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Efficacy of abamectin alone or in combination with emamectin benzoate, lambda-cyhalothrin and lufenuron against the infestation of cucurbit fruit fly, *Bactrocera cucurbitae* (Coq.)

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Abstract
In this study, abamectin, emamectin benzoate, lufenuron and lambda-cyhalothrin were evaluated against the *Bactrocera cucurbitae*. Abamectin was applied alone and in combination with the others. A total of two sprays were given and data on percent fruit infestation, number of marketable fruit/m^2, infested and marketable fruit yield (t/ha) were collected on 3, 7 and 10 DAT. All the combined treatments significantly reduced percent fruit infestation. The highest infestation was observed in control ranged from 12.07 to 67.61%. Abamectin significantly reduced the fruit infestation (16.81%) compared to control which was further reduced in abamectin plus lambda-cyhalothrin (13.40%) treatment. Others parameters like maximum number of marketable fruit/m^2 (6.50/m^2), the highest marketable yield (9.39 t/ha) and lowest infested yield (3.36 t/ha) were also recorded from the same treatment. However, the combined treatments of abamectin with the others had no additive effects. Therefore, abamectin plus lambda-cyhalothrin could serve as an effective strategy for the management of the cucurbit fruit fly.

Keywords: *Bactrocera cucurbitae,* combination, abamectin, lambda-cyhalothrin, efficacy, biopesticide

Introduction

Momordica charantia, commonly known as bitter gourd, is one of the most popular vegetables grown in Bangladesh. The fruits of bitter gourd are rich in folate and vitamin C and are used in a variety of culinary preparations. The medicinal value of the gourd in the treatment of infectious diseases and diabetes is attracting the attention of scientists worldwide. This priced vegetable is cultivated on more than 16 thousand hectare of land and annual production is approximately 185 thousand tons in Bangladesh [1].

However this yield is often less than the expectation due to various insect and pests. Among various pest cucurbit fruit fly, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae) is a destructive pest of bitter gourd and distributed widely in temperate, tropical and sub-tropical regions of the world [2]. This pest is difficult to control due to the internal feeding habit of the larvae and protected from direct contact by insecticides. Crop loss is often 30 - 100% considering the suitable condition as well as cultivation of susceptible varieties [3].

Various synthetic insecticides from different groups like organophosphate, organocarbamate, pyrethroids, nicotinoids have been used effectively in controlling melon fruit fly in cucumber and bitter gourd [4, 5]. Sometimes farmers used combination form/cocktail form at the same time without the consideration of synergistic or antagonistic effects. But most of them cause potential threats for human being, environments, beneficial organisms, resistance development and ecological-balance [6, 7].

To overcome these problems and for safe, economic, environment friendly pest management, biorational insecticides could serve a lot. Applications of different bio-rational insecticides were reported to be effective for controlling cucurbit fruit fly. It was revealed that abamectin (0.0015%) was the most effective treatment in terms of reducing the fruit infestation as well as number of maggots in both the crops followed by lambda-cyhalothrin (0.004%) [8]. In a laboratory bio-assay study showed that abamectin has the greatest potential for controlling the *B. cucurbitae* [9]. Abamectin was also reported to be highly effective against *B. cucurbitae* on water melon [10]. It was also reported that emamectin benzoate significantly reduced fruit damage [4, 11]. Another laboratory evaluation revealed that dietary lufenuron reduces egg hatch and influences protein expression in the fruit fly, *B. latifrons* [12].

Most of the farmers in developing countries applied different combination form/cocktail form of various insecticides to get rid of from the infestation caused by insect pest. But the effect of these combined application are not always satisfactory, most of them creates hazardous impact on environment as well as human being due to their antagonistic or negative effect.

Keeping in mind that the fruits of bitter gourd are consumed a fresh; a field trial was conducted for evaluation of three combination mix formulations of some bio-rational insecticides to determine their effectiveness against the cucurbit fruit fly, *B. cucurbitae* as well as to check their compatibility.

Materials and methods

Location and experimental layout

Field experiments were conducted at the Entomological field laboratory, Bangladesh Agricultural University, Mymensingh during March to July, 2015. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications for each treatment.

