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Efficacy of Sex Pheromone and Bio-Pesticides against Brinjal Shoot and Fruit Borer (*Leucinodes orbonalis*) and Yield of Brinjal

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A b s t r a c t

Pests are major constraints in production of vegetables. Brinjal shoot and fruit borer is considered the most damaging pest of brinjal. Therefore, an experiment was conducted in the Entomology field laboratory, Bangladesh Agricultural University, Mymensingh, during the period from April to September, 2023 to evaluate the efficacy of sex pheromone (BSFB-Phero) and bio-pesticidesagainst brinjal shoot and fruit borer. Four treatments viz. BSFB-Phero 1 lure @ 3mg, BSFB-Phero 1 lure @ 3mg + Tracer 45 SC @ 0.4 ml/L ,BSFB-Phero 1 lure @ 3mg + Bio BTK @ 1.0g/L and untreated control were selected for the study.BSFB-Phero 1 lure @ 3mgwas applied individually or in combination with bio- pesticides (Tracer 45 SC and Bio BTK) and their efficacies were evaluated on different parameters viz. percent healthy shoots, number of marketable fruits/m^2 and marketable fruit yield (t/ha).All the treatments were significantly increased. The best result was achieved from sex pheromone (BSFB-Phero)+Bio BTK (*Bacillus thuringiensis*) treated plots where minimum shoot infestation (14.47%) was obtained from BSFB-Phero + Bio BTK aplication with the dose of 1lure @ 3mg BSFB- Phero and 1 g/L Bio BTK compared to control (33.85%). Maximum shoot infestation (33.85%) was found in untreated plots. The maximum number of marketable fruits (7.15/m^2) and yield (7.11t/ha) were also achieved from BSFB-Phero +Bio BTK treated plots followed by BSFB-Phero + Tracer 45 SC and BSFB-Phero,respectively. As the BSFB-Phero +Bio BTK treated plots showed the highest efficacy among the treatments. Considering the higher yield and control of brinjal shoot and fruit borer, this treatmentis more effective for brinjal growing areas of Bangladesh.

Keywords: Brinjal; efficacy; pheromone; bio-pesticide; and shoot and fruit borer.

Introduction

Brinjal is a popular vegetable in Bangladesh. The country has ranked 3rdof brinjal production in the world (FAO, 2019). In Bangladesh, over 49 thousand acres landare cultivated for brinjal with annual production of over 209 thousand metric tons (BBS 2023).Brinjal is abundant in bioactive compounds (Raigón*et al*., 2008; Plazas *et al*., 2014) and a good source of vitamins, minerals and popular because of its low caloric content (Plazas *et al*., 2014; Docimo*et al*., 2016). It is one of the top ten vegetables known to have oxygen radical absorbance capacity (Cao *et al*., 1996). Its fruit flesh contains considerable amount of phenolic acid, while the fruit skin contains a notable amount of anthocyanins (Plazas *et al*., 2013; Stommel*et al*., 2015). Such compounds have antioxidant activity and are known to have multiple beneficial impacts on health (Plazas *et al*., 2013; Braga *et al*., 2016).

