



## Article

# Evaluation of Biological Approaches for Controlling Shoot and Fruit Borer (*Earias vitella* F.) of Okra Grown in Peri-Urban Area in Bangladesh

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**Abstract:** Irrational applications of insecticides on vegetable crops are very common in Bangladesh, resulting in harmful consequences for the environment and human health. Therefore, a study was conducted to evaluate the efficacy of biological and botanical insecticides on okra shoot and fruit borer grown in open fields. Four insecticides were used in this study, namely *Bacillus thuringiensis* (Bt), Spinosad 45 SC, Abamectin 1.8 EC, and Azadirachtin 1% EC an untreated control. The experiment used a randomized complete block design (RCBD) with three replications. The results showed that the rate of shoot infestation was the lowest in the Spinosad-treated plot (3.80%), and the highest was in the control (20.67%). The lowest fruit infestation (3.56%) was recorded in the treated plot of Spinosad. The rate of reduction of fruit infestation over control was 80.69, 60.14, 56.45, and 55.58% in the plots treated with Spinosad, Bt, Azadirachtin, and Abamectin, respectively. Consequently, the Spinosad-treated plot attained the highest yield (8.65 t ha<sup>-1</sup>), which was followed by the plots treated with Azadirachtin (6.74 t ha<sup>-1</sup>), Bt (6.28 t ha<sup>-1</sup>), and Abamectin (6.12 t ha<sup>-1</sup>). The highest net return and benefit–cost ratio (BCR) were 542.36 US\$ and 2.64, obtained respectively from the Spinosad-treated plot. The second highest BCR (1.70) was obtained from the Azadiratin-treated plot, and the lowest BCR (1.18) was recorded in the Abamectin-treated plot. Therefore, the studied insect management practices could be incorporated to attain higher yields and economic benefits for growing okra in Bangladesh.

**Keywords:** pest management; biological insecticide; economic return; fruit yield

## 1. Introduction

Okra or lady's finger (*Abelmoschus esculentus* L.) is a prominent vegetable crop grown in the peri-urban and rural areas in Bangladesh [1–3]. It belongs to the Malvaceae family and

originated in tropical Africa [4]. It is an important summer crop, and the total production was 56,145 tons from 11,458 hectares in 2017–2018 [5].

Okra plays an important role in meeting the country's demand for vegetables [6]. However, insect-pest infestation heavily affects the okra fruit quality and the economic return. Research revealed that a total of 69% of the okra yield was affected by insect pests [7].

The okra shoot and fruit borer (*Earias vitella* F.) is one of the major destructive pests of okra in Bangladesh [8–11]. Okra shoot and fruit borer (OSFB) infestations typically accounted for a 48.97% loss in the okra pod yield [12]. The OSFB larvae cause damage in the vegetative and reproductive phases of the okra. Larvae also bore into the flower buds and fruits in the reproductive stage, and feed on internal tissues. Therefore, the infested flower buds' drop-off and infested fruits become deformed in shape, which lowers their market value [13]. OSFB alone causes a damage of between 52.33% and 70.75% [14].

Chemical insecticides are commonly used in Bangladesh to control insect pest attacks on vegetable crops [15]. A study found that chemical insecticides have been used at least 180 times/year to protect vegetable crops from insect pests in Bangladesh. Many problems such as insect resistance and resurgence, environmental pollution, consumer health hazards, and increased production costs have been caused by such irrational applications of chemical insecticides [16–19].

