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Md. Mahi Imam Mollah
Department of Entomology, Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali, Bangladesh

Nayem Hassan
Russell IPM Ltd., Unit 45, First Avenue, Deeside Industrial Park Deeside, Flintshire, CH5 2NU United Kingdom

Soyema Khatun
Crop Physiology Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensing, Bangladesh

Md. Mahbubar Rahman
Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur, Bangladesh

Corresponding Author:
Md. Mahi Imam Mollah
Department of Entomology, Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali, Bangladesh

Sequential application of bio-pesticides suppresses eggplant shoot and fruit borer, *Leucinodes orbonalis* Guenee infestation

Md. Mahi Imam Mollah, Nayem Hassan, Soyema Khatun and Md. Mahbubar Rahman

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Abstract

Different bio-pesticides were evaluated against eggplant shoot and fruit borer, *Leucinodes orbonalis* G. in combination. All combination of bio-pesticides were effective against eggplant shoot and fruit borer but Lycomax + Biotin M + Antario and Lycomax + Biotin M + Fytomax 3% found most potent and control 88.43 and 84.06 percent shoot infestation; 69.67 and 66.44 percent fruit infestation by count; 72.70 and 70.49 percent fruit infestation by weight, respectively. Lycomax + Biotin M + Antario and Lycomax + Fytomax 0.1% + Biomax increased 32.90 and 28.66 percent gross yield; 120.19 and 87.5 percent marketable yield, respectively over control. Individual fruit weight found maximum from Lycomax + Fytomax 0.1% + Biomax and Biotin M + Antario where it was 51.74 g and 48.13 g for marketable fruit while 44.05 g and 44.61 g for infested fruit. The present study revealed that Lycomax + Biotin M + Antario and Lycomax + Biotin M + Fytomax 3% effectively control ESFB while Lycomax + Biotin M + Antario and Lycomax + Fytomax 0.1% + Biomax increases the yield. Therefore, application of Lycomax + Biotin M + Antario might be recommended for successful production of eggplant to get maximum yield with minimum infestation.

Keywords: Eggplant, *Leucinodes orbonalis* G., bio-pesticides, *Bacillus thuringiensis*, *Trichoderma* spp.

1. Introduction

Eggplant, also known as brinjal or aubergine (*Solanum melongena* L.), is the second most important vegetable after potato grown in Bangladesh. It is cultivated in 50,955 hectares of land with a total production of 507,000 metric tons involving about 150,000 resource-poor farmers covering 4.7% of winter and 9.6% of summer vegetable production [2]. Brinjal can be grown in almost all agro-climatic zones but mostly cultivated and popular in South and South-East Asia [38], Central America and some parts of Africa [13] prevailing hot-wet climate [12]. Over 100 varieties of brinjal are being cultivated, providing fruits of different color, size, shape, and taste around the world [35]. Brinjal has high content of vitamins, minerals and bioactive compounds but very low caloric value that helps sound human health [28, 24, 7]. It is also rich in anthocyanins and phenolic acids having multiple beneficial properties for human health [25, 3].

The longer fruiting and harvesting period as well led to higher yield and content of high nutritional value causes the increased cultivation of eggplant [10]. But frequent infestation of various insect pests like whiteflies, aphids, mites, eggplant shoot and fruit borer, leafhopper, thrips, leaf roller, stem borer, spotted beetles and blister beetle [17, 29] affect its successful production. Among them, eggplant shoot and fruit borer (ESFB), *Leucinodes orbonalis* Guenee is most destructive to eggplant [17; 4, 30]. It causes severe damage in most of the growing areas [8] especially in south Asia [38] inflicting 30 to 60% yield loss, even when the crop is frequently sprayed with insecticides [22]. Larvae damage shoots and flowers, although the most serious damage is caused by their boring into the fruit and rendering it unmarketable [35]. Control of ESFB is not easy as the larvae lives inside the bored holes blocking the entrance with frass which protects them from most topically applied insecticides and natural enemies [6]. The damaged fruits lose content of vitamin C up to 80 percent [34]. Brinjal crops are typically sprayed with insecticides over 80 times in a season of 4-5 months in most of the major growing areas in Bangladesh [20].

