded during the first year *kharif*, 2018. During first spray, the microbial biopesticide treatment T_5 – *B. thuringiensis* @ 5 g/litre (0.71 larva(e)/plant) found as effective biocontrol agent by reducing the larval population of *E. vittella*. The egg parasitoid T_4 - *T. chilonis* @ 50,000 parasitoids/ha was proved to be the next effective treatment (0.87 larva(e)/plant) followed by the treatment T_3 – *B. bassiana* @ 5 g/litre (0.89 larva(e)/plant). The treatment T_5 - *B. thuringiensis* @ 5 g/litre was statistically at par with T_4 - *T. chilonis* @ 50,000 parasitoids/ha and T_3 - *B. bassiana and* T_6 - NSKE 5%.

After second spray, the lowest larval population of 0.62 larva(e)/plant was recorded in the treatment T_5 - *B. thuringiensis* @ 5 g/litre followed by T_4 - *T. chilonis* @ 50,000 parasitoids/ha (0.78 larva(e)/plant). The treatment T_5 - *B. thuringiensis* @ 5 g/litre was found statistically at par with T_4 - *T. chilonis* @ 50,000 parasitoids/ha and they were statistically superior to T_6 - NSKE 5%. Similarly, the data on larval population after third spray showed the lowest larval population in treatment T_5 - *B. thuringiensis* @ 5 g/litre (0.33 larva(e)/plant) followed by T_4 - *T. chilonis* @ 50,000 parasitoids/ha (0.50 larva(e)/plant) and T_6 - NSKE 5% (0.56 larva(e)/plant). All these three effective biocontrol agents against *E. vittella* were found statistically at par in reducing the larval population of *E. vittella*.

The pooled over periods over sprays data of larval population followed the similar trend as documented during the first year. The treatment of microbial biopesticide T_5 - *B. thuringiensis* @ 5 g/litre was effective with the lowest larval population (0.54 larva(e)/plant). The treatment T_4 – *T. chilonis* @ 50,000 parasitoids/ha (0.71 larva(e)/plant) was the next effective biocontrol agent in reducing the larval population and these two effective biocontrol agents were statistically at par with each other. The highest larval population of 2.67 larva(e)/plant was recorded in untreated control treatment.

Fruit damage and yield

The biocontrol agents were found effective in reducing the fruit damage caused by *E. vittella*. The data pertaining to the efficacy of treatments in reducing fruit damage on number and weight basis is presented in Table 5. The lowest fruit damage (%) was recorded in the treatment T_5 - *B. thuringiensis* @ 5 g/litre (6.72% - number basis, 7.65%

Table 4. Bio-efficacy of different biocontrol agents against larval population of *Earias vittella* infesting okra (*Kharif* 2019)

Treatments		No. of larva(e)/plant			Pooled over periods over sprays
		1st spray	2nd spray	3rd spray	
		Pooled	Pooled	Pooled	
T1	*Lecanicillium lecanii* @ 5 g/litre	1.45c (1.60)	1.50e (1.75)	1.50e (1.75)	1.48e (1.69)
T2	*Metarhizium anisopliae* @ 5 g/litre	1.36c (1.35)	1.29d (1.16)	1.21d (0.96)	1.29d (1.16)
T3	*Beauveria bassiana* @ 5 g/litre	1.18b (0.89)	1.15bc (0.82)	1.06c (0.62)	1.13c (0.78)
T4	*Trichogramma chilonis* @ 50,000 parasitoids/ha	1.17b (0.87)	1.13bc (0.78)	1.00bc (0.50)	1.10bc (0.71)
T5	*Bacillus thuringiensis* @ 5 g/litre	1.10b (0.71)	1.06b (0.62)	0.91b (0.33)	1.02b (0.54)
T6	NSKE 5%	1.21b (0.96)	1.19cd (0.92)	1.03bc (0.56)	1.14c (0.80)
T7	Emamectin benzoate 5 SG @ 0.0025%	0.94a (0.38)	0.82a (0.17)	0.79a (0.12)	0.85a (0.22)
T8	Untreated control	1.71d (2.42)	1.77f (2.63)	1.87f (3.00)	1.78f (2.67)
S. Em. ±		0.04	0.04	0.04	0.03
C. D. at 5%		0.12	0.11	0.13	0.07
C. V. (%)		10.16	9.67	11.32	10.58

Note: *Figures are √x + 0.5 transformed values whereas those in parentheses are retransformed values Treatment means with the letter/letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance

Table 5. Bio-efficacy of different biocontrol agents against *Earias vittella* fruit damage and its influence on yield of okra (*Kharif* 2019)

