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Evaluation of Microbial Insecticides for the Management of Eggplant Shoot and Fruit Borer, *Leucinodes orbonalis* Guenee

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ABSTRACT

Eggplant Shoot and Fruit Borer (ESFB), *Leucinodes orbonalis* Guenee, is an economically important pest in Bangladesh. Different toxic chemical insecticides are frequently applied in the field to control this notorious pest. In this study, we tested several non-toxic microbial insecticides for their efficacy against ESFB as well as marketable yield. Abamectin 1.2% + Emamectin benzoate 1%, Spinosad 45 SC and *Bacillus thuringiensis* var. *Kurstaki* 5% WP significantly prevents shoot infestation compared to control. Fruit infestation was also reduced by Abamectin + Emamectin benzoate, Spinosad 45 SC, and *Bacillus thuringiensis* var. Kurstaki 5% WP, in contrast, to control by both number and weight basis, respectively. Marketable yield increased exponentially upon Spinosad 45 SC and Abamectin 1.2% + Emamectin benzoate 1% application. Finally, gross yield also increased notably by Spinosad 45 SC application. From this study, we found that all the microbial insecticides especially Spinosad 45 SC and Abamectin 1.2% + Emamectin benzoate 1% found effective to reduce ESFB infestation both in the shoot and fruit. These also increase the marketable fruit yield by increasing the healthy fruit weight and decreasing the infested fruit weight individually.

Keywords: *Leucinodes orbonalis*, Microbial insecticides, Spinosad, *Bacillus thuringiensis*, Abamectin, Emamectin benzoate.

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INTRODUCTION

Eggplant (*Solanum melongena* L.), also called aubergine or brinjal, is the fifth most economically important crop after potato, tomato, pepper, and tobacco from the Solanaceae family [1]. This species is mostly cultivated and popular in the Indian sub-continent [2], some parts of Africa, and Central America [3] with a hot-wet climate [4]. Two other less-known species; the scarlet eggplant (*S. aethiopicum* L.) and African eggplant (*S. macrocarpon* L.) are cultivated in sub-Saharan Africa with local importance [5]. The annual production of eggplant is close to 50 million tons globally, providing a net return of more than US$10 billion per year [6]. Nutritionally important eggplant has an increased content of vitamins, minerals, and bioactive compounds but a very reduced caloric value needed for sound human health [7, 8]. Phenolic compounds [9], particularly phenolic acid in the form of anthocyanins present in fruit skin [10] and chlorogenic acid of fruit flesh [11] increase the bioactive properties of eggplant. Both anthocyanins and phenolic acids have multiple beneficial properties for human health [12].

Longer fruiting and harvesting periods, higher yields, higher nutritional value, increased planting of eggplants [13-15]. In Bangladesh, Brinjal (*Solanum melongena* L.) is cultivated in 50,955 hectares of area with a total production of 507,000 metric tons [16] making it the second most important vegetable crop. However, eggplant production is severely affected by the increased cost of production on the management of different insect pests attacking from the seedling to the fruiting stage [17]. Eggplant is frequently attacked by various insect pests including mites, whiteflies, aphids, eggplant shoot and fruit borers, leafhoppers, thrips, spotted beetles, leaf roller, stem borers, and blister beetle [17]. Among them, eggplant shoot and fruit borer (ESFB), *Leucinodes orbonalis* Guenee is the key pest of eggplant [18, 19] inflicting considerable damage in almost all the growing areas [20], especially in south Asia [21]. Prevention of ESFB is difficult as larvae live within the bored holes blockading it with frass which defends them from most topically applied insecticides and natural enemies [22]. Because of internal feeding, the fruits miss the content of vitamin C up to 80% [23], market value, and yield up to 90% [24]. Frequent use of synthetic insecticides to manage this pest leads to toxic consumption, destabilization of the ecosystem, increased insect resistance [25], and mortality of biological control agents including ladybird beetle [26] and stink bug [27]. Microbial insecticides have the potential to be a safe alternative to synthetic insecticides in eggplant fields [28] with the least hazardous impact. The potency of microbial insecticides may be because of their immune suppressive activity [29, 30], Toxemia [31], or cell death by apoptosis [32]. Therefore, this literature is aimed at evaluating the field efficacy of microbial insecticides as alternatives to synthetic insecticides against the shoot and fruit borer of eggplant.

