Insectia: Journal of Entomology

Open Access Research Article

Development of IPM modules using microbials and their derivatives for managing bean aphid, *Aphis craccivora* Koch

Farzana Akter[1], Mohammad Mahir Uddin*[2], Khandakar Shariful Islam[2]
[1]MS student, Department of Entomology, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh, Bangladesh.
[2]Professor, Department of Entomology, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh, Bangladesh.
Corresponding Author: Mohammad Mahir Uddin: mahir@bau.edu.bd, Professor, Department of Entomology, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.

Received
12th June 2020

Accepted
3rd November 2020

Available online
12th November 2020

© 2020 Mohammad Mahir Uddin. Published by Apertus Journals. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Abstract

Bean aphid is a serious pest which causes enormous loss of yield of country bean. An experiment was conducted at the Entomology Field Laboratory of Bangladesh Agricultural University, Mymensingh, Bangladesh during October 2018 to March 2019 to develop IPM modules using microbials and their derivatives and a botanical for managing bean aphid on IPSA Seem-2. IPM modules were evaluated based on different parameters viz. percentage of twig, flower and pod infestation at different time intervals and yield of marketable pod (ton ha-1). Eight treatments (seven IPM modules) viz. T1: Bt + Spinosad, T2: *B. bassiana* + Lufenuron, T3: Bt Abamectin, T4: Bt + Neem oil, T5: Bt + Lufenuron, T6: *B. bassiana* + Abamectin, T7: Bt + Buprofezin, T8: Control was included in the experiment. The experiment was laid out in RCB design with 3 replications of each treatment. The lowest infested twig, flower and pod were found 8.12, 4.55 and 5.13%, respectively at *Beauveria bassiana* + Abamectin sprayed plot after 1st spray. The efficacy of other IPM packages was more or less similar. After 2nd spray the lowest infested twig, flower and pod was observed 2.56, 1.73 and 2.16%, respectively at *Beauveria bassiana* + Abamectin sprayed plot. Similarly, after 3rd spray the lowest infested twig, flower and pod were 1.08, 0.47, and 0.78%, respectively at *Beauveria bassiana* + Abamectin sprayed plot. The highest twig, flower and pod infestation was always recorded from control treatment in all three sprays. The highest reduction of infested twig, flower, and pod over

control was observed 98.33, 98.9 and 98.99%, respectively from the plots treated with *Beauveria bassiana* + Abamectin. The highest yield (12.46 ton ha-1) was also found from *B. bassiana* + Abamectin sprayed plot but the lowest yield was in control plots. From the present findings it can be concluded that *B. bassiana* + Abamectin might be applied successfully for the management of country bean aphid as it provided significant protection of twig, flower and pod and subsequently produced the highest pod yield.

Keywords: *Bacillus thuringiensis, Beauveria bassiana*, Abamectin, Buprofzin, Lufenuron, Spinosad, Neem.

Introduction

Country bean, *Lablab purpureus* (L) is an internal vegetable of Indo-Bangladesh region. The plant is long trailing and branched. It is a very important leguminous vegetable of Bangladesh. In the perspective of dry matter, calorie, protein, fat, vitamin A and B the pods are the superior most in spreading nature. Nutritionally, the seed is top in the list of pulse crop. It is rich in carbohydrate, protein, fat, minerals. The leaves and seeds contain 20–28% protein, with a well-balanced amino acid composition[1]. Bean contains several vital nutrients, including folate which can help to prevent neural tube defects in a fetus during pregnancy. It also contains antioxidant called polyphenols which reduces risk of cancer. Bean is normally grown during the rabi or winter season. In Bangladesh total land area under bean cultivation 51595 acres and the production is about 137495 ton 2016-17 years[2]. But the production is low according to the demand.

Bean aphid, *Aphis craccivora* Koch is a destructive pest of country bean. The young plants suffer heavily from the attack of bean aphid and may die[3]. All growth stages of bean crop are very susceptible to bean aphid infestation and may result in high yield loss if not controlled. Bean aphid causes both the direct and indirect damage. By sucking cell sap they cause direct damage to the host and also they transmit common mosaic viruses during the sucking activity which is the indirect damage. Aphids secret honey dew which attracts sooty mould fungus on leaf surfaces and reduces photosynthetic area depriving the growing plant and the developing grains in the pods of

nutrients thus causing low yields[4]. *Aphis craccivora* Koch is the most serious pest of bean plants from seedling to pod bearing stage, causing considerable yield loss[5]. The pest causes up to 40% reduction of crop yields in Asia[6]. It has been reported as high as 100% yield reduction of different bean crops due to aphid infestation[7]. Due to severity of infestation plants fail to give flowering and pods setting resulting in 20-40% yield loss[8].