Treatments		Fruit damage (%)		Yield (q/ha)
		Number basis	Weight basis	
T1	*Lecanicillium lecanii* @ 5 g/litre	24.63d (17.37)	23.77d (16.25)	81.48d
T2	*Metarhizium anisopliae* @ 5 g/litre	21.38cd (13.29)	20.67cd (12.46)	92.45cd
T3	*Beauveria bassiana* @ 5 g/litre	18.65bc (10.23)	19.28bc (10.90)	101.12bc
T4	*Trichogramma chilonis* @ 50,000 parasitoids/ha	16.55b (8.11)	18.14bc (9.69)	105.66bc
T5	*Bacillus thuringiensis* @ 5 g/litre	15.02ab (6.72)	16.06b (7.65)	112.95b
T6	NSKE 5%	16.63b (8.19)	18.38bc (9.94)	105.14bc
T7	Emamectin benzoate 5 SG @ 0.0025%	11.31a (3.85)	12.23a (4.46)	126.20a
T8	Untreated control	32.65e (29.11)	34.93e (32.78)	58.81e
S. Em. ±		1.26	1.16	4.09
C. D. at 5%		3.81	3.53	12.41
C. V. (%)		11.10	9.87	7.23

Note: Figures outside the parentheses are arcsine transformed values, those inside are retransformed values. Treatment means with the letter/letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance

Table 6. Bio-efficacy of different biocontrol agents against fruit borer *Earias vittella* on okra (Pooled over years)

Treatments		No. of larvae / plant									Pooled
		1st spray			2nd spray			3rd spray			
		2018*	2019*	Pooled**	2018*	2019*	Pooled**	2018*	2019*	Pooled**	
T1	*Lecanicillium lecanii* @ 5 g/litre	1.39d (1.43)	1.45c (1.60)	1.42g (1.52)	1.46d (1.63)	1.50e (1.75)	1.48e (1.69)	1.44d (1.57)	1.50e (1.75)	1.47e (1.66)	1.45e (1.60)
T2	*Metarhizium anisopliae* @ 5 g/litre	1.23cd (1.01)	1.36c (1.35)	1.30f (1.19)	1.28c (1.14)	1.29d (1.16)	1.29d (1.16)	1.18c (0.89)	1.21d (0.96)	1.19d (0.92)	1.26d (1.09)
T3	*Beauveria bassiana* @ 5 g/litre	1.16bc (0.85)	1.18b (0.89)	1.17cde (0.87)	1.13b (0.78)	1.15bc (0.82)	1.14c (0.80)	1.02b (0.54)	1.06c (0.62)	1.04c (0.58)	1.12c (0.75)
T4	*Trichogramma chilonis* @ 50,000 parasitoids/ha	1.16bc (0.85)	1.17b (0.87)	1.17cde (0.87)	1.08b (0.67)	1.13bc (0.78)	1.11bc (0.73)	0.95b (0.40)	1.00bc (0.50)	0.97bc (0.44)	1.08c (0.67)
T5	*Bacillus thuringiensis* @ 5 g/litre	1.05ab (0.60)	1.10b (0.71)	1.08b (0.67)	1.02b (0.54)	1.06b (0.62)	1.04b (0.58)	0.90b (0.31)	0.91b (0.33)	0.90b (0.31)	1.01b (0.52)
T6	NSKE 5%	1.17bc (0.87)	1.21b (0.96)	1.19e (0.92)	1.11b (0.73)	1.19cd (0.92)	1.15c (0.82)	0.99b (0.48)	1.03bc (0.56)	1.01c (0.52)	1.12c (0.75)
T7	Emamectin benzoate 5 SG @ 0.0025%	0.96a (0.42)	0.94a (0.38)	0.95a (0.40)	0.80a (0.14)	0.82a (0.17)	0.81a (0.16)	0.73a (0.03)	0.79a (0.12)	0.76a (0.08)	0.84a (0.21)
T8	Untreated control	1.66e (2.26)	1.71d (2.42)	1.68h (2.32)	1.83e (2.85)	1.77f (2.63)	1.80f (2.74)	1.84e (2.89)	1.87f (3.00)	1.85f (2.92)	1.78f (2.67)
S. Em. ±Treatment(T)		0.05	0.04	0.03	0.04	0.04	0.03	0.04	0.04	0.03	0.02
C. D. at 5% T		0.13	0.12	0.09	0.11	0.11	0.08	0.12	0.13	0.09	0.05
C. V. (%)		11.14	10.16	10.65	9.82	9.67	9.74	10.84	11.32	11.09	10.66