MATERIALS AND METHODS

Location and soil type

The experiment was carried out at Gazipur, Bangladesh with the brinjal variety 'Singnath' during the *Kharif* season to evaluate the efficacy of microbial insecticides against eggplant shoot and fruit borer (*Leucinodes orbonalis* L.) as well as their impact on yield potentiality. The study area is situated at 24.09 N latitude and 90.26 E longitude with an elevation of 8.4 meters from the sea level. The area represents the Agro-Ecological Zone of the Madhupur tract (AEZ-28) with p^H 5.8-6.5, CEC 25.58, and the soil was silty clay loam in texture [33].

Experimental design and treatments

The experiment was designed following a randomized complete block design with 3 replications. The plot size was 10.0 x 2.0 m with a spacing of 0.7 x 0.7 m between rows and plants, respectively. Each plot contains two rows with 13 plants in a row. The intercultural operations and fertilizations were conducted whenever necessary as previously [25]. The applied treatments were: Spinosad 45 SC @ 0.2 mL/L water (T1), *Bacillus thuringiensis* var. *Kurstaki* 5% WP @ 1.5 g/L water (T2), Carbosulfan 20 EC @ 3 mL/L water (T3), Abamectin 1.2% + Emamectin benzoate 1% @ 2.0 mL/L water (T4) and only water (T5). The synthetic insecticide was purchased from a local market and the microbial were provided by Russell IPM, UK, the details are given in **Table 1**. Water was directly added to all spray mixtures of insecticides to get desired concentration and for convenient foliar spray. Spraying was carried out using a knapsack sprayer, with 500 to 750 liters of insecticide applied per hectare, depending on the growth stage of the plants. Spraying began at the vegetative stage and continued at 7-day intervals until final harvest.

Table 1. List of insecticides used in this study with their Information

Trade name	Common name	Trading Company	Dose
Tracer 45 SC	Spinosad 45 SC	Auto Crop Care Ltd.	0.2 mL/L
Antario 32 KAB	*Bacillus thuringiensis* var. *Kurstaki* 5% WP	Russell IPM, UK	1.5 g/L
Marshal 20 EC	Carbosulfan 20 EC	Auto Crop Care Ltd.	3 mL/L
Biotin M	Abamectin 1.2% + Emamectin benzoate 1%	Russell IPM, UK	2.5 mL/L

Data collection and annotation

The quantity of infested and healthy shoots in every plot was documented on every 3rd day from all the plants and the percentage of shoot infestation was worked out. Fruits were picked every 5 days from all plants in all plots, and diseased fruits and healthy fruits were separated. The total quantity and weight of healthy and infested fruits were documented distinctively for every plot at each picking and the percent fruit damage was worked out. The total yield was calculated by summing the yield of infested and healthy fruits from all the harvests. Finally, the yield was converted to tons per hectare. Individual fruit weight also was calculated. Shoot infestation was recorded 8 times and fruit infestation was recorded 8 times. The percent shoot and fruit damage were worked out using the following formulae:

$$Percent\ (\%)\ shoot/fruit\ infestation = \frac{Number\ of\ infested\ shoot/fruits}{Total\ number\ of\ shoot/fruits} \times 100 \quad (1)$$

$$\text{Percent (\%) increase/reduction over control} = \frac{\text{Mean value of the control} - \text{Mean value of the treatment}}{Mean\ value\ of\ the\ control} \times 100 \quad (2)$$

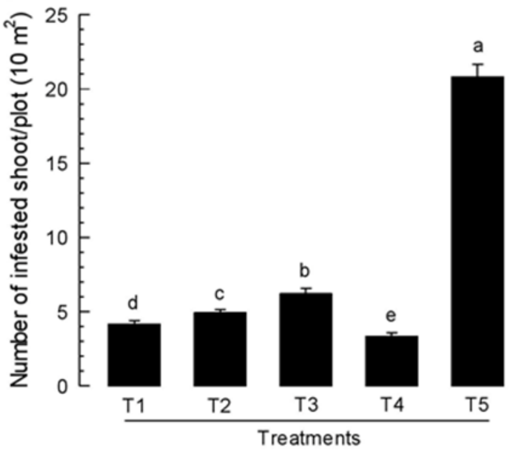
Statistical analysis of data

The data which were gathered were arranged and calculated using Microsoft Accel. All the data for continuous variables were exposed to a one-way analysis of variance (ANOVA) by the use of PROG GLM in the SAS program [34]. Means were associated with the minimum significant difference (LSD) test at 0.05 level of Type I error. Data was represented as a graph using Sigma Plot 12.5 software. Each treatment was replicated three times with 8 consecutive observations. Different letters above the error bar denote significant differences (p >0.05, LSD Test) among the treatments.