This frequent application of insecticides results in very high pesticide residue levels on the fruit, exposes farm workers to hazards, kills beneficial insects and contributes to polluting the local environment [27].

Bio-rational insecticides with least toxicity have the potential to be a safe alternative of synthetic insecticides [9, 1] with least hazardous impact. Hence, the study was coined to evaluate the field efficacy of bio-rational insecticides as alternatives to synthetic insecticides against the shoot and fruit borer of eggplant as well as their impact on yield.

2. Materials and Methods

2.1 Location and Soil type

The experiment was carried out at research field of Entomology Department in Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh with brinjal variety 'Khotokhotia' during rainy season.

The study area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with p^H 5.8-6.5, CEC 25.58 and the soil was silty clay loam in texture [21]. This area is situated at 24.09 N latitude and 90.26 E longitudes with an elevation of 8.4 meter from the sea level.

2.2 Experimental design and treatments

The experimental design was laid out at randomized complete block design (RCBD) with three replications. The plot size was 4.8 x 1.6 m with spacing of 0.8 x 0.8 m between rows and plants, respectively. Each plot contains two rows with 5 plants in a row. The applied combinations were Biotin M + Antario (T1), Lycomax + Biotin M + Antario (T2), Biomax (T3), Fytomax 0.1% + Biotin M (T4), Lycomax + Biotin M + Fytomax 3% (T5), Fytomax 3% (T6), Lycomax + Fytomax 0.1% + Biomax (T7) and untreated control (T8). Lycomax was applied on the basal area of the plant. All other bio-pesticides were applied by spraying. In case of insecticide combinations, these were applied sequentially for each alternative spray schedule. All the bio-pesticides were collected from Russell IPM ltd, United Kingdom and Russell IPM Ltd. Bangladesh and their details provided in Table 1. The spray mixture of insecticides was prepared by adding water directly to the sprayer tank to get desired concentration and for convenient foliar application. Spraying was carried out using a knapsack sprayer and insecticide mixture were applied @ 500-750 liters per hectare based on the growth stage of the plants. Spraying was started at vegetative stage and continued up to last harvest with an interval of 7 days during vegetative and fruiting stage.

Table 1: Bio-pesticides used in this study with their Informations

Bio-pesticides	Active ingredients	Trading Company	Dose
Lycomax	*Trichoderma harzianum* + *Metarhizium anisopila*	Russell IPM Ltd., BD	4.0 kg/ha
Biotin M	Abamectin 1.2% + Emamectin benzoate 1%	Russell IPM Ltd., UK	2 ml/L
Antario	*Bacillus thuringiensis* 1.4% + Abamectin 0.1%	Russell IPM Ltd., BD	1.5 g/L
Biomax	Abamectin 1.2%	Russell IPM Ltd., BD	2 ml/L
Fytomax 0.1%	Azadirachtin 0.1%	Russell IPM Ltd., BD	1.5 mL/L
Fytomax 3%	Azadirachtin 3%	Russell IPM Ltd., UK	1.5 mL/L

2.3 Data collection and presentation

Number of infested and healthy shoots from each plot was recorded at each 4th and 7th day of treatment application and percentage of shoot infestation was calculated. Fruit picking was performed at each 7th day from all the plants of all plots and infested fruit was separated from healthy. The number and weight of healthy and infested fruit was recorded separately from each plot during each picking to work out percent fruit infestation. Total or gross yield was calculated by adding the yield of infested and healthy fruits from all the harvest. Weight of individual fruit was worked out by dividing the weight of all fruit by their number. Finally, the yield was converted to tons per hectare. The per cent shoot damage and per cent fruit damage was worked out using following formulae:

$$\text{Percent (\%) shoot infestation} = \frac{\text{Number of infested shoots}}{\text{Total number of shoots}} \times 100$$

$$\text{Percent (\%) fruit infestation} = \frac{\text{Number/weight of infested fruit}}{\text{Total number/weight of fruit}} \times 100$$

Percent (%) increase/decrease/change over control

$$= \frac{\text{Mean value of the treatment} - \text{Mean value of the control}}{\text{Mean value of the control}} \times 100$$