Alternative approaches are paramount to avoid dependence on chemical insecticides. Botanical insecticides are an alternative promising approach that only damage target insects without harming beneficial natural enemies and establish food and healthy environments [20]. The *Bacillus thuringiensis* (Bt) bacterium generates delta-endotoxins that are toxic and can be used as biopesticides [21]. Azadirachtin isolated from the seeds of the neem tree (*Azadirachta indica* L.) is usually chosen among botanical insecticides to control different insect pests in various crops, particularly vegetables [22]. Spinosad is a natural substance made by a soil bacterium that can be toxic to insects. It is a mixture of two chemicals known as spinosyn A and spinosyn D and is used to control a wide variety of pests. Spinosad affects the nervous system of insects that ingest or touch it. Abamectin is a biological insecticide that works by targeting the transmissions in the neural and neuromuscular systems of insects. Therefore, botanical insecticides can be used as an integral insect control program that can substantially minimize the use of synthetic insecticides. So far, very little research on the biological management of OSFB has been conducted in Bangladesh. However, the excessive and blind uses of synthetic pesticides have created many problems for the environment. The present experiment was therefore undertaken to determine the efficacy, benefit–cost ratio, and best performance of selected microbial, bio-rational, and botanical insecticides to control the OSFB.

## 2. Materials and Methods

### 2.1. Experimental Site

The experiment was performed in an open field at Sylhet Agricultural University, Sylhet, Bangladesh, situated approximately 5 km north-east of Sylhet City Centre, at 24°54'27" N latitude and 91°54'19" E longitude, and 35 m elevation from the sea level [23]. The land belongs to the Khadimnagar soil series Eastern Surma-Kushiara Floodplain under the Agroecological Zones-20 [24].

### 2.2. Seed Sowing and Crop Management

Hybrid okra (*Abelmoschus esculentus* L. cv. Canchon) seeds were collected from the local market in Sylhet, Bangladesh. The seeds were soaked in water for 24 h and then sown in the field. Gap filling was performed with good seedlings raised in poly bags. Mulching, irrigation, weeding, and other intercultural operations were carried out as and when necessary for the proper growth of the plants. Suggested doses of manure (cow dung at 15 t ha<sup>-1</sup>) and fertilizer (Urea 150 kg ha<sup>-1</sup>, Triple Super Phosphate (TSP) 100 kg ha<sup>-1</sup> and Muriate of potash (MP) 150 kg ha<sup>-1</sup>) were used [25].

### 2.3. Experimental Design and Treatments

The experiment adopted a randomized complete block design (RCBD) with three replications during the summer season (April–September) in 2019. The entire field was divided into three blocks of equal size, with a space of 1 m between the blocks, and again each block was subdivided into five plots. The individual plot size was 1.8 m × 1.8 m. There were 18 plants in each unit plot, maintaining a row-to-row and plant-to-plant spacing of 60 and 30 cm, respectively. The treatments and their doses and duration are shown in Table 1.

**Table 1.** Treatments and components of this experiment.

Treatment	Dose	Interval
T1: <i>Bacillus thuringiensis</i> (Bt)	2.0 gm L <sup>-1</sup> of water	10 days interval
T2: Spinosad 45 SC	0.4 mL L <sup>-1</sup> of water	
T3: Abamectin 1.8 EC	1.2 mL L <sup>-1</sup> of water	
T4: Azadirachtin 1% EC (1000 ppm)	3.0 mL L <sup>-1</sup> of water	
T5: Untreated Control	-	-

Insecticides were used with the aid of a Knapsack sprayer. Both treatments were performed at a time interval of 10 days from the first appearance of the shoot infestation. Nine liters of spray volumes were required to spray three plots at each spray, and four sprayings were carried out during the season. Both spray materials were applied to the upper and lower surfaces of the leaves and shoots to ensure maximum coverage of the plants. Spraying was often performed in the afternoon to prevent sunburn and insecticide drift and to protect pollinating wild bees and other beneficial insects. During the use of insecticides, steps were taken to prevent drifting to neighboring plots.