Land preparation, horticultural practices and plant development

Land was ploughed with a power tiller followed by laddering and leveling the surface of soil. Cowdung and other fertilizers were applied as per recommended dose [13]. Seeds of a local popular variety of bitter gourd (Taj korola - 88) were collected from local market and then soaked in water overnight. After that the seedlings were raised in well prepared plots. There were 4 pits per plot and single plant per pit. All necessary horticultural practices were done for proper growth and development of the plants. Infestation of the insects like epilachna beetle, red pumpkin beetle was kept low by collecting and destroying the adults.

Insecticides selection and treatments

Three biorational insecticides namely, abamectin, emamectin benzoate, lufenuron and one newer pyrethroid viz. lambda-cyhalothrin were selected to determine the combined effects. There were five treatments including control with three replications for each. The detailed specifications of treatments are presented in the table 1 with their doses, trade name and group.

Table 1: Specification of treatments for combined effects of the selected insecticides

	Treatments	Active ingredients	Group/ Family
T_1	Ambush 1.8 EC @ 2.5 ml/L	Abamectin	Avermectin
T_2	Ambush 1.8 EC @ 2.5 ml/L+ Suspend 5 SG @ 1.25 g/L	Abamectin + Emamectin Benzoate	Avermectin +Avermectin
T_3	Ambush 1.8 EC@ 2.5 ml/L + Jubas 2.5 EC @ 1.5 ml/L	Abamectin + Lambda-cyhalothrin	Avermectin + Pyrehtroids
T_4	Ambush 1.8 EC@ 2.5 ml/L+ Haron 5 EC @ 1.5 ml/L	Abamectin + Lufenuron	Avermectin + Insect Growth Regulator
T_5	Control	-	-

Data collection

Data were collected on before and 3, 7 and 10 days after treatment (DAT) application. A total number of two sprays were applied at ten days interval. Fruits were picked thrice at 10 days after treatment application. Before and after treatment application, infested and total numbers of bitter gourds were counted from each plant/plot.

Data were counted from each on the following parameters:

Percentage of infested fruits

$$= \frac{\text{Number of infested fruit}}{\text{Number of total fruit}} \text{ X } 100$$

Percentage fruit protection over control

$$= \frac{Ic - It}{Ic} \text{ X } 100$$

Where,
Ic = Fruit infestation level in control plot
It = Fruit infestation level in treated plot

Number of healthy fruits per square meter

The unit plot size was 4 m^2. Total numbers of healthy fruits of bitter gourd were counted from each plot and finally number of healthy fruits per square meter was calculated.

Yield of marketable fruits (t/ha)

Marketable fruits of bitter gourd were defined as the fruits having no hole, no deformation or no pseudo-puncture present on the fruits. Fruits were harvested at 10 days after treatment application and marketable fruits were separated carefully. Weight of the collected fruits was then taken and yield was converted to tons per hectare. Three pickings were done and total marketable fruit yield was than calculated. Increase of marketable yield (times) due to application of different treatments over control was calculated by the following formula:

Increase of marketable yield (times) over control

$$= \frac{Yt}{Yc},$$

Where,
Yc = Cumulative yield in control plot
Yt = Cumulative yield in treated plot

Yield of infested fruits (t/ha)

Deformed, yellowish and fruits with hole are considered as infested fruits of bitter gourd. They were separated from the healthy fruits and yield was calculated following the same procedures described for yield of marketable fruits.

Statistical analysis

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

Results and discussion

Effectiveness of the selected insecticides on the reduction of percent fruit infestation

The resultant effects of abamectin in combination with other tested insecticides on the reduction of percent fruit infestation of bitter gourd caused by the cucurbit fruit fly, *B. cucurbitae* is presented in the Table 2. It is found from the results of present field evaluation of the selected insecticides against fruit flies on bitter gourd exerted variable efficacy in reducing the fruit infestation over check significantly.