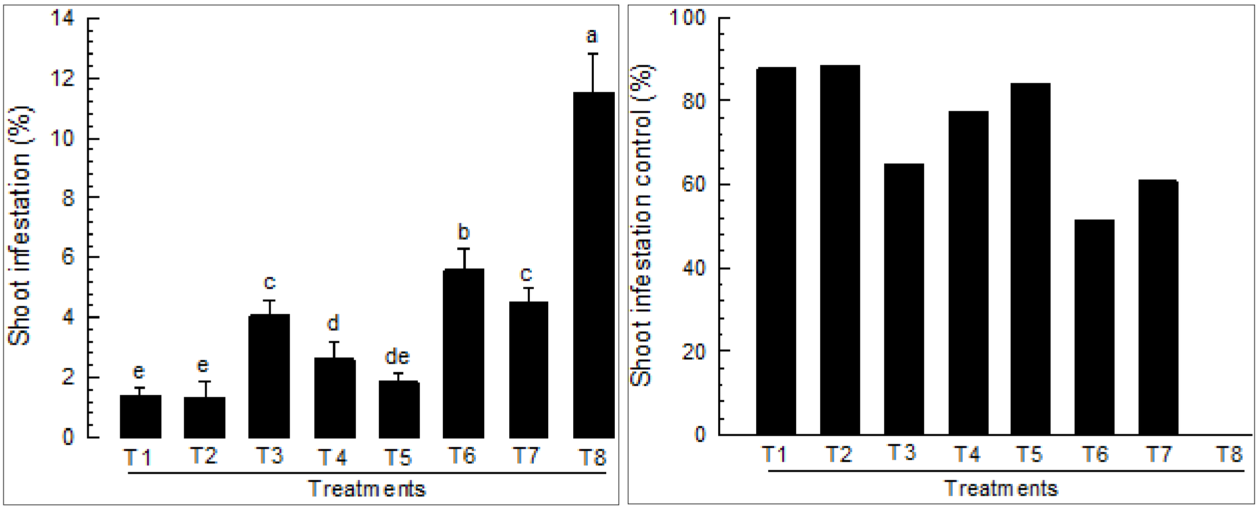
2.4 Statistical analysis of data

The collected raw data were arranging and inputted in Microsoft Accel for calculation. All the data for continuous variables were subjected to one-way analysis of variance (ANOVA) using PROG GLM in SAS program [31]. Means were compared with the least significant difference (LSD) test at 0.05 level of Type I error. Data was represented as graph using Sigma Plot 12.5 software. All the treatments were replicated in three plots. Shoot infestation data are mean of 10 consecutive observations and fruit infestation and yield data are mean of 7 observations.

3. Results

3.1 Bio-pesticides successfully control shoot infestation

Combination of bio-pesticides were evaluated for their efficacy against the shoot damage caused by eggplant shoot and fruit borer (ESFB) and all the treatments significantly ($p < 0.05$) control the shoot infestation (Figure 1). Among the packages, T1, T2 and T5 found most effective ensuring lowest infestation rate of 1.41, 1.33 and 1.83 percent shoot infestation, respectively (Figure 1A) which was much less than untreated control (11.49 percent shoot infestation). These three treatments are statistically similar. Potency of any treatments can be determined by their capability to reduce shoot infestation over control (Figure 1B). In this aspect, T1 (88.42%) followed by T2 (87.70%) and T5 (85.05%) was most potent. However, all the combination of insecticides confirmed more than 85 percent shoot infestation reduction in comparison to untreated control. Based on the above results, T1, T2 or T5 can be the best choice to prevent shoot infestation needed for successful eggplant production.