RESULTS AND DISCUSSION

Effect of microbial insecticides on shoot formation and infestation

Eggplant shoot and fruit borer attack the shoot at the vegetative a wither and dried later. Four insecticides were a s well as reproductive stage causing the shoot ssessed for their effectiveness against shoot infestation by eggplant shoot and fruit borer **(Figure 1).** All the insecticides reduce the number of infested shoots significantly (p <0.05) and effectively but Abamectin 1.2% + Emamectin benzoate 1% and Spinosad 45 SC were found most effective compared to the control **(Figure 1a**). These insecticides also have a role in the total number of healthy shoot production where Carbosulfan 20 EC and Spinosad 45 SC was most potent **(Figure 1b**). Therefore, the shoot infestation rate was affected by insecticides. The lowest shoot infestation rate was achieved from Abamectin 1.2% + Emamectin benzoate 1% and Spinosad 45 SC while the maximum was from Carbosulfan 20 EC after control **(Figure 1c**). In comparison to the control, shoot infestation reduction by Abamectin 1.2% + Emamectin benzoate 1% and Spinosad 45 SC was 75.76% and 71.43% respectively. Thus, Abamectin 1.2% + Emamectin benzoate 1% and Spinosad 45 SC were found effective for controlling the shoot infestation.



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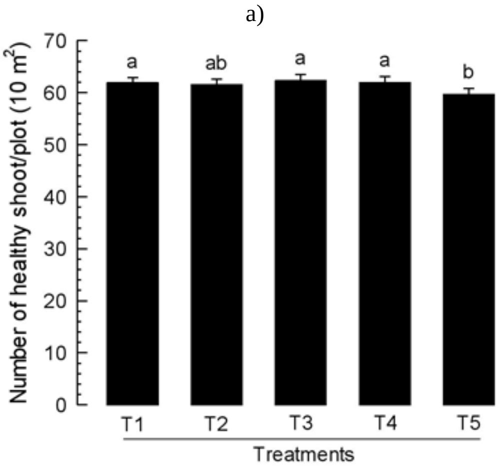

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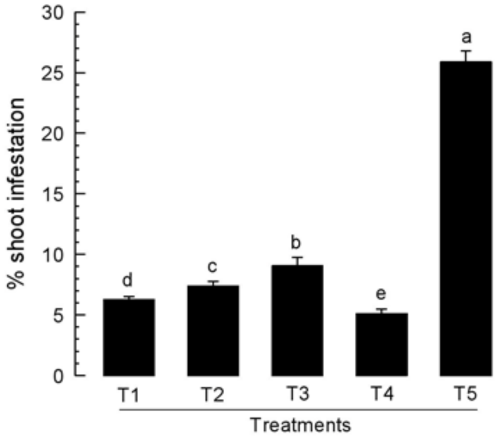

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Figure 1. Effect of insecticide on shoot infestation caused by eggplant shoot and fruit borer. a) Number of infested shoots per plot. b) Number of healthy shoots per plot. c) Percent shoot infestation reduction by insecticides.