Table 2: Percent fruit infestation caused by *B. cucurbitae* after combined application of abamectin along with emamectin benzoate, lamda-cyhalothrin or lufenuron

		% fruit infestation after different spray							%
Treatments	Before spray	1st spray			2	nd spray	Cumulative protection		
		3 DAT	7 DAT	10 DAT	3 DAT	7 DAT	10 DAT	mean	over control
T1*	10.13^{c}	12.33^{c}	12.97^{c}	15.73^{b}	17.90^{c}	18.21^{b}	23.70^{b}	16.81^{b}	57.65
T2	11.21^{ab}	12.82^{b}	13.27^{c}	16.68^{b}	18.25^{b}	18.51^{b}	24.98^{b}	17.42^{b}	55.12
T3	9.59^{c}	10.03^{c}	12.41^{c}	13.59^{c}	14.61^{c}	14.57^{c}	15.16^{c}	13.40^{c}	66.24
T4	10.74^{bc}	13.25^{b}	15.29^{b}	17.53^{b}	19.34^{b}	20.86^{b}	22.98^{b}	18.20^{b}	54.14
Control	12.07^{a}	17.53^{a}	20.68^{a}	33.35^{a}	41.59^{a}	57.39^{a}	67.61^{a}	39.69^{a}	-
LSD0.05	1.28	2.01	1.84	2.20	2.42	2.94	3.98	2.46	-
SE (±)	0.52	1.55	1.86	4.44	6.13	9.94	12.19	5.99	-
Level of NS significance		**	**	**	**	**	**	**	-

Means of similar letter(s) in a column do not differ significantly.

*=T1= Ambush 1.8 EC @ 2.5 ml/L (Abamectin); T2= Ambush 1.8 EC @ 2.5 ml/L plus Suspend 5 SG @ 1.25 g/L (Abamectin plus Emamectin Benzoate); T3= Ambush 1.8 EC @ 2.5 ml/L plus Jubas 2.5 EC @ 1.5 ml/L (Abamectin plus Lambda-cyhalothrin); T4= Ambush 1.8 EC @ 2.5 ml/L plus Haron 5 EC @ 1.5 ml/L (Abamectin plus Lufenuron).

NS = Not Significant, ** = Significant at 1% level

The highest percentage of fruit infestation was observed in control which was ranged from 12.07 to 67.61% for different day's treatment whereas the cumulative mean was 39.69%. On the other hand, abamectin in combination with lambda-cyhalothrin results the lowest fruit infestation (13.40%). This result was followed by abamectin alone (16.81%) and combined application of abamectin plus emamectin benzoate (17.42%). The least efficacy was recorded in combined form of abamectin with lufenuron where percent fruit infestation was found about 18.20%.

Percent fruit protection of bitter gourd over control

The resultant effects of abamectin in combination with other tested insecticides on percent fruit protection of bitter gourd over control is also presented in the Table 2. About 57.65% fruits were protected from infestation when treated with abamectin only and the protection level was increased to 66.24% due to the combined application of abamectin with lambda-cyhalothrin. The percent protection of bitter gourds for abamectin plus lufenuron and abamectin plus emamectin benzoate level were 54.14% and 55.12%, respectively. Thus, abamectin with lambda-cyhalothrin combination provides the highest protection of bitter gourds fruits whereas combination of abamectin with other tested insecticides gave almost similar level of protection.

Effectiveness of the selected insecticides on the number of healthy fruits/m^2

The resultant effects of abamectin in combination with other tested insecticides on the number of healthy fruits /m^2 were also evaluated and are presented in the Table 3. There were statistically significant differences were observed among the treatments ($P < 0.01\%$). The abamectin plus lambda-cyhalothrin combination produced the maximum cumulative number (6.50/m^2) of marketable fruits followed by abamectin alone (5.14/m^2). The lowest numbers (2.50/m2) of marketable fruits were found in control. Statistically similar numbers of healthy fruits/m^2 were produced by the combination of abamectin plus emamectin benzoate (4.75/m^2) and abamectin plus lufenuron (4.59/m^2). Table 3 also showed significant variation on the number of healthy fruits /m^2 among the three different pickings of fruits. Higher number of healthy fruits was picked during 1st picking which was gradually reduced to the 3rd picking of fruits.