Note: *Figures are $\sqrt{x + 0.5}$ transformed values whereas those in parentheses are retransformed values Treatment means with the letter/letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance *Pooled over periods, **Pooled over periods and years

- weight basis) which was found statistically at par with the fruit damage recorded in chemical check treatment T7 - Emamectin benzoate 5 SG (3.85% – number basis). The next effective biocontrol treatment was T_4 - *T. chilonis* @ 50,000 parasitoids/ha (8.11% - number basis, 9.69% - weight basis) which was statistically at par with T_6 - NSKE 5% (8.19% - number basis, 9.94% - weight basis) and T_3 - *B. bassiana* @ 5 g/litre (10.23% - number basis, 10.90% - weight basis) in reducing the fruit damage. The highest fruit damage of 29.11% - number basis, 32.78% - weight basis was recorded in untreated control treatment. The efficacy of treatments in reducing the larval population and fruit damage was exhibited in yield of the crop. The highest fruit yield was recorded in T_5 - *B. thuringiensis* @ 5 g/litre (112.95 q/ha) which was statistically at par with the fruit yield recorded in the treatments T_4 - *T. chilonis* @ 50,000 parasitoids/ha (105.66 q/ha) and T_6 - NSKE 5% (105.14 q/ha). The lowest fruit yield of 58.81 q/ha was recorded in untreated control treatment.

Pooled over periods and years

Larval population

The pooled over periods over years data on larval population (Table 6) revealed that the treatment T_5 - *B. thuringiensis* @ 5 g/litre was effective in reducing the larval population (0.52 larva(e)/plant) and it was significantly the lower larval population as compared to other biocontrol agents tested. The *E. vittella* larvae infected with *B. thuringiensis* were noticed in the treated plots (Plate 2). Next effective treatments were T_4 - *T. chilonis* @ 50,000 parasitoids/ha (0.67 larva(e)/plant), T_6 - NSKE 5% (0.75 larva(e)/plant) and T_3 - *Beauveria bassiana* @ 5 g/litre (0.75 larva(e)/plant). It was noted that the treatment T_4 - *T. chilonis*

@ 50,000 parasitoids/ha was statistically at par with T_6 - NSKE 5% and T_3 – *B. bassiana* @ 5 g/litre. The treatment T_1 - *Lecanicillium lecanii* @ 5g/litre (1.60 larva(e)/plant) was found least effective against *E. vittella.* The findings of the present study are in concurrence with the various reports. Sumathi and Balasubramaniam (2002) reported the efficacy of *T. chilonis* @ 50000/ha against *E. vittella* and *E. insulana* on okra crop. Similar findings were also reported by Varma and Gill (1992); Raja *et al.* (1998). Dhaker *et al*. (2017) reported that the bio-agent *T. chilonis* released @ 1 lakh/ha followed by the use of microbial bio-pesticide *Ha*NPV (250 LE/ha) after 10 days was more effective in managing fruit borer *Helicoverpa armigera* than untreated control.

Fruit damage and yield

The pooled over periods over years data on the bio-efficacy of biocontrol agents in reducing the fruit damageis presented in table 7. The treatment T_5 – *B. thuringiensis* @ 5 g/litre recorded the lowest fruit damage (7.00% - number basis, 8.09% - weight basis). The next effective treatment was T_4 – *T. chilonis* @ 50,000 parasitoids/ha (8.19% - number basis, 9.97% - weight basis) which was statistically at par with T_6 - NSKE 5% (8.50% - number basis, 10.04% - weight basis) in reducing the fruit damage as compared to the untreated control T_8 - (29.33% - number basis, 32.34% - weight basis). Similar observation was witnessed in pooled data of fruit yield (Table 8). Among biocontrol agents evaluated, T_5 - *B. thuringiensis* @ 5 g/litre recorded the highest fruit yield (111.02 q/ha, CB ratio 1:2.79) which was statistically at par with the treatments T_4 - *T. chilonis* @ 50,000 parasitoids/ha (105.10 q/ha, CB ratio 1:2.77) and T_6 - NSKE 5% (104.64 q/ha, CB ratio 1:2.76). The efficacy of bioagents and microbial biopesticides against *E. vittella* also gets support from Devi *et al*. (2015), who reported the lowest mean fruit infestation (5.75%) in emamectin benzoate 12g a.i./ha followed by spinosad 12.5% SC (6.22%), *B. thuringiensis* (7.15%), *B. bassiana* (8.08%), neem oil (8.20%) and *Verticillium lecanii* (8.63%). Similarly, Reddy *et al*. (2019) reported the highest lowest fruit infestation in *T. chilonis* @ 150000/ha + chlorantraniliprole 18.5% SC (64.86 %), followed by chlorantraniliprole 18.5% SC treatment (44.89 %).