Effect of insecticides on fruit infestation

Eggplant shoots and fruit borers feed on the internal fleshy part of the fruit and cause significant damage. The microbial insecticides have a significant ($p < 0.05$) role in reducing fruit infestation **(Figure 2)**. Extend of infested fruit number varies based on insecticides **(Figure 2a)**. Among the insecticides, Abamectin 1.2 % + Emamectin benzoate 1% as well as *Bacillus thuringiensis* var. *Kurstaki* 5% WP was found potent than Carbosulfan 20 EC and Spinosad 45 SC. Insecticides also contribute to healthy fruit production **(Figure 2b)**. Spinosad 45 SC and Abamectin 1.2 % + Emamectin benzoate 1% produce more healthy fruit than Carbosulfan 20 EC and *Bacillus thuringiensis* var. *Kurstaki* 5% WP. Finally, microbial insecticides controlled the rate of fruit infestation **(Figure 2c)**. Abamectin 1.2 % + Emamectin benzoate 1% and Spinosad 45 SC confirmed less fruit infestation rate than *Bacillus thuringiensis* var. *Kurstaki* 5% WP and Carbosulfun 20 EC compared to control. The performance of insecticides in reducing fruit damage can be explained by the percentage reduction in fruit damage relative to controls. In this context, Abamectin 1.2 % + Emamectin benzoate 1% (70.88% reduction over control) was best followed by Spinosad 45 SC (66.39% reduction over control), *Bacillus thuringiensis* var. Kurstaki 5% WP (63.69% reduction over control) and Carbosulfun 20 EC (46.09% reduction over control).

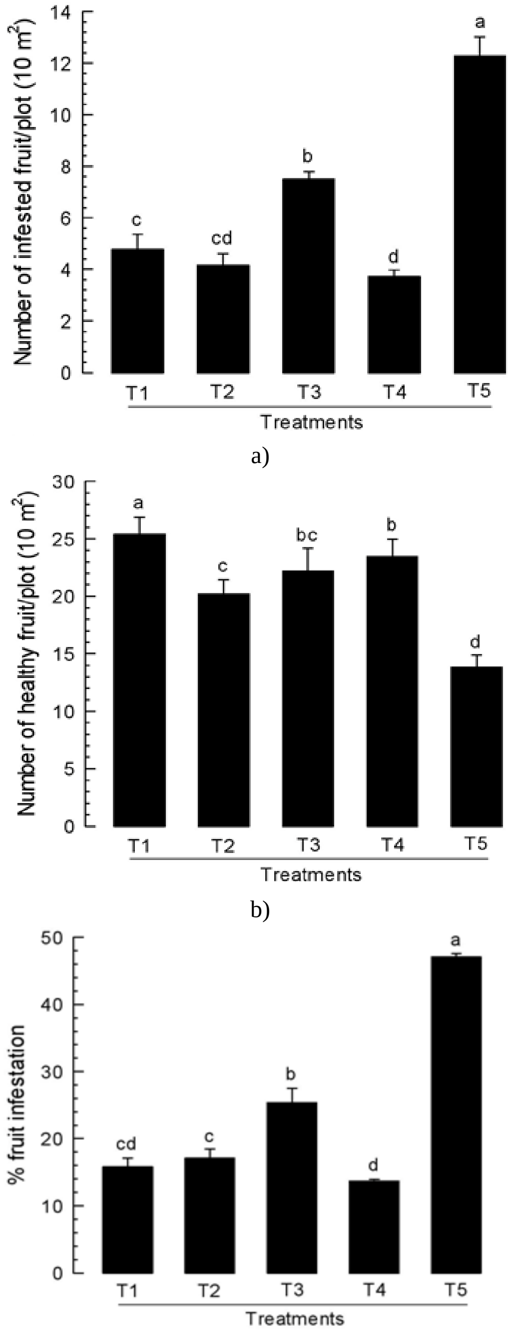

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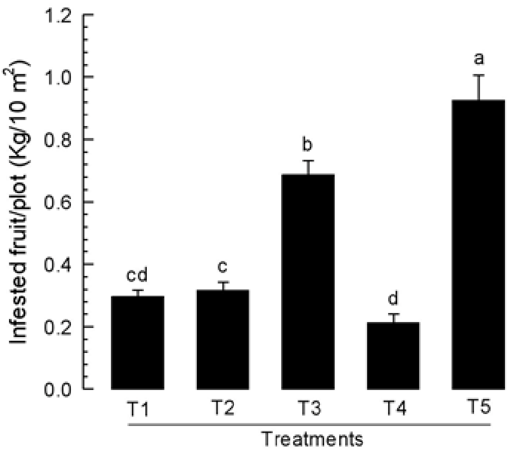
Figure 2. Effect of microbial insecticide on fruit infestation (number basis) caused by eggplant shoot and fruit borer. a) Number of infested fruits per plot. b) Number of healthy fruits per plot. c) Percent fruit infestation (number basis).