Pests are major constraints in production of fruits and vegetables, especially in developing countries (Daunay and Hazra 2012).The insect and pest infection cause 30-40% crop production losses even after insecticide application while it could be 100% production loss if control measure is not taken in the field (Sarwar*et al*., 2013). Because of its long growth period and its large and soft fruits, brinjal is vulnerable to a broad range of pests and diseases. Among all the sucking and chewing insect pests, brinjal shoot and fruit borer (BSFB), *Leucinodesorbonalis* (Lepidoptera: Crambidae) is the major pest of brinjal crop worldwide (Chakraborty and Sarkar 2011, Dutta *et al*., 2011). It may cause 80-90% loss brinjal production (Patnaik HP 2000, Misra HP 2008, Jagginavar SB *et al*., 2009). Brinjal shoot and fruit borer is considered the most damaging pest of brinjal (Taylo*et al*., 2016). Intensive spraying for pest control is common but this can result in health hazards and environmental damage issues (Srinivasan, 2009).The indiscriminate and injudicious application of synthetic insecticides is the cause for the problems viz., increased production costs, residual toxicity, and development of pesticide resistance, resurgence, secondary pest outbreak, health risk environmental threats and destruction of natural enemies (Dhankhar BS, 1998). Pesticides usage for the control of the insect pests in brinjal is high (Shetty 2004). For example, it has been reported that in certain areas of the Philippines and Bangladesh, the farmers sprayed 56 and 180 times, respectively, during a cropping season. Therefore, it is needed to switch for other environmentally safe pest control methods, such as the bio-agents/bio-pesticides for pest management (Kabadwa*et al*., 2019). Sex pheromones are specific natural compounds have been proven immensely successful in controlling low density pest populations and achieving long-term reduction in pest numbers with minimal impact on their natural predators(Rizvi SAH *et al*., 2021). This method is environmentally benign, lack of toxicity to mammals and species specific. Another bio pesticide named spinosad, commercially known as Tracer 45 SC has several key advantages over traditional chemical insecticides. It is considered more environmental friendly because it has a relatively low toxicity to non-target organisms, such as mammals, birds and breaks down relatively quickly in the environment (Hertlein M *et al*., 2011.). Furthermore, spinosadhas been classified as an organic pesticide by various certification bodies, making it a desirable choice for organic farmers (Lacey LA *et al*., 2000). Being safe to environment and highly specified, *Bt* spores and crystals have been used successfully as bio insecticide for controlling of different lepidopteran, coleopteran and dipteran insect pests (Schnepf*et al*., 1998).

However, only a few new studies are available on the combined use of pheromones and bacteria against crop insect pests. Application of sex pheromone trap + spinosad has provided minimum shoot and fruit damage and maximum protection from *L. orbonalis* infestation compared to their individual application although spinosad and pheromone trap both were found significantly effective in comparison with that in the untreated control (Al Mamun M.A *et al*., 2013). Hence, keeping the above points in view, this study was carried out to determine the efficacy of sex pheromone and biopesticides (Spinosad and *Bacillus thuringiensis*) against brinjal fruit and shoot borer.

Materials and Methods

Experimental site

The experiment was conducted in the Entomology Field Laboratory, Department of Entomology, Bangladesh Agricultural University, Mymensingh-2202. Mymensingh is located at 24.75" N latitude, 90.5 E longitude with a mean elevation of 7.9 to 9.1 m above sea level. The period of the study was from March to June, 2023. The soil of the experimental area was silty loam belonging to the Old Bramhaputra Floodplain Alluvial Tract under the Agro Ecological Zone 9 (UNDP and FAO, 1988).

Design of the field experiment

The treatments were laid out in a Randomized Complete Block Design (RCBD) with 5 replications in each treatment. The experiment field (11m×8m) was divided into 5 equal blocks with 4 equal plots (2m×2m) in each. A total of 20 plots were prepared keeping 20 cm gaps in between two adjacent plots and blocks for intercultural operations. Where,

Treatments

T_1= Untreated control

T_2= BSFB-Phero 1 lure@ 3 mg

T_3= BSFB-Phero 1 lure@ 3 mg + Tracer 45 SC @ 0.4 ml/L

T_4= BSFB-Phero 1 lure@ 3 mg + Bio BTK @ 1.0g/L

Table 1: Specification of treatments

Treatments	Chemical Name	Sources/Company
T_1 = Untreated control	-----	-----
T_2= BSFB-Phero 1 lure@ 3 mg	E-11-16:Ac, E-11-16:OH 97%w/w	IspahaniAgro Limited
T_3= BSFB-Phero 1 lure@ 3 mg + Tracer 45 SC @ 0.4 ml/L	E-11-16:Ac, E-11-16:OH 97%w/w + Spinosad 45% SC	IspahaniAgro Limited and Auto Crop Care Limited
T_4= BSFB-Phero 1 lure@ 3 mg + Bio BTK @ 1.0g/L	E-11-16:Ac, E-11-16:OH 97%w/w + Bacillus thuringiensis 32000 IEEU/mg WP AP Bio-54	IspahaniAgro Limited

Treatments application schedule

There were two treatments for individual including control and two for combined effects. Field was monitored regularly to confirm the infestation level and when considerable shoots were found to be infested then spraying was initiated. In case of individual effects, a sex pheromone trap was installed. In case of combined effects, a total of three sprays were given at 10 days interval. Spraying was started at 9.00 a.m to avoid bright sun shine and drift caused by strong wind.