Table 3: Number of marketable fruits/m^2 after combined application of emamectin benzoate, lamda-cyhalothrin or lufenuron

Treatments	No. of marketable fruits/m^2			
	1st picking	2nd picking	3rd picking	Cumulative number
T1*	1.89^{b}	1.68^{b}	1.57^{b}	5.14^{b}
T2	2.08^{a}	1.50^{b}	1.17^{b}	4.75^{b}
T3	2.17^{a}	2.42^{a}	1.92^{a}	6.50^{a}
T4	1.67^{b}	1.50^{b}	1.42^{b}	4.59^{b}
Control	0.67^{c}	1.00^{c}	0.83^{c}	2.50^{c}
LSD0.05	0.189	0.252	0.275	0.384
SE (±)	0.054	0.073	0.080	0.112
Level of significance	**	**	**	**

In a column, means of similar letter (s) do not differ significantly.
*=T1= Ambush 1.8 EC @ 2.5 ml/L (Abamectin); T2= Ambush 1.8 EC @ 2.5 ml/L plus Suspend 5 SG @ 1.25 g/L (Abamectin plus Emamectin Benzoate); T3= Ambush 1.8 EC @ 2.5 ml/L plus Jubas 2.5 EC @ 1.5 ml/L (Abamectin plus Lambda-cyhalothrin); T4= Ambush 1.8 EC @ 2.5 ml/L plus Haron 5 EC @ 1.5 ml/L (Abamectin plus Lufenuron).
** = Significant at 1% level

Effectiveness of the selected insecticides on marketable fruit yield (t/ha)

The marketable fruit yield (t/ha) was increased significantly when abamectin was applied in combination with lambda-cyhalothrin, emamectin benzoate or lufenuron ($P < 0.01$). The highest yield (9.39 t/ha) was found when abamectin was sprayed in combination with lambda-cyhalothrin (Table 4) followed by the individual application of abamectin (8.22 t/ha). The abamectin plus emamectin benzoate and the abamectin plus lufenuron produced statistically similar yield of marketable fruits (Table 4).

Increase of marketable fruit yield in terms of times over control was also calculated. Moreover the yield was increased 2.26 times over control when abamectin was sprayed in combination with lambda-cyhalothrin which was higher than the individual application of abamectin (1.98 times). Unexpectedly, the marketable yield was reduced to 1.66 and 1.72 times from 1.98 times (abamectin only) when plants were treated with abamectin + lufenuron and abamectin + emamectin benzoate respectively.

Table 4: Yield (t/ha) of marketable fruits after combined application of emamectin benzoate, lamda-cyhalothrin or lufenuron

	Yield (t/ha) of marketable fruits			Yield	increases
Treatments over control	**1stpicking**	**2nd picking**	**3nd picking**	**Cumulative yield**	**(times)**
T1*	3.57^{a}	2.68^{b}	1.97^{b}	8.22^{b}	1.98
T2	2.53^{d}	2.30^{b}	2.21^{a}	7.12^{c}	1.72
T3	3.90^{a}	3.20^{a}	2.38^{a}	9.39^{a}	2.26
T4	2.80^{c}	2.45^{b}	1.63^{b}	6.90^{c}	1.66
Control	1.60^{e}	1.30^{d}	1.20^{d}	4.15^{d}	-
LSD0.05	0.236	0.189	0.268	0.709	-
SE (±)	0.473	0.391	0.271	1.07	-
Level of significance	**	**	**	**	-

In a column, means of similar letter (s) do not differ significantly.

* = T1= Ambush 1.8 EC @ 2.5 ml/L (Abamectin); T2= Ambush 1.8 EC @ 2.5 ml/L plus Suspend 5 SG @ 1.25 g/L (Abamectin plus Emamectin Benzoate); T3= Ambush 1.8 EC @ 2.5 ml/L plus Jubas 2.5 EC @ 1.5 ml/L (Abamectin plus Lambda-cyhalothrin); T4= Ambush 1.8 EC @ 2.5 ml/L plus Haron 5 EC @ 1.5 ml/L (Abamectin plus Lufenuron);

** = Significant at 1% level,

Effects of combined treatments of the selected insecticides on infested fruit yield (t/ha)

The infested fruit yield was significantly ($P < 0.01$) reduced when abamectin was applied in combination with lambda-cyhalothrin, emamectin benzoate and lufenuron in comparison with that in the control (Table 5).

The highest infested cumulative yield (6.15 t/ha) was obtained from control plots and the lowest yield (3.36 t/ha) was obtained from abamectin plus lambda-cyhalothrin treated plots followed by the application of abamectin alone (3.82 t/ha). Application of abamectin plus emamectin benzoate and abamectin plus lufenuron yielded 4.12 and 4.28 t/ha infested fruits, respectively. There were no statistically significant differences observed between the efficacy of abamectin plus emamectin benzoate; abamectin plus lufenuron and abamectin alone treatment on the yield of infested fruits (Table 5).