### 2.4. Shoot Infestation

The total number of shoots, as well as the number of infested shoots, were visually observed and recorded at weekly intervals from five selected plants in each plot. Shoot infestation was determined by percent using the following formula:

$$\% \text{ Shoot infestation} = \frac{\text{Number of infested shoots}}{\text{Number of total shoots}} \times 100$$

### 2.5. Fruit Infestation and Yield

Fruits were harvested at 3-day intervals, and the number of healthy and infested fruits was recorded for the calculation of the percentage of fruit bored and the number of fruits/plants. The weight of healthy and infested fruits was reported separately per plot per treatment. Harvests were made during the fruiting season, and the percentage of fruit infestation was determined using the following formula:

$$\% \text{ Fruit infestation (by number)} = \frac{\text{Number of infested fruits}}{\text{Number of total fruits}} \times 100$$

### 2.6. Economic Analysis

The benefit–cost ratio (BCR) was analyzed considering the total crop expenditure and the net return on that treatment. In this experiment, BCR was established for a hectare of land. In the following steps, the benefit–cost ratio was implemented.

### 2.7. Total Cost of Cultivation

This cost was estimated by adding all labor expenses and inputs for each treatment for all vegetative and fruiting times, including the control plot. The yield of each treatment was converted to tons per hectare (t ha<sup>-1</sup>).

### 2.8. Gross Return and Net Return

The gross return was determined by multiplying the marketable return by the okra unit price. Cutting out treatment–management costs from gross return yielded the net return.

### 2.9. Adjusted Net Return

The adjusted net return was calculated by extracting the net return of the control plot from the net return of a particular treatment.

Adjusted net return = Net return of a particular treatment – net return of control plot.

### 2.10. Benefit Cost Ratio (BCR) Calculation

The BCR was calculated according to the following formula:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Adjusted net return}}{\text{Total management cost}} \quad (1)$$

### 2.11. Data Analysis

All data were collected from the field experiment, and mean data of three replications were analyzed using IBM SPSS (version 25). Analysis of variance (ANOVA) was conducted for the parameters of shoot infestation (infested shoots, healthy shoots, total shoots, % shoots infestation), fruit infestation (infested fruits, healthy fruits, total fruits, % fruits infestation), and yield (individual fruit weight, yield per plot, and yield per hectare) to identify the significant differences between the treatments using F tests at  $p \leq 0.05$ . Then we performed DMRT (Duncan's multiple range tests) for those parameters to compare the significant differences between the treatment means.

## 3. Results

### 3.1. Shoot Infestation

The effects of various treatments on shoot infestation by okra shoot and fruit borer (OSFB) are presented in Table 2. The maximum number of infested shoots (8.00) was observed in the control plot, whereas the minimum (1.67) was recorded in Spinosad treated plot. Based on healthy shoots, the maximum number of healthy shoots (43.67) was recorded in the abamectin-treated plot, which was statistically identical to the Spinosad-treated plot (43.00), and the minimum number of healthy shoots was observed in the control treatment. In terms of the total number of shoots, the maximum shoot (46.33) was recorded in the abamectin-treated plot, which was statistically similar (44.66) to the Spinosad treatment. The minimum (3.80%) and maximum (20.67%) levels of shoot infestation were observed in the Spinosad-treated plot and the control plot, respectively. The second highest (10.49%) shoot infestations were found in the plot treated with Azadirachtin 1% EC, followed by the plots treated with *Bacillus thuringiensis* (8.20%) and Abamectin 1.8 EC (5.78%), which were statistically identical. The percentage of OSFB damage was calculated based on the control treatment. All the treatments showed a significantly reduced percent shoot infestation, and the highest reduction was recorded in the Spinosad-treated plot (81.66%), whereas the minimum (49.29%) was found in the Azadirachtin-treated plot compared to the control.

