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Field efficacy of some new insecticides against brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guen.) (Lepidoptera: Pyralidae) and their toxic effects on natural enemies

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ABSTRACT

Brinjal is susceptible to attack of various insect pests from seedling to fruiting stage. Among these, brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guen.) is the most destructive pest and is considered to be the limiting factor in quantitative as well asqualitative harvest of brinjal fruits. In the present study, efficacy of some new insecticides viz. Pine 6 WG (Emamectin benzoate + Abamectin), Heron 5 EC (Lufenuron), Belt 24 WG (Flubendiamide) and Cyclone 2.5 EC (Lambda-cyhalothrin) were evaluated against brinjal shoot and fruit borer (BSFB) in field condition from the period of October, 2015 to April, 2016. The experiment was laid out in a Randomized Complete Block Design (RCBD) having three replications and two concentrations of each of the insecticides. A total of three spraying was given and finally a cumulative mean was found out. Data were collected on percent shoot infestation, percent fruit infestation, marketable fruit yield (t/ha) and abundances of natural enemies per plant. Results clearly showed that all the insecticides significantly reduced BSFB infestation as well as increased marketable fruit yield compared to the untreated control. The highest shoot (27.40%) and fruit (55.93%) infestation were recorded from control plots. On the other hand, the lowest shoot (6.71%) and fruit (11.58%) infestation were recorded from Pine 6 WG treated plots @ 0.50 g/L that was followed by Heron 5 EC @ 1.0 ml/L (6.89% shoot; 14.51% fruits), Cyclone 2.5 EC @ 1.5 ml/L (15.73% shoot and 16.45% fruits) and Belt 24 WG @ 0.50 g/L (9.53% shoot and 25.47% fruits), respectively. Similar trend was found in case of marketable fruit yield as well. Pine 6 WG and Heron 5 EC were found to be comparatively safe for both ladybird beetle and lynx spiders as their abundances were not changed significantly compared to untreated control. In contrast, the application of Belt 24 WG and Cyclone 2.5 EC has reduced 50 to 60% of the ladybird beetle and lynx spiders populations in brinjal eco-system. The results suggested that two biopesticides viz., Pine 6 WG and Heron 5 EC can be used successfully against BSFB considering minimum shoot and fruit infestation, higher fruit yield and less toxicity to natural enemies in brinjal eco-system.

Introduction

Brinjal is one of the important solanaceous year-round vegetable crops cultivated widely throughout Bangladesh and covers about 15% of the total vegetable cultivation area of the country (Rahman, 2005). In Bangladesh, it is the second most important vegetable crop after potato in relation to its total production. It is also used as a raw material in pickle making and as an excellent remedy for those suffering from liver complaints. It is a good appetizer, aphrodisiac, cardiotonic, laxative and reliever of inflammation (Kalawate and Dethe, 2012).

Brinjal is susceptible to attack of various insects from seedling to fruiting stages. This crop is infested by 53 different insect species (Thapa, 2010) including (1) Brinjal shoot and fruit borer, BSFB (*Leucinodes orbonalis* Guen.) (2) Epilachna beetle (*Epilachna vigintioctopunctata* Fab.), (3) Aphid (*Aphis gossypii* Glover), (4) Jassid (*Amrasca biguttula* Ishida), (5) White fly (*Bemisia tabaci*) and so on. In Bangladesh, about eight insect species are considered as major pests causing damage to brinjal (Datta *et al*., 2011). Among these insect pests, brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee is the most notorious (Latif *et al.*, 2010) and destructive one. In vegetative stage of the crop growth,

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larva bores into the shoots resulting in drooping, withering and drying of the affected shoots. In fruiting stage, the larva enters into fruit, feeding inside and finally fruits become unmarketable and yield losses occur up to 90 percent (Baral *et al.,* 2006).