CONCLUSION

The order of efficacy of biocontrol agents against shoot and fruit borer, *E. vittella* was documented as T5 - *B. thuringiensis*<T4 - *T. chilonis*<T6 - NSKE 5%<T3 – *B. bassiana* <T2- *M. anisopliae*<T1 - *L. lecanii.* However, the chemical check treatment witnessed the significantly lowest pest population and highest fruit yield. Nevertheless, the findings of the present study will be useful to frame BIPM or IPM strategy for the management of shoot and fruit borer, *E.*

Table 7. Bio-efficacy of different biocontrol agents against *Earias vittella* fruit damage in okra (pooled over years)

Treatments		Fruit damage (%)					
		Number basis		Pooled	Weight basis		Pooled
		2018	2019		2018	2019	
T1	*Lecanicillium lecanii* @ 5 g/litre	24.06d (16.62)	24.63d (17.37)	24.35d (17.00)	24.76d (17.54)	23.77d (16.25)	24.26e (16.88)
T2	*Metarhizium anisopliae* @ 5 g/litre	21.79cd (13.78)	21.38cd (13.29)	21.58d (13.53)	21.82cd (13.82)	20.67cd (12.46)	21.25d (13.14)
T3	*Beauveria bassiana* @ 5 g/litre	18.64bc (10.22)	18.65bc (10.23)	18.64c (10.22)	20.44bc (12.20)	19.28bc (10.90)	19.86cd (11.54)
T4	*Trichogramma chilonis* @ 50,000 parasitoids/ha	16.71bc (8.27)	16.55b (8.11)	16.63bc (8.19)	18.69bc (10.27)	18.14bc (9.69)	18.41bc (9.97)
T5	*Bacillus thuringiensis* @ 5 g/litre	15.66ba (7.29)	15.02ba (6.72)	15.34b (7.00)	16.98b (8.53)	16.06b (7.65)	16.52b (8.09)
T6	NSKE 5%	17.27bc (8.81)	16.63b (8.19)	16.95bc (8.50)	18.55bc (10.12)	18.38bc (9.94)	18.47bc (10.04)
T7	Emamectin benzoate 5 SG @ 0.0025%	11.30a (3.84)	11.31a (3.85)	11.30a (3.84)	12.02a (4.34)	12.23a (4.46)	12.12a (4.41)
T8	Untreated control	32.92e (29.54)	32.65e (29.11)	32.79e (29.33)	34.39e (31.90)	34.93e (32.78)	34.66f (32.34)
S. Em. ±		1.51	1.26	0.88	1.13	1.16	0.74
C. D. at 5%		4.57	3.81	2.53	3.44	3.53	2.13
C. V. (%)		13.17	11.10	12.19	9.37	9.87	9.62

Note: Figures outside the parentheses are arcsine transformed values, those inside are retransformed values Treatment means with the letter/letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance

Table 8. Effect of different biocontrol treatments on yield of okra

Treatments		Yield (q/ha)			CB Ratio
		2018	2019	Pooled	
T1	*Lecanicillium lecanii* @ 5 g/litre	80.50d	81.48d	80.99e	2.04
T2	*Metarhizium anisopliae* @ 5 g/litre	90.93cd	92.45cd	91.69d	2.31
T3	*Beauveria bassiana* @ 5 g/litre	101.33bc	101.12bc	101.23c	2.55
T4	*Trichogramma chilonis* @ 50,000 parasitoids/ha	104.55bc	105.66bc	105.10bc	2.77
T5	*Bacillus thuringiensis* @ 5 g/litre	109.10b	112.95b	111.02b	2.79
T6	NSKE 5%	104.14bc	105.14bc	104.64bc	2.76
T7	Emamectin benzoate 5 SG @ 0.0025%	122.45a	126.20a	124.32a	3.17
T8	Untreated control	59.44e	58.81e	59.12f	1.61
S. Em. ±		4.13	4.09	2.63	
C. D. at 5%		12.54	12.41	7.54	
C. V. (%)		7.42	7.23	7.32	

Note: Treatment means with the letter/letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance

vittella in okra. Hence, three sprays of *Bacillus thuringiensis* (1% WP - 2x10^8cfu/g) @ 5/litre water at fifteen days interval or six releases of *Trichogramma chilonis* @ 50000/ha at weekly interval or application of NSKE 5% for three times at fifteen days interval with the initiation of pest will be an effective biological control strategy for the management of shoot and fruit borer infesting okra.

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