Likewise, microbial insecticides have a significant ($p < 0.05$) effect on controlling fruit infestation on a weight basis **(Figure 3)**. Among the treatments, less amount of infested fruit was recorded from Abamectin 1.2 % + Emamectin benzoate 1% and Spinosad 45 SC than Carbosulfan 20 EC and *Bacillus thuringiensis* var. Kurstaki 5% WP after control **(Figure 3a)**. In contrast, more amount of healthy fruit was collected from Spinosad 45 SC and Abamectin 1.2 % + Emamectin benzoate 1% than Carbosulfan 20 EC and *Bacillus thuringiensis* var. *Kurstaki* 5% WP **(Figure 3b)**. Therefore, the lowest percent fruit infestation by weight was recorded from Abamectin 1.2 % + Emamectin benzoate 1% which was followed by Spinosad 45 SC, *Bacillus thuringiensis* var. *Kurstaki* 5% WP and Carbosulfun 20 EC while the maximum of that was from control (43.24%) **(Figure 3c)**. The performance of the insecticides for fruit infestation reduction can be clarified by the percent reduction of fruit infestation over control. In this context, Abamectin 1.2 % + Emamectin benzoate 1% (77.41% reduction over control) was best followed by Spinosad 45 SC (73.68% reduction over control), *Bacillus thuringiensis* var. Kurstaki 5% WP (63.62% reduction over control) and Carbosulfun 20 EC (34.07% reduction over control). The above results thus revealed that the microbial origin Abamectin 1.2 % + Emamectin benzoate 1% and Spinosad 45 SC are most effective for controlling eggplant shoot and fruit borer.



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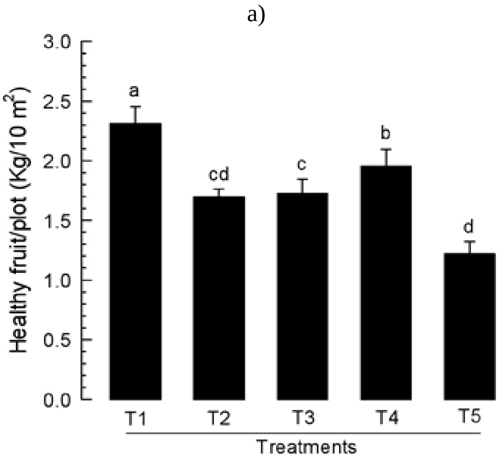

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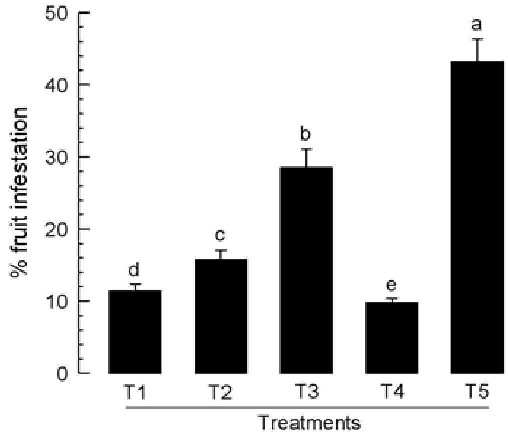

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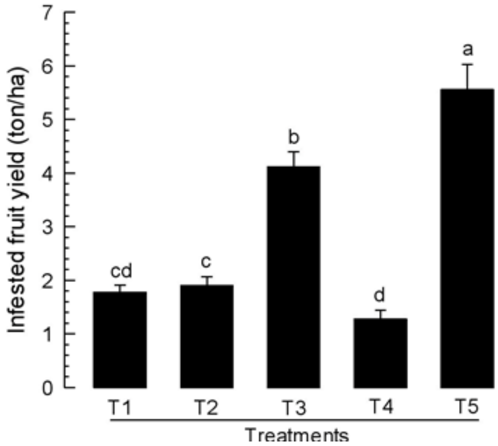
Figure 3. Effect of insecticide on fruit infestation (weight basis) caused by eggplant shoot and fruit borer. a) Number of infested fruits per plot. b) Number of healthy fruits per plot. c) Percent fruit infestation (weight basis).