Chemical control is the most common practice in Bangladesh for controlling BSFB. Frequent and indiscriminate use of chemical insecticides against BSFB posed different problems like resistance development, resurgence, secondary pest outbreak, killing of natural enemies etc. (Mehrotra, 1990). Insecticides with different active compounds and modes of action are likely to be more effective than those have been so far used in controlling *L. orbonalis* control. Emamectin benzoate and Abamectin are most promising microbial biopesticides those are applied individually or in combined way (Islam *et al*., 2016). Flubendiamide (Belt 24 WG) and Lambda-cyhalothrin (Cyclone 2.5 EC) are new class of insecticides having new mode of action, showed strong insecticidal activity against lepidopteran insect pests including their resistant strains (Pawar *et al*. 1986; Mathirajan *et al*., 2000). Heron 5 EC (Lufenuron) is a moulting disruptor that could be the integral part of IPM in coming days due to their multi-function properties like eggs sterility, disrupting fecundity, post-embryonic development, behaviour, diapause etc (Mondal and Parween, 2000). Therefore, in the present study, four newer insecticides from different groups like Pine 6 WG (Emamectin benzoate + Abamectin), Heron 5 EC (Lufenuron), Cyclone 2.5 EC (Lambda-cyhalothrin) and Belt 24 WG (Flubendiamide) were evaluated in the field condition to find out their toxic effects against BSFB as well as on the natural enemies.

Materials and Methods

The study was conducted in the field laboratory of the Department of Entomology, Bangladesh Agricultural University, Mymensingh from the period of October, 2015 to April 2016. The field was located at 24.75`` N latitude 90.5``E longitude at a mean elevation of 7.9 to 9.1 m above the sea level. The field experiments were conducted under sub-principal climate which is characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds in kharif season (April-September) and scanty rainfall associated with moderately low temperature during the rabi season (October-March). Field experiments were consisted of nine treatments including untreated control. All the treatments were laid out in the Randomized Complete Block Design (RCBD). Each of the treatments was replicated thrice. The experimental land was gradually ploughed and cross-ploughed several times with a power tiller. Then stubbles were removed and experimental plots were made by spade. The size of a unit plot was 2 m × 2 m. Two adjacent unit plots and blocks were separated by 60 cm and 80 cm apart, respectively. Plots were allocated randomly and they were separated in such way so that impact of every treatment can be quantified. Then, cowdung and other chemical fertilizers were applied as recommended by Rashid (1993) for eggplant at the rate of 15000 kg cowdung and 250, 150, 125 kg of Urea, TSP and MP respectively per hectare. In this study, Singnath (Upshi) was used as the tested variety. Healthy and disease free brinjal seedlings of 30 days old were collected from the horticulture centre, BAU, Mymensingh. The collected seedlings were transplanted in the experimental plots at the rate of 6 seedlings/plot. The plant spacing was followed viz. 80 cm × 60 cm. Then, different cultural operations like weeding, irrigation, mulching, top dressing of urea were done when necessary.

The study is consisted of nine treatments from four insecticides (Table 1) including untreated control. Treatments were: T_1: Pine 6 WG @ 0.25 g/L (Emamectin Benzoate + Abamectin), T_2 : Pine 6 WG @ 0.50 g/L (Emamectin Benzoate + Abamectin), T_3: Heron 5 EC @ 0.50 ml/L (Lufenuron), T_4: Heron 5 EC @ 1.0 ml/L (Lufenuron), T_5: Belt 24 WG @ 0.25 g/L (Flubendiamide), T_6: Belt 24 WG @ 0.50 g/L (Flubendiamide), T_7: Cyclone 2.5 EC @ 1.0 ml/L (Lambda-cyhalothrin), T_8: Cyclone 2.5 EC @ 1.5 ml/L (Lambda-cyhalothrin), T_9: Untreated control. Treatments were applied in the brinjal field following the treatment specifications. A total of three spraying were given in the experimental field at 7 days interval. Spraying was done within 9.00 to 11.00 AM to avoid bright sun shine and drift caused by strong wind.

Data were collected on shoot and fruit infestation, fruit yield and abundances of natural enemies. In case of shoot infestation, data were collected at 3 and 7 days after providing each spray. On the other hand, fruit infestation data was recorded after each of the harvest. After collection, shoot and fruit data were converted in to percentage using the following formulae:

$$I_S = \frac{S_I}{S_T} \times 100$$

Where, I_s = infested shoot (%), S_I = number of infested shoots per plot, and, S_T = total number of shoots per plot.

$$I_F = \frac{F_I}{F_T} \times 100$$

Where, I_F = infested fruit (%), F_I = number of infested fruits per plot, and F_T = total number of fruits per plot.