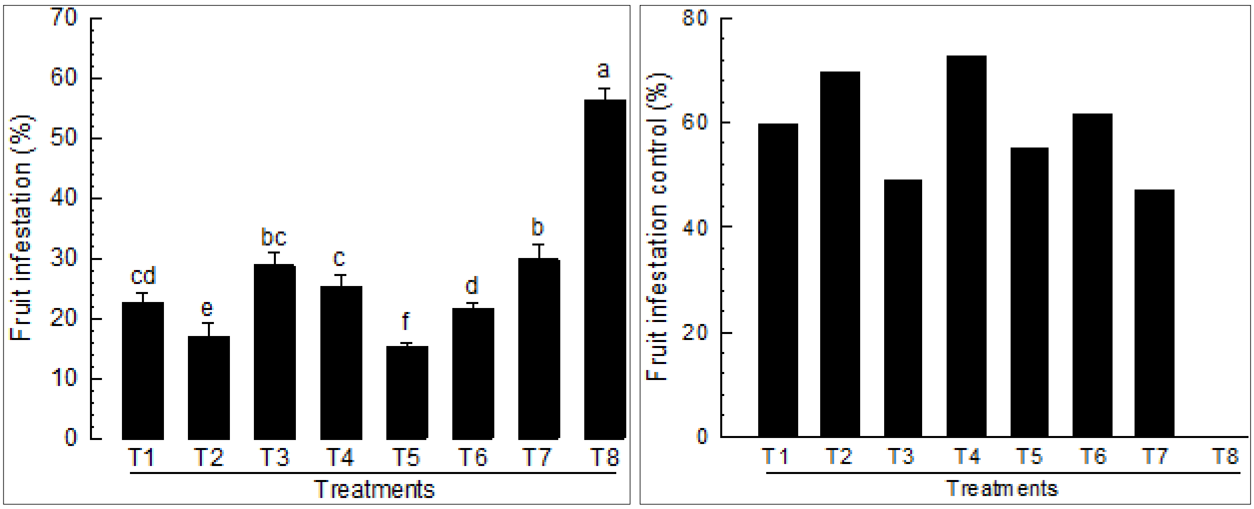


(A) **(B)**

Fig 1: Effect of bio-pesticides on shoot infestation caused by eggplant shoot and fruit borer. (A) Percent shoot infestation (B) Shoot infestation control by applied insecticides.

3.2 Bio-pesticides for fruit infestation reduction

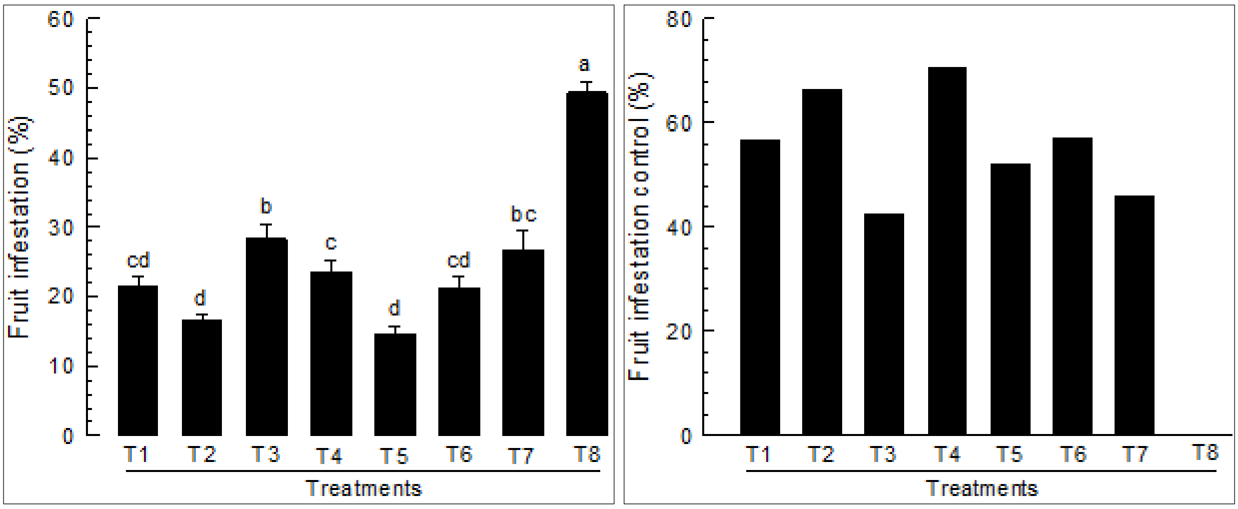
At fruiting stage ESFB migrate from shoot to tender fruit to feed on the internal fleshy part causing significant damage. All the treated insecticides significantly ($p < 0.05$) lessen the fruit infestation (Figure 2). Rate of infestation (by number) varies based on insecticides combination (Figure 2A). Among the treated insecticide packages, lowest extend of fruit infestation was confirmed by T5 (15.32%) which is statistically different but closely followed by T2 (17.10%), T6 (21.69%) and T1 (22.73%) while maximum of the same was observed from T7 (29.87%) followed by T3 (28.77%) and T4 (25.32%). However, the fruit infestation found much increased in untreated control (56.38%) compared to treated plots. In context to fruit infestation reduction over control, T5 found most potent ensuring 72.70% control that was followed by T2, T6 and T1 providing 69.67, 61.52 and 59.68 percent control of fruit infestation, respectively (Figure 2B).