Data collection parameter

Data were collected on the following parameter;

- **Percent infested Shoots:** The number of infested and healthy shoots per m^2were recorded. The data were converted into percentages and used in the statistical analysis.
- **Percent reduction healthy shoot over control:** Percent reduction of shoot infestations were calculated by using the following formulae;

% Reduction in Shoot infestation=

$$\frac{\%\text{ healthy Shoot in treatment} - \%\text{ healthy shoot in control}}{\%\text{ healthy shoot in control}} \times 100$$

- **Number of healthy fruits/m^2:** The unit plot size was 4 m^2. The number of healthy brinjalswere counted from each plot and converted into healthy fruits/m^2.
- The percent increases of marketable brinjal over control was calculated using following formulae-

% increases of marketable brinjal over control =$\frac{T-C}{C} \times 100$

Where,

T= Number of fruits after treatment application

C= Number of fruits when the plot left untreated

- **Yield (t/ha) of marketable or healthy fruits:** Marketable brinjalwas defined as the visibility of no hole, no deformation or no pseudo-puncture on fruits. The matured brinjal is suitable for harvesting and marketing. Finally, the total harvested marketable brinjals per plots was used to calculate the yield per ha.
- **Increase of marketable yield (times) over control:** It was calculated by using the following formula;

Increase of marketable yield (times) over control =$\frac{Yt}{Yc}$

Where,

Yc = Cumulative yield in case of control.

Yt = Cumulative yield in case treated condition

Data analysis

The recorded data were compiled and tabulated for statistical analysis. Analysis of variancewas done with the help of computer package Statistics 10.

Results and Discussions

Effects of selected treatments against the infestation of brinjal shoot and fruit borer

It was found that the selected BSFB-Phero alone as well as in combination with bio pesticides significantly ($F>133, P<0.001$) reduced infestation caused by *Leucinodesorbonalis*and increased marketable yield in comparison with that in the untreated control.

Efficacy of BSFB-Phero,BSFB-Phero + Tracer 45 SC and BSFB-Phero + Bio BTK on percent healthy shoot production

A total of three sprays (at 10 days interval) were given for each treatment to know the consistency of treatments effects (Table2).

Data were collected before and after installing BSFB-Phero. Data were collected at 7 days interval and finally a cumulative mean were found out.

All the selected sex pheromone and bio pesticides significantly (P<0.03) increased percent healthy shoot compared to the control (Table2).The highest percent of healthy shoot was observed in case of BSFB-Phero + Bio BTK which ranged from 72.360 to 95.074%,where the cumulative mean of healthy shoot was 85.53%. On the other hand, the lowest healthy shoot ranged from 74.37 to 58.82%(Cumulative mean, 66.15%)was observed when brinjal plants were untreated. Moreover, the second highest healthy shoot range from 69.03% and 90.2% (Cumulative mean, 80.84%) were noticed when the brinjal plants were treated with BSFB-Phero@ 3 mg/lure+ tracer 45SC @ 1g/L ,respectively.

The 3rdhighest percent of healthy brinjal shoot vary with 68.57 to 85.43%(Cumulative mean, 79.04%) when the plant treated with BSFB-Phero@ 3 mg/lure followed by untreated plot.

Application of BSFB-Phero + Bio BTK provided 29.29% increase of healthy shoot over control when it was applied @ 1lure (3mg) BSFB-Phero and 1g/L Bio BTK respectively(Table. 2).

Table 2. Percent increase of healthy shoot with the application BSFB-Phero and bio pesticide

Insecticides	Doses	BS (% healthy shoot)	After application of pheromone and biopesticide (% healthy shoot)				Combined mean	(%) increase of healthy shoot over control
		7 Day	14 Day	21 Day	28 Day	35 Day		
BSFB-Phero	1 lure@ 3 mg	68.570 ± .93 a	76.292 ± 0.37 ab	81.522 ± 0.44 b	83.408 ± 0.33 b	85.438 ± 0.35 c	79.046	19.49
BSFB-Phero + Tracer 45 SC	1 lure@ 3 mg+ 0.4ml/L	69.032 ± 0.54a	75.390 ± 0.6 ab	82.244 ± 0.53 ab	87.326 ± 0.32 ab	90.208 ± 0.25 b	80.84	22.20
BSFB-Phero + Bio BTK	1 lure@ 3mg+1.0g/L	72.360 ± 0.87 a	81.386 ± 1.2 a	87.720 ± 0.42 a	91.16 ± 0.21 a	95.074 ± 0.45 a	85.53	29.29
Control		74.376 ± 1.15 a	70.074 ± 1.21b	66.098 ± 1.2 c	61.412 ± 1.04c	58.822 ± 0.96 d	66.15	
F		2.13	4.22	25.59	96.57	133.82		
p		0.1497	0.0296	0.00	0.00	0.00		
Significance		NS	**	**	**	**		
CV (%)		5.97	6.65	5.07	3.75	3.80		
LSD		5.8451	6.9463	5.5494	4.1869	4.3135		