Brinjal fruits were harvested after 7 days of each spray and then marketable fruits were separated carefully from total fruits. The marketable brinjal fruits were defined as the visibility of no hole or even no deformation on the fruits. In contrast, infested fruits were defined as visibility of clear hole or excreta on the fruits.

Table 1. List of new insecticides assayed in field condition

Trade name	Chemical name	Group/Family	Company
Pine 6 WG	Emamectin Benzoate + Abamectin	Avermectin	Asia Trade International
Heron 5 EC	Lufenuron	Insect Growth regulator	Haychem (Bangladesh) Ltd.
Belt 24 WG	Flubendiamide	Diamide	Bayer Crop Science
Cyclone 2.5 EC	Lambda-cyhalothrin	Pyrethroid	Haychem (Bangladesh) Ltd.

Weight of marketable and infested fruits were taken from the three replicated plots regarding the treatments and yield was converted into ton/hectare (t/ha). Finally, total yield (t/ha) was calculated by adding marketable and infested yield from four pickings.

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance (ANOVA) was done with the help of computer package MSTAT-C. The mean differences among the treatments were adjudged with Duncan's Multiple Range Test (DMRT) and Least Significant Difference (LSD) when necessary.

Results

Effect of insecticides on percent shoot infestation

The percentage of shoot infestation was significantly ($P<0.01$) reduced when brinjal plants were treated with selected new insecticides (Table 2). It was observed that each of the treatment was significantly effective against the infestation caused by brinjal shoot and fruit borer. The highest percentage of shoot infestation was observed in case of untreated control which was ranged from 11.48% to 45.45% where the cumulative mean of infestation was 27.40% (Table 2). In the present study, four new insecticides *viz*. Pine 6 WG, Heron 5 EC, Cyclone 2.5 EC and Belt 24 WG were evaluated with two doses of each against BSFB. Data were collected at 3 and 7 DAT after given each spray and finally a cumulative mean value was found out from three sprayings. The data clearly showed that all the insecticides had significant ($P<0.01$) effects on the reduction of percent shoot infestation compared to the untreated control.

The lowest percentage of shoot infestation was recorded when brinjal plants were treated with Pine 6 WG @ 0.50 g/L (6.71%) which was significantly followed by Pine 6 WG @ 0.25 g/L (11.61%). In case of Heron 5EC (Lufenuron), 6.89 and 7.88% infested shoots were found @ 1.0 ml/L and 0.5 ml/L respectively. Moreover, the effect of Lambda-cyhalothrin (1.0 and 1.5 ml/L) was found effective against BSFB infestation. Among four selected insecticides, Flubendiamide was found least effective regarding shoot infestation. About 15.73 and 20.57% shoots were found infested when brinjal plants were treated with Belt 24 WG @ 0.50 and 0.25 g/L respectively.

Effect of selected insecticides on percent fruit infestation

The effects of selected insecticides on percent fruit infestation has shown in Table 3. Similar to shoot protection, all the selected insecticides significantly ($P<0.01$) reduced percent fruit infestation in comparison with that of control treatment. A total of four pickings were done and %fruit infestation was calculated after completion of each picking. The highest percentage of infested fruits from all 4 pickings was obtained when brinjal plants were left untreated (29.00%, 53.00%, 64.13% and 79.60% after first, second, third and fourth picking, respectively) where the cumulative mean was found 55.93 percent (Table 3). This higher fruit infestation was significantly reduced when brinjal plants were treated with selected insecticides. More clearly, 11.58% mean fruit infestation was recorded when brinjal plants were treated with Pine 6 WG with the dose of 0.50 g/L which was significantly followed by 0.25 g/L (18.31%). This result was followed by Heron 5 EC (14.51% @ 1.0 ml/L; 16.23% @ 0.50 ml/L), Cyclone 2.5 EC (16.45% @ 1.5 ml/L; 18.01% @ 1.0 ml/L) and Belt 24 WG (25.47% @ 0.50 g/L; 29.71% @ 0.25 g/L) respectively.