(A) (B)

Fig 2: Effect of bio-pesticides on fruit infestation (number basis) by eggplant shoot and fruit borer. (A) Percent fruit infestation (B) Fruit infestation control by applied insecticides.

Likewise, bio-pesticides have significant ($p < 0.05$) effect for controlling fruit infestation in weight basis (Figure 3). Among the treatments, lowest percent fruit infestation by weight was recorded from T5 (14.56%) which was statistically similar and closely followed by T2 (16.56%), T6 (21.22%) and T1 (21.42%) while the maximum of that was recorded from T3 (28.39%) followed by T7 (26.66%), T4 (23.60%) (Fig. 3A). However, the untreated control plots face much more infestation (49.34%) than treated plots. Performance of the insecticides for fruit infestation reduction can be described from percent reduction of fruit infestation over control (Fig. 3B). In this context, T5 (70.49% control) found most effective, then T2 (66.43% control), T6 (56.99% control) and T1 (56.58% control). The above results thus revealed that T5 and T2 are most effective for controlling fruit infestation against eggplant shoot and fruit borer.



(A) (B)

Fig 3: Effect of bio-rational insecticide on fruit infestation (weight basis) by eggplant shoot and fruit borer. (A) Percent fruit infestation (B) Fruit infestation control by treated insecticides.

3.3 Bio-pesticides for increased fruit yield

Yield of eggplant depends mainly on management practices against eggplant shoot and fruit borer infestation. The treated insecticides increased the yield significantly ($p < 0.05$) after controlling the ESFB infestation effectively (Table 2). Infested fruit yield was lowest in T5 (0.87 ton/ha) which was statistically different and followed by T2 (1.36 ton/ha) and T6 (1.51 ton/ha) while maximum of that was recorded from control (3.07 ton/ha) and followed by T7 (2.12 ton/ha). In context to infested fruit yield decrease over untreated control, T5 found most effective ensuring 71.66% decrease compared to control followed by T2 and T6 providing 55.70 and 50.81 percent reduction of infested fruit yield, respectively.

The most essential and concern marketable fruit yield was also significantly ($p < 0.05$) increased by bio-pesticides (Table 2). Highest marketable yield was confirmed by T2 (6.88 ton/ha) followed by T7 (5.85 ton/ha), T1 (5.67 ton/ha), T6 (5.58 ton/ha) and T5 (5.13 ton/ha) whereas the lowest of that was harvested from untreated control (3.12 ton/ha) followed by T3 (4.03 ton/ha) and T4 (4.98 ton/ha) (Fig. 5A). For marketable fruit yield, increase in yield over control was maximum for T2 (120.19%) which was followed by T7 (87.50%) and T1 (81.73%).

Therefore, the gross yield was also controlled by insecticides (Table 2). Consistently, maximum gross yield was produced by T2 (8.25 ton/ha) which is statistically similar and closely followed by T7 (7.98 ton/ha), T1 (7.22 ton/ha) and T6 (7.09 ton/ha) while lowest of that found in T3 (5.61 ton/ha) that is followed by T5 (6.00 ton/ha) and T4 (6.54 ton/ha). However, the gross yield in untreated control was 6.21 ton/ha. Rate of change in total yield over control was analyzed and presented in Table 2 to see the yield contribution of the treated insecticides. In this perspective, T2 increased the highest (32.90%) followed by T7 (28.66%), T1 (16.45%), T6 (14.35%) and T4 (5.32%). However, gross yield was decreased for T3 (9.68%) and T5 (3.22%). The above discussion thus revealed that T2 and T7 are highly potential for increasing eggplant total yield compared to untreated control.