In a column, means of similar letter (s) do not differ significantly. **= Significant at 5% level, CV= Co-efficient of Variation, BA: Before application, LSD= Least Significant difference

Application of BSFB-Phero@ 3 mg/lure+ tracer 45SC @ 1g/L provides 22.20% increased of healthy shoot which is statistically similar with BSFB-Phero + Bio BTK. There is little or no significance different among them. Installation of BSFB-Phero only offered 19.49 % increase of healthy shoot over control.

The present result has close agreement with the result of Dutta, *et al*., (2011), where they found that pheromone trap starting from 15 days after transplanting till final harvest gave substantial protection in shoot damage (58.39%).

Efficacy of selected treatments on number of marketable fruits /m²

The result showed that the cumulative number of marketable fruits were less in untreated plot than the other treated plots(Table3).It was observed that BSFB-Phero,BSFB-Phero+Tracer 45 SC, and BSFB-Phero+ Bio BTK significantly (F=75.64, F=32.32 and P<0.01) increased the number of marketable brinjal in comparison with that of control.

The highest cumulative number(7.15/m^2) of marketable brinjal was obtained when the plants were treated with BSFB-Phero1 lure@ 3 mg + Bio BTK @ 1.0g/L(3.20 and 3.95/m^{2}after 1stand 2nd, respectively followed by BSFB-Phero1 lure@ 3 mg + Tracer 45 SC @ 0.4 ml/L, where the cumulative number was found 5.35/m^2(2.45 and2.90/m^{2}after 1stand 2ndpicking, respectively).From this observation it was clear that number of marketable fruit increased significantly when different combination were applied. Highest Percent increase of marketable brinjal over control were 137.54% when treated with BSFB-Phero 1 lure@ 3 mg + Bio BTK @ 1.0g/L

Table 3. Efficacy of selected treatments on the number of marketable fruits

Insecticides	Doses	Number of marketable fruits/m2			% increases of marketable brinjal over control
		1st picking	2nd picking	Cumulative number	
BSFB-Phero	1 lure@ 3 mg	1.90 ± 0.02 c	2.20 ± 0.06c	4.1	36.21
BSFB-Phero+ Tracer 45 SC	1 lure@ 3 mg+ 0.4ml/L	2.45 ± 0.04b	2.90 ± 0.06b	5.35	77.74
BSFB-Phero+ Bio BTK	1 lure@ 3mg+1.0g/L	3.20 ± 0.08a	3.95 ± 0.14a	7.15	137.54
Control		1.30 ± 0.04d	1.71 ±0.02c	3.01	
F		75.64	32.32		
P		0.00	0.00		
Significance		**	**		
Cv(%)		9.40	14.21		
LSD		0.2865	0.5266		

In a column, means of similar letter (s) do not differ significantly. **= Significant at 5% level, CV= Co-efficient of Variation. LSD= Least Significant difference

Table-4: Efficacy of selected treatments on the yield (t/ha) of marketable fruits

Insecticides	Doses	Yield of marketable fruits (t/ha)			increased yield (times) over control
		1st picking	2nd picking	Cumulative yield	
BSFB-Phero	1 lure@ 3 mg	1.72± 0.023 c	1.87 ± 0.06c	3.59	1.24
BSFB-Phero+ Tracer 45 SC	1 lure@ 3 mg+ 0.4ml/L	2.31 ± 0.04b	2.78 ± 0..05b	5.09	1.76
BSFB-Phero+ Bio BTK	1 lure@ 3mg+1.0g/L	3.32 ± 0.08a	3.79± 0.12a	7.11	2.46
Control		1.27 ± 0.03d	1.62 ± 0.03d	2.89	
F		87.97	52.05		
P		0.00	0.00		
Level of significance		**	**		
CV (%)		9.75	12.13		
LSD		0.2904	0.4212		