Effects of selected insecticides on the yield of brinjal fruits

The efficacy of selected insecticides on the yield of marketable and infested fruits (t/ha) has been shown in Table 4. A total of four pickings were done and finally cumulative yield (t/ha) was calculated. The maximum marketable yield (10.19 t/ha @ 0.25 g/L; 12.14 t/ha @ 0.50 g/L) and the lowest infested yield (3.17 t/ha @ 0.25 g/L; 1.17 t/ha @ 0.50g/L) was obtained from Pine 6 WG treated plots. Next to Pine 6WG, Heron 5 EC (Lufenuron) provided 2nd highest marketable yield (10.08 t/ha @ 0.50 ml/L; 11.60 t/ha @ 1.0 ml/L) and 2nd lowest infested yield (3.42 t/ha @ 0.25 g/L; 2.30 t/ha @ 0.50g/L). Moreover, application of Cyclone 2.5 EC (Lambda-cyhalothrin) and Belt 24 WG (Flubendiamide) has significantly increased marketable yield and decreased infested yield compared to untreated control (Table 4).

Table 2. Mean percentage of shoot infestation caused by *L. orbonalis* at different sprayings against different treatments

Treatments	Pre-treated shoot (%)	Mean percent of shoot infestation at different DAT						Cumulative mean
		1st spray		2nd spray		3rd spray		
		3 DAT	7 DAT	3 DAT	7 DAT	3 DAT	7 DAT	
Pine 6 WG@ 0.25 g/L	4.45	5.86cd	7.24cd	10.41d	15.05c	16.40d	14.67ef	11.61d
Pine 6 WG@ 0.50 g/L	5.01	5.81cd	6.61d	6.83f	7.26d	6.62g	7.11g	6.71g
Heron 5 EC@ 0.50 ml/L	4.78	6.12bc	8.08cd	9.93e	14.49c	16.30d	23.34c	7.88f
Heron 5 EC@ 1.0 ml/L	5.12	5.51d	8.67c	8.67f	9.45d	10.12f	11.96f	6.89g
Belt 24 WG@ 0.25 g/L	4.12	5.23d	8.35cd	13.60c	14.54c	16.24d	19.49d	12.91d
Belt 24 WG@ 0.50 g/L	5.00	5.85d	7.70cd	8.12f	9.20d	13.42e	12.85f	9.53e
Cyclone 2.5 EC@ 1.0 ml/L	4.23	6.79c	12.92b	16.39b	28.01a	30.55b	29.77b	20.57b
Cyclone 2.5 EC@ 1.5 ml/L	5.19	7.07c	11.82b	16.15b	21.16b	20.93c	17.20e	15.73c
Untreated control	4.89	11.48a	19.19a	23.00a	28.93a	36.33a	45.45a	27.40a
$LSD_{0.05}$	0.52	0.91	1.61	1.94	2.28	1.92	3.88	2.32
Level of significance	NS	*	*	*	*	*	*	*
CV (%)	6.34	7.97	9.26	8.95	8.01	6.00	11.11	13.69

In a column, means followed by same letter(s) are not significantly different. NS: Not significant. *P<0.05, DAT: Days After Treatment

Table 3. Mean percentage of fruit infestation by *L orbonalis* at different pickings against different treatments.