Effect of insecticides on fruit yield

The yield of eggplant is dependent on management practices of eggplant shoot and fruit borer infestation. The managed microbial insecticides effectively control the ESFB infestation and increase the yield significantly ($p < 0.05$) **(Figure 4)**. Infested fruit yield was less in Abamectin 1.2 % + Emamectin benzoate 1% and Spinosad 45 SC than *Bacillus thuringiensis* var. *Kurstaki* 5% WP and Carbosulfan 20 EC after control **(Figure 4a)**. The most crucial healthy fruit yield or marketable fruit yield also significantly ($p < 0.05$) increased by microbial insecticide application **(Figure 4b)**. Maximum marketable yield was confirmed by Spinosad 45 SC which was followed by Abamectin 1.2 % + Emamectin benzoate 1%, Carbosulfan 20 EC, and *Bacillus thuringiensis* var. *Kurstaki* 5% WP whereas the lowest was harvested from control. Therefore, the gross yield was also controlled by insecticides **(Figure 4c)**. Constantly, the maximum gross yield was collected from Spinosad 45 SC which is statistically similar to Carbosulfan 20 EC while the lowest of that was found in *Bacillus thuringiensis* var. *Kurstaki* 5% WP that is statistically similar and close to control and Abamectin 1.2 % + Emamectin benzoate 1%. The rate of change in yield over control was evaluated and shown in **Figure 4d** to observe the yield performance of the treated insecticides. For marketable yield, the surge in yield over control was maximum by Spinosad 45 SC (90.00%) which is followed by Abamectin 1.2 % + Emamectin benzoate 1% (60.68%), Carbosulfun 20 EC (41.78%) and *Bacillus thuringiensis* var. *Kurstaki* 5% WP (39.32%). But little change was observed for gross yields like a 21.71% increase by Spinosad 45 SC, 12.61% increase by Carbosulfun 20 EC, 1.25% increase by Abamectin 1.2 % + Emamectin benzoate 1%, and 6.18% decrease by *Bacillus thuringiensis* var. *Kurstaki* 5% WP. The above discussion thus revealed that Spinosad 45 SC and Abamectin 1.2 % + Emamectin benzoate 1% are highly effective to increase marketable fruit yield by controlling ESFB infestation.



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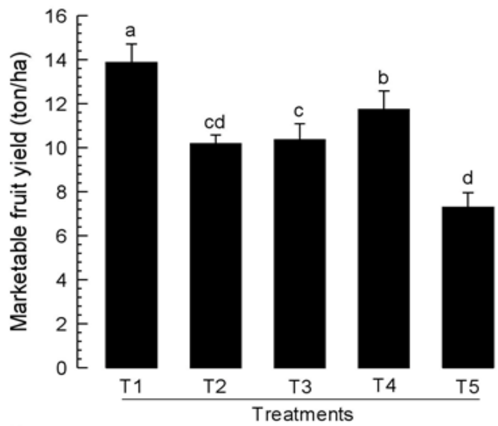

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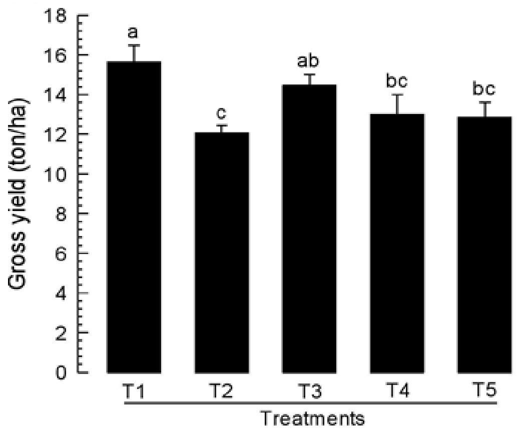

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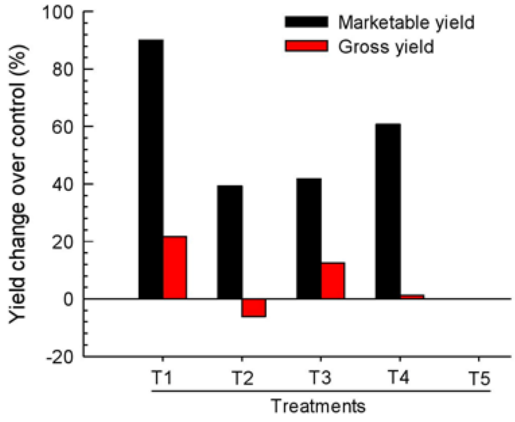

d)

Figure 4. Effect of insecticide on fruit yield by controlling eggplant shoot and fruit borer. a) Infested fruit yield. b) Marketable fruit yield. c) Gross yield. d) Yield change over control.