Table 2: Effect of bio-pesticide combinations on yield of eggplant

Treatments	Infested fruit yield (ton/ha)		Healthy fruit yield (ton/ha)		Gross yield (ton/ha)	
	Mean ± SD	Decrease over control	Mean ± SD	Increase over control	Mean ± SD	Change over control
T1	1.55 ± 0.29 c	- 49.51	5.67 ± 0.55 bc	+ 81.73	7.22 ± 1.03 ab	+ 16.45
T2	1.37 ± 0.22 cd	- 55.70	6.88 ± 0.50 a	+ 120.19	8.25 ± 1.01 a	+ 32.90
T3	1.59 ± 0.14 c	- 48.21	4.02 ± 0.25 e	+ 28.53	5.61 ± 0.30 d	- 9.68
T4	1.55 ± 0.26 c	- 71.66	4.70 ± 0.48 d	+ 64.42	5.57 ± 0.59 cd	- 3.23
T5	0.87 ± 0.12 d	- 49.84	4.99 ± 0.39 cd	+ 59.62	6.54 ± 0.65 b	+ 5.32
T6	1.51 ± 0.29 c	- 50.81	5.58 ± 0.52 bc	+ 78.53	7.09 ± 0.81 ab	+ 14.35
T7	2.13 ± 0.26 b	- 30.94	5.85 ± 0.38 b	+ 87.50	7.98 ± 0.51 a	+ 28.66
T8	3.08 ± 0.20 a	0.00	3.13 ± 0.34 f	0.00	6.21 ± 0.54 bc	0.00

Values are mean of 3 replications from 7 consecutive harvest. In the column, different letter denotes significant difference by LSD test at 5% level of significance

3.4 Bio-pesticides effect on individual fruit weight

Eggplant shoot and fruit borer larvae bore into the tender fruit and feed on internal fleshy part of the fruit, growth and development of fruit is also little interrupted that causes weight loss. Insecticides prevent the fruit infestation, finally weight loss is controlled significantly in differential manner (Figure 4). All the treated insecticides confirm gain of individual healthy fruit weight in comparison to control where it was 42.66 g for control. Maximum weight gain was achieved from T7 (51.74 g) followed by T1 (48.13 g), T5 (46.93 g) and T2 (46.21 g). Similarly, individual infested fruit weight also increased by insecticide application where it was 32.09 g for control. Maximum weight gain of that was confirmed by T1 (44.61 g) followed by T2 (44.43 g), T7 (44.03 g) and T5 (43.84 g). Therefore, the above results reveal that without insecticide application individual fruit weight decrease for both infested and healthy fruit which leads to significant yield loss.

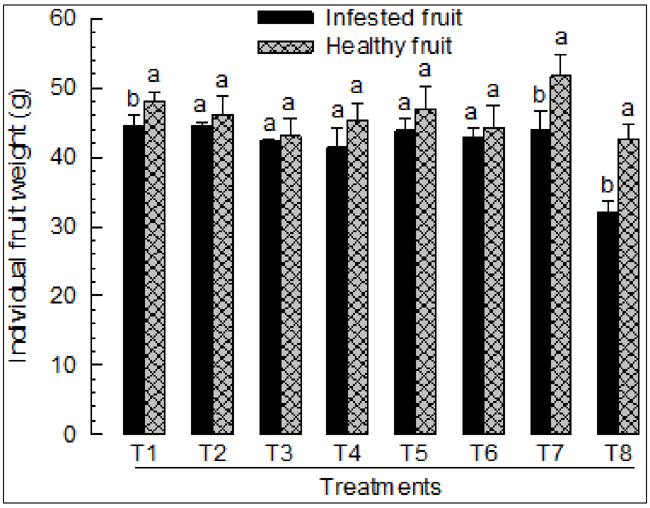


Fig 4: Effect of bio-pesticides on individual fruit weight.