**Table 2.** Effect of different insecticides on okra shoot and fruit borer(OSFB) in shoots of okra plants.

Treatment	Number of Infested Shoots Plot <sup>-1</sup>	Number of Healthy Shoots Plot <sup>-1</sup>	Number of Total Shoots Plot <sup>-1</sup>	% Shoot Infestation	% Infestation Reduction Over Control
T1	3.00 ± 0.00 c	33.67 ± 2.08 bc	36.67 ± 1.20 d	8.20 ± 0.26 bc	60.27
T2	1.67 ± 0.33 d	43.00 ± 3.61 a	44.67 ± 1.76 ab	3.80 ± 0.86 d	81.66
T3	2.67 ± 0.33 cd	43.67 ± 2.31 a	46.33 ± 1.20 a	5.78 ± 0.77 cd	72.08
T4	4.33 ± 0.33 b	37.00 ± 2.65 b	41.33 ± 1.66 bc	10.49 ± 0.67 b	49.29
T5	8.00 ± 0.57 a	30.67 ± 1.15 c	38.67 ± 0.88 cd	20.67 ± 1.25 a	-

Values within a column are means of three replications for each treatment ± standard errors. Means within the same letter(s) within a column do not differ significantly ( $p \leq 0.05$ ) according to Duncan's multiple range tests(DMRT). T1: *Bacillus thuringiensis* (Bt), T2: Spinosad 45 SC, T3: Abamectin 1.8 EC, T4: Azadirachtin 1% EC, and T5: Untreated Control.

### 3.2. Fruit Infestation

All treatments reduced the fruit infestation compared to the control (Table 3). The maximum number of infested fruits (15.00) was found in the control plot, whereas the minimum number of infested fruits (5.67) was recorded in the Spinosad-treated plot. The maximum number of healthy fruits (148.33) was recorded in the Spinosad-treated plot, and the minimum number (67.00) in the control treatment. The highest number of fruits (154.00) was counted in the Spinosad-treated plot, whereas the lowest number of fruits (82.66) was found in the control plot. The lowest percent of fruit infestation was recorded in the plot treated with Spinosad 45 SC (3.56%) and was significantly lower among the treatments, and the highest percent of fruit infestation was observed in the control plot (18.44%), followed by the plots treated with Bt (7.35%) Azadiractin (8.03%), and Abamectin 1.8 EC (8.19%). All treatments considerably reduced fruit damage over the control, as shown in Table 3. The treatments with Bt, Spinosad, Abamectin, and Azadiractin caused a respective reduction of 60.14, 80.69, 55.58, and 56.45% in fruit infestation over the control. The lowest reduction (55.58%) was found in the plot treated with Abamectin 1.8 EC, and the highest (80.69%) in the Spinosad 45 SC plot.

**Table 3.** Effect of different insecticides on OSFB in fruits of okra plants.

Treatment	Number of Infested Fruits Plot <sup>-1</sup>	Number of Healthy Fruits Plot <sup>-1</sup>	Number of Total Fruits Plot <sup>-1</sup>	% Fruit Infestation	% Infestation Reduction Over Control
T1	9.00 ± 1.15 cd	116.67 ± 12.14 ab	125.67 ± 11.66 a	7.35 ± 1.24 bc	60.14
T2	5.67 ± 1.85 d	148.33 ± 14.43 b	154.00 ± 15.82 a	3.56 ± 1.04 c	80.69
T3	9.33 ± 0.33 c	105.67 ± 8.09 bc	115.00 ± 8.08 ab	8.19 ± 0.61 b	55.58
T4	10.33 ± 0.88 b	124.67 ± 16.25 ab	135.00 ± 15.37 a	8.03 ± 1.65 bc	56.45
T5	15.00 ± 0.91 a	67.00 ± 7.44 c	82.66 ± 7.31 b	18.44 ± 1.88 a	-

Values within a column are means of three replications for each treatment ± standard errors. Means within the same letter(s) within a column do not differ significantly ( $p \leq 0.05$ ) according to DMRT. T1: *Bacillus thuringiensis* (Bt), T2: Spinosad 45 SC, T3: Abamectin 1.8 EC, T4: Azadiractin 1% EC, and T5: Untreated Control.