Effect of insecticides on individual fruit weight

Eggplant shoot and fruit borer larvae bore into the tender fruit and feed the internal fleshy part of the fruit. Due to infestation, feeding internal part as well as the growth and improvement of fruit is slight retarded which leads reduction of weight. Insecticides stops weight loss significantly ($p < 0.05$) in a differential manner **(Figure 5)**. From the treated insecticides, Carbosulfan 20 EC and Spinosad 45 SC confirm gain of individual healthy fruit weight than control which is 4.03% and 3.75% of weight gain over control. On the other hand, weight loss was observed for *Bacillus thuringiensis* var. *Kurstaki* 5% WP and Abamectin 1.2% + Emamectin benzoate 1% which was 4.59% and 5.11% over control **(Figure 5a)**. In case of infested fruit, Carbosulfan 20 EC and *Bacillus thuringiensis* var. *Kurstaki* 5% WP confirms gain of individual fruit weight than control which is 3.29% and 0.62% of weight gain over control. On the other hand, weight loss was observed for Spinosad 45 SC and Abamectin 1.2% + Emamectin benzoate 1% which was 17.47% and 24.68% over control **(Figure 5b)**. However, the difference between the healthy and infested fruit weight was recorded as Spinosad 45 SC (28.93 g), Abamectin 1.2% + Emamectin benzoate 1% (26.58 g), and Carbosulfun 20 EC (13.50 g) are more than control (12.44 g) while *Bacillus thuringiensis* var. *Kurstaki* 5% WP (7.93 g) provided lower than the control **(Figure 5c)**. The results thus revealed that Spinosad 45 SC and Abamectin 1.2% + Emamectin benzoate 1% found potential to ensure more marketable yield.