4. Discussion

Bio-pesticides are essential and promising against major insect pests in eggplant because of their least or non-toxicity towards environment and non-target insects. In the present study, all the bio-pesticide combinations found effective against ESFB. But two of these, Lycomax + Biotin M + Antario and Lycomax + Biotin M + Fytomax 3% was most potent for shoot and fruit infestation reduction. Active ingredients of these insecticides are *Trichoderma Spp*. for Lycomax; Abamectin 1.2% + Emamectin benzoate 1% for Biotin M; *Bacillus thuringiensis* 1.4% + Abamectin 0.1% for Antario and Azadirachtin 3% for Fytomax 3%. Both the potent insecticides combination includes Lycomax that contains soil born fungi *Trichoderma* and *Metarhizium* with biocontrol effect on *Leucinodes orbinalis* G pupae inhibiting in soil [11]. Foliar application of Bt @ 2 g/liter of water recorded lowest shoot and fruit infestation followed by Neem Seed Kernel Extract, NSKE (5%) [23]. Five percent NSKE was found to be the most effective treatments in reducing the shoot and fruit borer infestation as well as whitefly on brinjal [19, 38] concluded that Bt and neem oil may be incorporated for integrated management practices of brinjal shoot and fruit borer. It was reported that application of Emamectin benzoate 5 SG and Spinosad found effective against shoot damage in eggplant [16, 14, 15] concluded that application of Phonate at transplanting followed by foliar spray of Bt + Carbaryl reduced the shoot infestation from 6.71 to 9.30%. [16] describe that Emamectin benzoate was most effective in reducing the fruit damage in brinjal.

From the applied insecticide combination, Lycomax + Biotin M + Antario and Lycomax + Fytomax 0.1% + Biomax produces maximum marketable and gross fruit yield. Active ingredient of these insecticides is *Trichoderma* and *Metarhizium* for Lycomax; Abamectin 1.2% + Emamectin benzoate 1% for Biotin M; *Bacillus thuringiensis* 1.4% + Abamectin 0.1% for Antario; Azadirachtin 0.1% for Fytomax 0.1% and Abamectin 1.2% for Biomax. It is assumed that because of *Trichoderma* in Lycomax, yield increased for these two treatments [18]. Reported that *Trichoderma viride* significantly increased the height and weight of dwarf tomato plants. Another species, *Trichoderma harzianum* enhances germination, rapid and increased flowering, increased heights, and fresh weights in several plant species, including pepper, periwinkle and chrysanthemum [5]. Another treatment, Biotin M + Fytomax 3% + Lycomax also contain *Trichoderma* spp. but yield decreased although potent for infestation reduction. The reason may be the repeated application of Fytomax 3% (Azadirachtin 3%) that have bad impact on plant growth-promoting rhizobacteria (PGPR) and soil microorganisms [32]. The present findings are supported by [23] who reported that foliar application of Bt @ 2 g/liter of water produces highest marketable yield followed by NSKE (5%). [36] reported that Bt formulation 'halt' treated plots yield maximum fruit of brinjal while 'delfin' recorded minimum fruit yield. Five percent NSKE was found to be the most effective treatments to record maximum yield of brinjal [19]. Another study reported that Emamectin benzoate 5 SG and Spinosad 45 SC produces highest marketable fruit yield while untreated check produces lowest healthy fruit yield [14; 37. 26] reported that *B. thuringiensis* (Bt) formulation, Dipel 0.2 per cent at 10 days interval resulted maximum yield of marketable fruits (196.96 q/ha) [33]. reported that Btk @ 0.15 per cent found to be effective resulting in higher yield. Therefore, it can be concluded that bio-pesticides can effectively control the Eggplant shoot and fruit borer (*L. orbonalis* G.) providing increased fruit yield.

5. Conclusions

Farmers of Bangladesh face a serious challenge in eggplant production because of its vulnerability to several insects including eggplant shoot and fruit borer. Therefore, it is imperative to develop effective management strategies and tools for ESFB conserving safety issues. In this context, the bio-pesticides could be the best alternative. Among the tested insecticides, Lycomax + Biotin M + Antario and Lycomax + Biotin M + Fytomax 3% found effective for ESFB control and Lycomax + Biotin M + Antario and Lycomax + Fytomax 0.1% + Biomax found potent for increasing yield. However, further research is needed, such as efficacy cost-benefit ratio, plant growth control, effect on other insets in eggplant field.

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