Treatments	Mean percent of fruit infestation by *L. orbonalis* at different pickings				Cumulative Mean (%)
	1st picking	2nd picking	3rd picking	4th picking	
Pine 6 WG @ 0.25 g/L	7.52de	16.92d	21.66de	27.15cd	18.31d
Pine 6 WG @ 0.50 g/L	5.89e	10.50f	15.08g	14.83f	11.58f
Heron 5 EC @ 0.50 ml/L	8.22d	14.88de	19.93ef	21.88e	16.23e
Heron 5 EC @ 1.0 ml/L	7.64de	12.26ef	17.19f	20.96e	14.51e
Cyclone 2.5 EC @ 1.0 ml/L	7.56de	15.85de	23.39d	25.23d	18.01d
Cyclone 2.5 EC @ 1.5 ml/L	7.78d	13.92def	21.46de	22.63e	16.45d
Belt 24 WG @ 0.25 g/L	15.84c	33.44b	34.74b	34.81b	29.71c
Belt 24 WG @ 0.50 g/L	18.11b	25.82c	28.77c	29.18c	25.47b
Untreated control	29.00a	53.00a	64.13a	79.60a	55.93a
$LSD_{0.05}$	1.682	3.432	2.997	2.456	7.867
Level of significance	*	*	*	*	*
CV (%)	8.13	9.08	6.33	4.62	23.47

In a column, means followed by same letter(s) are not significantly different. *P<0.05.

Table 4. Effect of different treatments on yield of brinjal

Treatments	Marketable Yield (t/ha)	Infested Yield (t/ha)
Pine 6 WG @ 0.25 g/L	10.19a	3.17a
Pine 6 WG @ 0.50 g/L	12.14b	1.71b
Heron 5 EC @ 0.50 ml/L	10.08a	3.42a
Heron 5 EC @ 1.0 ml/L	11.60b	2.30b
Cyclone 2.5 EC @ 1.0 ml/L	7.67c	4.78c
Cyclone 2.5 EC @ 1.5 ml/L	10.57a	2.86b
Belt 24 WG @ 0.25 g/L	8.12c	4.57c
Belt 24 WG @ 0.50 g/L	10.12a	2.73b
Untreated control	7.26c	5.34c
$LSD_{0.05}$	1.27	1.77
Level of significance	*	*
CV (%)	13.14	12.23

In a column, means followed by same letter(s) are not significantly different. *P<0.05.

Table 5. Abundances of ladybird beetle in brinjal ecosystem following treated with different treatments

Treatments	Number of ladybird beetle per plant at 7 days after given each spray			Cumulative mean
	1st spray	2nd spray	3rd spray	
Pine 6 WG 0.25 g/L	6.83ab	6.17a	6.33a	6.44a
Pine 6 WG 0.50 g/L	6.50ab	5.83a	6.17a	6.17a
Heron 5 EC @ 0.5 ml/L	6.00b	6.17a	6.17a	6.31a
Heron 5EC @ 1.0 ml/L	7.03a	6.00a	6.00b	6.34a
Belt 24 WG @ 0.25 g/L	3.17c	2.33b	2.67c	2.61b
Belt 24 WG @ 0.50 g/L	3.00c	2.17b	2.17c	2.39b
Cyclone 2.5 EC 1.0 ml/L	2.83c	2.67b	2.33c	2.72b
Cyclone 2.5 EC 1.5 ml/L	2.33c	2.17b	2.67c	2.45b
Control	7.50a	7.00a	8.00a	7.50a
$LSD_{0.05}$	1.03	1.15	1.01	0.51
Level of significance	*	*	*	*
CV (%)	12.17	14.81	12.42	6.29

In a column, means followed by same letter(s) are not significantly different. *$P<0.05$.

Table 6. Abundances of lynx spiders in brinjal ecosystem following treated with different treatments

Treatments	Number of ladybird beetle per plant at 7 days after given each spray			Cumulative mean
	1st spray	2nd spray	3rd spray	
Pine 6 WG 0.25 g/L	2.33ab	2.00ab	2.33a	2.22a
Pine 6 WG 0.50 g/L	2.00bc	2.17a	2.33a	2.17a
Heron 5 EC @ 0.5 ml/L	2.00bc	2.33a	1.83ab	2.05a
Heron 5EC @ 1.0 ml/L	1.67cd	1.83abc	2.33a	1.94a
Belt 24 WG @ 0.25 g/L	1.50cd	1.17bc	1.33b	1.22b
Belt 24 WG @ 0.50 g/L	1.50cd	1.00c	1.33b	1.11b
Cyclone 2.5 EC 1.0 ml/L	1.33d	1.17bc	1.17b	1.33b
Cyclone 2.5 EC 1.5 ml/L	1.17d	1.17bc	1.00b	1.28b
Control	2.67a	2.17a	2.50a	2.45a
$LSD_{0.05}$	0.57	0.82	0.78	0.39
Level of significance	*	*	*	*
CV (%)	18.46	18.50	15.34	12.88

In a column, means followed by same letter(s) are not significantly different. *$P<0.05$.