Table 5: Yield (t/ha) of infested fruits after combined application of emamectin benzoate, lamda-cyhalothrin or lufenuron.

Treatments		Yield (t/ha) of infested fruits		
	1st picking	**2nd picking**	**3rd picking**	**Cumulative yield**
T1*	0.89^{c}	1.28^{c}	1.55^{b}	3.82^{b}
T2	1.79^{b}	1.35^{b}	0.97^{c}	4.12^{b}
T3	0.81^{c}	1.27^{bc}	1.38^{bc}	3.36^{c}
T4	2.47^{a}	1.04^{c}	0.77^{e}	4.28^{b}
Control	2.04^{b}	1.75^{a}	2.36^{a}	6.15^{a}
LSD0.05	0.394	0.260	0.063	0.357
SE (±)	0.35	0.15	0.35	0.59
Level of significance	**	**	**	**

In a column, means of similar letter (s) do not differ significantly.

* = T1= Ambush 1.8 EC @ 2.5 ml/L (Abamectin); T2= Ambush 1.8 EC @ 2.5 ml/L plus Suspend 5 SG @ 1.25 g/L (Abamectin plus Emamectin Benzoate); T3= Ambush 1.8 EC @ 2.5 ml/L plus Jubas 2.5 EC @ 1.5 ml/L (Abamectin plus Lambda-cyhalothrin); T4= Ambush 1.8 EC @ 2.5 ml/L plus Haron 5 EC @ 1.5 ml/L (Abamectin plus Lufenuron);

** = Significant at 1% level

Thus, it is revealed that all the parameters tested viz. fruit infestation, number of marketable fruits/m^2, healthy fruit yield, yield of infested fruits were found better when abamectin was applied in combination with lambda-cyhalothrin and these results were often higher than the individual application of abamectin (Table 3, 4 and 5). Unexpectedly, percent fruit infestation was increased more even when abamectin was sprayed in combination with either emamectin benzoate or lufenuron, respectively compared to the abamectin alone (Table 2). Like as fruit infestation, the marketable fruit number as well as yield was decreased and infested fruit yield was increased when abamectin was applied in combination with emamectin benzoate or lufenuron respectively.

The abamectin is a class of biopesticide derived from fermented product of the soil bacterium *Streptomyces avermitilis* proved highly effective against fruit flies resulting in lower per cent fruit infestation on bitter gourd. Although, we have not tested, the high efficacy of abamectin could be due to its antiovipositional and reproductive inhibitory effect. High efficacy of abamectin was reported against *B. cucurbitae* on water melon [10] and against Mediterranean fruit fly, *Ceratitis capitata*, Oriental fruit fly, *B. dorsalis* and melon fruit fly *B. cucurbitae* [14]. On the other hand, Lambda-cyhalothrin possesses low water solubility and high binding affinity of with plant surface. Therefore, when abamectin was applied with lambda-cyhalothrin in cocktail form, all the above mentioned characteristics might have contributed in its bio-efficacy against fruit flies on bitter gourd crop.

The present findings clearly indicated that there had either additive or antagonistic effects of combined treatments on marketable yield. Application of abamectin alone yielded 8.22 t/ha which is increased to 9.39 t/ha when abamectin was applied in combination with lambda-cyhalothrin. This suggested that additive/synergistic effect occurred when abamectin and lambda-cyhalothrin applied in combined form. In contrast, the yield was reduced to 7.12 and 6.90 t/ha when treated with abamectin plus emamectin benzoate or abamectin plus lufenuron, respectively compared to the effect of abamectin alone (8.22 t/ha) which raises the possibility that there had an antagonistic effect between abamectin and emamectin benzoate or abamectin and lufenuron.

Thus, abamectin has provided the additive or synergistic effects only when applied with lambda-cyhalothrin but showed negative or antagonistic effects when applied with emamectin benzoate or lufenuron. The exact reasons of incompatibility between these two groups of insecticides with abamectin are unidentified and require further experimentation. Farmer's carefulness and awareness is advised when selecting different insecticides from different groups as combined or cocktail form for insect pest management. Finally, our study suggests that abamectin with lambda-cyhalothrin could serve as an effective and economically viable treatment for fruit fly management in Bangladesh.

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