### 3.3. Yield Related Parameter

The effects of different treatments significantly influenced the individual fruit weight of okra (Table 4). The maximum weight of fruit (19.00 g) was recorded in the Spinosad-treated plot, which was statistically similar to the Abamectin (18.67 g) and Azadiractin (17.67 g) plots, whereas the minimum weight (15.67 g) was found in the control treatment. In terms of yield, the highest yield (2.80 kg) was obtained in the Spinosad-treated plot, which was statistically similar (2.18 kg) to the Azadiractin-treated plot, and the lowest yield per plot was found in the control plot (1.06 kg). Total yield was calculated by hectare of land, and the maximum yield (8.65 t ha<sup>-1</sup>) was found in the Spinosad-treated plot, which was statistically similar to the Azadiractin-treated plot (6.74 t ha<sup>-1</sup>). The minimum yield (3.27 t ha<sup>-1</sup>) was found in the control treatment, followed by the plots treated with Bt (6.28 t ha<sup>-1</sup>) and Abamectin (6.12 t ha<sup>-1</sup>).

**Table 4.** Effect of different insecticides on OSFB in okra fruit yield.

Treatments	Individual Fruit Weight (g)	Yield (Kg Plo <sup>-1</sup> )	Yield (t ha <sup>-1</sup> )
T1	17.33 ± 0.88 b	2.04 ± 0.29 b	6.28 ± 0.91 b
T2	19.00 ± 0.57 a	2.80 ± 0.21 a	8.65 ± 0.59 a
T3	18.67 ± 0.66 ab	1.98 ± 0.19 b	6.12 ± 0.68 b
T4	17.67 ± 0.67 ab	2.18 ± 0.23 ab	6.74 ± 0.67 ab
T5	15.67 ± 0.33 c	1.06 ± 0.13 c	3.27 ± 0.39 c

Values within a column are means of three replications for each treatment ± standard errors. Means within the same letter(s) within a column do not differ significantly ( $p \leq 0.05$ ) according to DMRT. T1: *Bacillus thuringiensis* (Bt), T2: Spinosad 45 SC, T3: Abamectin 1.8 EC, T4: Azadiractin 1% EC, and T5: Untreated Control.

### 3.4. Economic Analysis

The benefit–cost ratio (BCR) was calculated on the basis of the expenses incurred and value of crops obtained against the treatment used in the present study (Table 5). It is to be noted here that the expenses incurred refer to those only related to pest control. It was revealed that the BCR was the highest (2.64) for Spinosad 45 SC, followed by 1.70 for Azadirachtin, and the lowest BCR (1.18) was for Abamectin.

**Table 5.** Economic analysis of different treatments against the okra shoot and fruit borer of okra ( $t\ ha^{-1}$ ) grown during summer season.

Treatment	Cost of Control ( $ha^{-1}$ ) (US\$)	Marketable Yield ( $t\ ha^{-1}$ )	Gross Return (US\$)	Net Return (US\$)	Adjusted Net Return (US\$)	Benefit Cost Ratio (BCR)
T1	212.23	6.28	1056.91	844.68	253.90	1.20
T2	205.75	8.65	1238.88	1133.14	542.36	2.64
T3	157.08	6.12	933.62	775.92	185.14	1.18
T4	192.28	6.74	1105.25	918.17	327.39	1.70
T5	0.00	3.27	590.78	590.78	0.00	-

T1: *Bacillus thuringiensis* (Bt), T2: Spinosad 45 SC, T3: Abamectin 1.8 EC, T4: Azadirachtin 1% EC, and T5: Untreated Control.