In a column, means of similar letter (s) do not differ significantly. **= Significant at 5% level, CV= Co-efficient of Variation, LSD=Least significant difference

followed by the 2nd highest was 77.74 % of marketable fruits increased over control was recorded from BSFB-Phero1 lure@ 3 mg + Tracer 45 SC @ 0.4 ml/L respectively. The lowest percentage increase of marketable brinjal over control was 36.21 % when treated with BSFB-Phero1 lure@ 3 mg individually.
Moreover, the cumulative number of marketable brinjal was 4.1/m^2 obtained when the plant treated with BSFB-Phero @ 1 lure(3 mg)(1.90and 2.20/m^2 after 1st, and 2nd picking, respectively) followed by untreated plot, where the cumulative number was found 3.01(1.30 and 1.71 after 1st and 2nd picking respectively).
These findings are closely related to the findings of Sharma *et al*., 2012 where they reported that the combined treatment including pesticides, botanicals and cultural methods resulted lower shoot and fruit damage as well as the number fruit yield was also increased.

Efficacy of selected treatments on the yield of marketable brinjal(t/ha)

Brinjalwere picked for two times at 10 days interval after maturation. Immediately after harvesting, healthy or marketable fruits were separated from total fruits and weight was taken regarding the treatment specification. Finally, total marketable yield (t/ha) was calculated from two pickings for each specific treatment. Like as number of marketable fruits, BSFB-Phero, BSFB-Phero + Tracer 45 SC and BSFB-Phero + Bio BTK significantly (P< 0.01) increased yield of marketable fruit in comparison with that of control (Table4).
The lowest yield (2.89 t/ha) was obtained from control plots where plants were left untreated. On the other hand, the highest yield was recorded from combined application of BSFB-Phero @ 1 lure(3mg) + Bio BTK @ 1g/L treated plots with(7.11 t/ha) which was significantly followed by BSFB-Phero @ 1 lure(3mg) + Tracer 45SC @ 0.4 ml/L(5.09 t/ha).The yield was increased2.46 and1.76 times over control when the plants were treated with BSFB-Phero @ 1 lure(3mg) + Bio BTK @ 1g/L and BSFB-Phero @ 1 lure(3mg) + Tracer 45SC @ 0.4 ml/Lrespectively. Application ofBSFB-Phero @ 1 lure(3mg) alone increase 1.241 times marketable brinjal over control(Table 4).
These findings is closely linked with Ajit Tripura *et al*., (2017) who revealed that application of bio-pesticides *[Bacillus thuringiensis*(*Bt*) @ (2g/l)],were found effective treatments in reducing shoot infestation. Highest percent reduction was observed in neem oil (53.56%) followed by *M. anisoplae*(50.38%) and *B. thuringiensis*(50.18%). *B. thuringiensis*(170.0 q/ha) recorded maximum yield followed by *M. anisoplae*(162.00 q/ha) and *Beauveriabassiana*(157.75 q/ha) whereas in untreated control plot marketable yield was 105.60 q/ha.

Conclusion

Among the treatments,BSFB-Phero + Bio BTK showed the best efficacy considering the reduction of percent fruit infestation, increasing fruit yield that was followed by BSFB-Phero + Tracer 45 SC and BSFB-Phero, respectively. Moreover, the maximum number of marketable fruits/m^2(7.15),the highest marketable yield(7.11 t/ha)were obtained from BSFB-Phero + Bio BTK treated plots. It was also noted that BSFB-Pheroalone provided the lowest efficacy among the treatments considering all parameters studied. Considering the efficacy against *Leucinodesorbonalis,*the potency was found as BSFB-Phero + Bio BTK> BSFB-Phero + Tracer 45 SC >BSFB-Phero.So, from the above discussion it can be concluded that all the selected insecticides significantly reduced the infestation caused by *Leucinodesorbonalis*although BSFB-Phero + Bio BTK showed the best performance considering the parameters studied.Therefore, based on the efficacy, brinjal farmers can apply BSFB-Phero + Bio BTK to control brinjal shoot and fruit borer effectively.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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