Effects of selected insecticides on the abundances of lady bird beetle and lynx spiders in brinjal ecosystem

In the present study, it was also investigated whether the selected insecticides has any toxic or adverse effect on natural enemies like ladybird beetle and lynx spiders in brinjal-ecosystem. Results showed that both Pine 6 WG (Emamectin benzoate + Abamectin) and Heron 5 EC were found comparatively safe both for ladybird beetle and lynx spider population in brinjal ecosystem while Cyclone 2.5 EC (Lambda-cyhalothrin) and Belt 24 WG (Flubendiamide) were potentially reduced the abundances of both of the natural enemies (Table 5, Table 6).

Discussion

Overall results confirmed that selected new insecticides had variable effects on reducing shoot and fruit infestation as well as increasing yield compared to control. Present findings could be linked with Anwar *et al.* (2015) who reported that Emamectin Benzoate was most effective against brinjal shoot and fruit borer and resulted in lower infestation (20.1%) followed by Cypermethrin (23.43%) whereas Flubendiamide offered moderate control (41.31%) of brinjal shoot and fruit borers. Tonishi *et al.* (2009) reported that fruit infestation both in terms of number and weight basis was minimum whereas hand removal of infested plant parts was done followed by Emamectin benzoate and Cartap hydrochloride treatments. Various insecticides are also evaluated against brinjal shoot and fruit borer by different researchers during last 10 years and reported variable result. Emamectin benzoate at 200 g/ha reduced fruit borer infestation and recorded higher fruit yield of brinjal. Emamectin benzoate @ 1.0 g/L and Spinosad 0.45 ml/L recorded lowest shoot and fruit infestation and highest marketable fruit yield (Sontakke *et al.*, 2007). Moreover, Emamectin benzoate @ 200 g/ha, reduced fruit borer infestation and recorded higher fruit yield of brinjal (Kumar and Devappa, 2006; Islam *et al.*, 2016). Application of Flubendiamide @ 500 g/ha resulted in minimum shoot and fruit damage with higher fruit yield (Tonishi *et al.*, 2009). Flubendiamide @ 90 and 72 g a.i./ha were significantly superior in reducing the shoot and fruit damage and recorded higher fruit yields of brinjal (Jagginavar *et al*., 2009).

In the present study, Pine 6 WG and Heron 5EC were found almost safe for ladybird beetle and lynx spiders while Flubendiamide and Lambda-cyhalothrin had toxic effects (50-60% natural enemies were reduced compared to control). Islam *et al*. (2017) recently reported that Emamectin benzoate and Abamectin both had little toxicity to ladybird beetle and lynx spiders. Rajesh *et al*. (2013) has confirmed in their study that both Buprofezin and Lufenuron are safe for coccinellid populations in rapseed mustard. The current study is in agreement with Cabral *et al.* (2008) who found that the adult survival, fecundity and the percentage of egg hatching of *Coccinella undecimpunctata* were not significantly affected by IGRs. These results are also consistent with the findings of Deng *et al.* (2008) who reported very lower toxicity of Lufenuron to wolf spiders under laboratory conditions. Munir *et al.* (2011) reported that Flubendiamide and Lambda-cyhalothrin are highly toxic to ladybird beetles and these results are in agreement with our present findings.

Conclusion

Based on present findings, it can be concluded that all the selected insecticides can be applied successfully for the management of BSFB in the field although Pine 6 WG @ 0.50g/L and Heron 5 EC @ 1.0 ml/L has showed the best efficacy considering all the parameters studied. Although Cyclone 2.5 EC and Belt 24 WG showed the significant efficacy against BSFB infestation but their applications should be minimized or restricted due to the adverse effect on natural enemies.

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