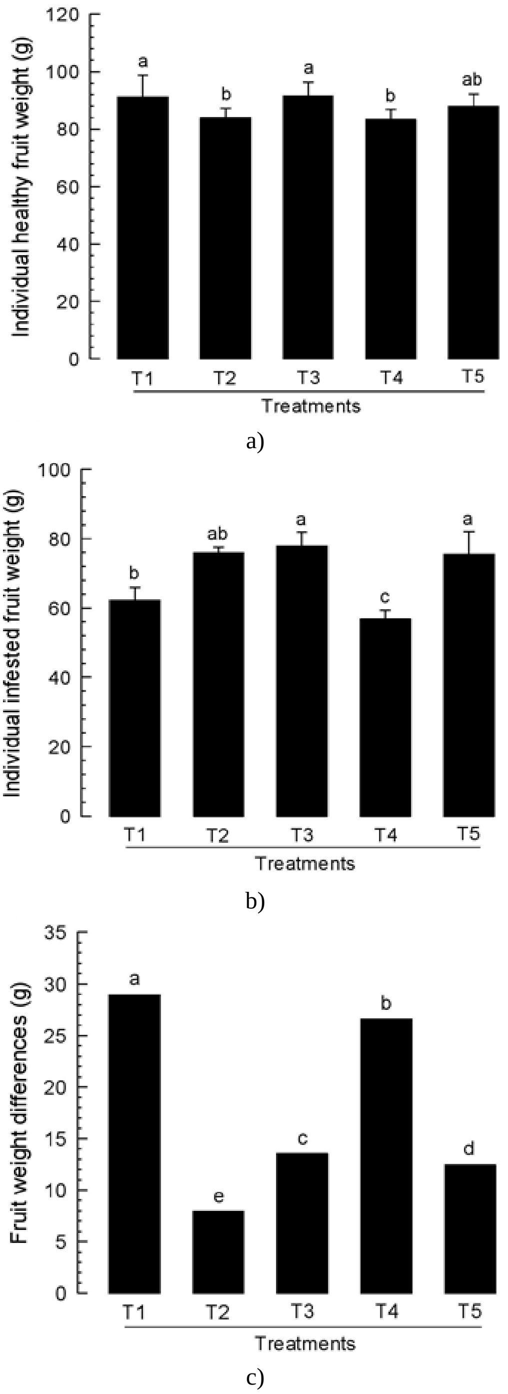

Figure 5. Effect of insecticide on individual fruit weight. a) Individual healthy fruit weight. b) Individual Infested fruit weight. c) Differences between healthy and infested fruit weight.

The microbial insecticides are promising against major insect pests in eggplant which in turn increased the yield. In the present study, we observed that all the insecticides viz. Spinosad 45 SG, *Bacillus thuringiensis* var. *Kurstaki* 5% WP, Carbosulfan 20 EC, Abamectin 1.2% + Emamectin benzoate 1% was effective for managing the shoot and fruit infestation by eggplant shoot and fruit borer larvae in comparison to control. Among these insecticides, Abamectin 1.2% + Emamectin benzoate 1%, Spinosad 45 SG, and *Bacillus thuringiensis* var Kurstaki were found most effective. The present findings are in accordance with [35] who found Spinosad 45 SC and Emamectin benzoate 5 SG as most effective against shoot damage providing 88.22% and 84.41% control, respectively. [36] described that the application of Emamectin benzoate 25 WG @ 0.4 g/L and Spinosad 45 SC @ 0.5 ml/L recorded the lowest fruit damage of 6.95 and 8.06 percent, respectively. [37] reported that spraying of Bt emulsion against shoot and fruit borer resulted in 78.8-100% control over the untreated check. Emamectin Benzoate 5 EC @ 15 g a.i./ha and Spinosad 45 SC @ 75 g a.i./ha were found effective in reducing the infestation of fruit borer [38]. [39] concluded that *B. thuringiensis* (Bt) formulations, Dipel 8L @ 0.2 per cent at 10 days interval resulted in the minimum shoot (9.56%) as well as fruit (11.78%) infestation.

From these insecticides, microbial origin Spinosad and Abamectin + Emamectin benzoate produce maximum healthy fruits providing the highest marketable fruit yield. The present finding is supported by the finding of [36] where Emamectin benzoate 25 WG @ 0.4 g/L and Spinosad 45 SC @ 0.5 ml/L produce the highest yield of 351.46 qt/ha and 341.75 q/ha, respectively. [38] also reported that Emamectin Benzoate 5 EC and Spinosad 45 SC produce the highest marketable fruit yield. Dipel 8L @ 0.2 per cent produces the maximum yield of marketable fruits (196.96 q/ha) [39]. All the microbial insecticides were found effective to kill ESFB larvae compared to Carbosulfan 20 EC. The reason may be the various function of microbial insecticides: immune suppression, toxicity or toxemia, and apoptosis [30-32]. Entomopathogenic bacteria release immune suppressor PLA_2 inhibitors that decrease the immunity of insects [29, 30]. Some microbial metabolites also have binding affinity to insect immune protein, dorsal switch protein 1 [40, 41]. In a lepidopteran insect, *Spodoptera exigua*, bacterial metabolites bind with dorsal switch protein 1 to interrupt the immune activation [41]. Dorsal switch protein 1 (DSP1) also has an immune role in a Coleopteran insect, *Tenebrio molitor* [42]. Therefore, further study is needed to know the mode of action of these microbial insecticides that kill the *L. orbonalis* larvae though we already know that Bacillus thuringiensis mode of action.

CONCLUSION

Several non-toxic microbial insecticides were tested against Eggplant Shoot and Fruit Borer (ESFB), *Leucinodes orbonalis* Guenee, for their efficacy to control ESFB as well as yield potentiality. All the microbial insecticides were found effective to reduce ESFB infestation both in the shoot and fruit. In context to control, Abamectin 1.2% + Emamectin benzoate 1% and Spinosad 45 SC found most potent. These also increase marketable fruit yield.

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CONFLICT OF INTEREST: None

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ETHICS STATEMENT: All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. This article does not contain any studies on human participants performed by any of the authors.

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