## 4. Discussion

Four treatments were compared in this study, namely *Bacillus thuringiensis* (Bt), Spinosad 45 SC, Abamectin 1.8 EC, and Azadirachtin 1% EC. The results indicated that all treatments led to less infestation in shoots and fruits and higher economic yield over unsprayed control. Among the insecticides, Spinosad 45 SC appeared to be the most effective and promising novel anti-OSFB biorational insecticide. Regarding the vegetative damage in Spinosad-treated plot, 2.56–3.33% shoot infestation was reported by Mohammad et al. [8], which is partly comparable with our current results (3.80% shoot infestation). Jalgaonkar et al. [26] and Rahman et al. [27] found higher shoot damage by *E. vitella* (12.98–26.81% and 17.29–19.78% shoot infestation, respectively) compared with our study. As for the fruit damage in the Spinosad-treated plot, we found 3.56% fruit infestation, whereas Birah et al. [28] and Rahman et al. [27] reported much higher fruit infestation (18.89–37.74% and 10.05–14.98%, respectively) by *E. vitella*. Regarding yield, it was observed that the Spinosad-treated plot achieved the highest yield ( $8.65\ t\ ha^{-1}$ ), while Panbude et al. [29] reported that a plot treated with Spinosad 45 SC 0.01% achieved the maximum yield ( $8.72\ t\ ha^{-1}$ ) over the control due to the lowest infestation of shoots and fruits by OSFB, which echoes our findings.

Although the plot treated with Spinosad 45 SC attained a higher yield with higher economic benefit, its yield was statistically identical to that of the plot treated with Azadirachtin 1% EC. In case of fruit, 8.03% infestation was noted in the present study, while Subbireddy et al. [30] found 11.82% infestation in okra, which was a little higher than our current finding; this might be owing to the use of a lower concentration in the treatment with Azadirachtin. Ukeh and Umoetok [31] reported that a yield of  $5.56\ t\ ha^{-1}$  in okra was obtained with Azadirachtin 0.15% EC. However, the higher yield in our study ( $6.74\ t\ ha^{-1}$ ) might be due to the use of Azadirachtin at higher concentration. Gulzar et al. [32] reported that Azadirachtin extract worked on *E. vittella* by exerting toxic effects on neurosecretory cells and on the endocrine system.

*Bacillus thuringiensis* (Bt) was statistically similar to Azadirachtin 1% EC in terms of efficacy in the inhibition of lepidopteran pest OSFB and in enhancing production of okra. *Bacillus thuringiensis* was found to be effective on a lepidopteran insect *Spodoptera litura* Fab. in okra grown under organic manure application [33]. Sarker et al. [34] also reported the effectiveness of *Bacillus thuringiensis* (Bt) kurstaki (0.15%) as a management tool against *E. vittella* and found very good results compared with the control, which strongly supports our present results.

Abamectin 1.8 EC, among the studied insecticides, showed the poorest performance in terms of reduction of shoot and fruit infestation, and increasing the yield of okra. Javed et al. [35] found that a plot treated with Abamectin 1.8 EC showed a 33% increase of

yield over the control by suppressing both *E. vittella* and *Helicoverva armigera* Hubner which is partly comparable with our findings.

Treatments with higher BCR values would be more economical for producing okra. Therefore, the use of Spinosad 45 SC would be the most profitable, and Abamectin use would be the least, for producing okra by controlling OSFB.

## 5. Conclusions

The present study revealed that among the four studied treatments, Spinosad 45 SC showed the highest efficacy against OSFB. Azadirachtin 1% EC, *Bacillus thuringiensis*, and Abamectin also evidenced their effectiveness against OSFB and might be considered as control tools in okra plantations. These findings would be useful in integrated pest management programs for managing OSFB.

**Author Contributions:** This work was conducted in collaboration with all authors. Authors M.A.R.C. designed the study; M.A.R.C. and J.U. performed the statistical analysis, interpreted the data, and wrote the draft of the manuscript. M.F.M., A.U.K., M.S.H., and M.O.K.A. validated the data, collected references, and revised, M.D.H.P., M.S.R., N.A., and K.Y.C. revised and improved the manuscript. M.T.N. designed and finalized the manuscript. All authors carefully reviewed and approved the final version of the manuscript.

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