To protect the crops from aphids, insecticides are considered essential for their management. A large number of insecticides have been evaluated and recommended from time to time for their control9. Some pesticides have shown efficacy in controlling bean insect infestation but not eco-friendly to natural enemies, to humans, to wildlife safety. So, there is a need for adopting other new alternative in controlling bean aphid. Controlling aphid using non chemical insecticides microbials and their derivatives are most promising and it is eco-friendly and hazardous residual effect free. But in our country the popularity of using microbials and their derivatives is so much negligible. *Beauveria bassiana* (soil borne fungus), *Bacillus thuringiensis* (soil dwelling bacteria), Spinosad derived from a soil born bacterium- *Saccharopolyspora spinosa*, Lufenuron (growth regulator), Neem oil (botanical), Abamectin, Buprofezin are also being used as environmentally safe product. So, the present study has been done giving emphasis on the development of some IPM modules using different microbials and their derivatives and a botanical for managing bean aphid.

Materials and Methods

Location and soil of the experiment

The experiment was conducted at the Entomology Field Laboratory of Bangladesh Agricultural University, Mymensingh-2202 during the period from October 2018 to March 2019 to develop IPM module using microbials and their derivatives for managing bean aphid in rabi season. The experimental site is located at 24.75^0 N latitude 90.5^0 E longitude with an elevation of about 9.2 m above from the sea. The field experiments were conducted under sub-tropical climate, which is characterized by moderately low temperature, scanty rainfall during October- March. The soil of the field experiment area was under Old

Brahmaputra Alluvial Tract under the Agro Ecological Zone 9 with sandy loam soil and texture having good irrigation and drainage facilities. The soil was silty loam in texture having pH 6.94, organic matter 1.62% and cation exchange capacity 15.00 m.eq 100^{-1} g soil[10].

Development of plants

The land was ploughed and cross-ploughed several times with a power tiller to obtain final tilth that was followed by laddering and spading. The stubbles of the crops and uprooted weeds were removed from the field and the land was then leveled prior to transplanting. The entire experimental field was divided into three blocks and then into 24 plots. Each plot size was 2 ft X 2 ft. Two adjacent unit plots and blocks both were separated by 1 foot apart. The plots were raised by 10 cm from the soil surface keeping the drain around the plots. Seem seeds (variety: IPSA-2 seem) were collected from Balughat bazar, Dhaka cantonment, Dhaka-1206. Seeds were sown in pits (five seeds/pit) followed by a light irrigation to ensure soil moisture for germination. Recommended fertilizer doses of 10 ton cowdung, 25 kg urea, 90 kg TSP, 60 kg MoP, Gypsum 5 kg and 5 kg Boric acid were adopted for one ha land. Half of the dose of urea and the total phosphorus, cowdung, gypsum, boric acid were applied as basal dose and the rest of the urea was applied at 30 days after sowing. Mustard oil cake was also applied at the vegetative stage. Weeding and all suitable agronomic practices were done for proper growth and development of plants. Bamboo stalking was made for propping, allowing easy standing and preventing the plant from lodging. Each experimental plot was tagged properly considering the treatments and replications.

Design of experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD). Each of the treatments was replicated for three times.

Specification of treatments

Treatments	IPM modules	Dose/L of water
T1	*Bacillus thuringiensis* (Bt)+ Spinosad (Tracer 45 SP)	5g + 0.5 ml
T2	*Beauvaria bassiana* (Bb)+ Lufenuron (Heron 5 EC)	5g + 0.5 ml
T3	*Bacillus thuringiensis* (Bt) + Abamectin (Ambush 1.8 EC)	5g + 2.5ml
T4	*Bacillus thuringiensis* (Bt)+ Neem oil	5g + 1.5 ml
T5	*Bacillus thuringiensis* (Bt)+ Lufenuron (Heron 5 EC)	5g + 0.5 ml
T6	*Beauveria bassiana* (Bb)+ Abamectin (Ambush 1.8 EC)	5g + 2.5 ml
T7	*Bacillus thuringiensis* (Bt)+ Buprofezin (Award 40 SC)	5g + 0.5ml
T8	Control	-

Data Collection

All the treatments were applied maintaining 15 days intervals and data were collected at 5, 10 and 15 days after spraying. Number of healthy and infested twig, flower and pods and weight of healthy pods for each plot were recorded. Then percentage of infested twig, flower or pod was calculated. The weight of healthy pods plot^{-1} was measured by an electrical balance. Finally, yield (ton ha^{-1}) was calculated from data found from the plots. Percentage reduction of twig, flower or pod infestation over control and percentage increase of yield over control was calculated using the following formulae.

(%) reduction of twig, flower or pod infestation over control

$$= \frac{\%\,IC - \%\,IT}{\%\,IC} \times 100$$

IC = Infestation in control plots

IT = Infestation in treated plots

(%) increase of pod yield over control = $\frac{\%YT - \%\,YC}{\%\,YT} \times 100$

YC = Yield in control plots

YT = Yield in treated plots

Data analysis

All the data collected on different parameters were compiled and arranged for statistical analysis. Then the data were analyzed statistically using MSTAT-C package programme. The means were separated using DMRT test.

Results

Effect of IPM modules on the infestation of twig caused by *A. craccivora*

The effect of IPM modules on the percentage of twig infestation was significant at different time intervals (Table 1). At 5 DAS, the lowest twig infestation was found at Bb + Abamectin sprayed plot (11.76%) followed by Bt + Spinosad (16.66%). The highest infested twig was observed from control (43.47%) plot. At 10 DAS, the lowest infested twig was recorded at Bb + Abamectin sprayed plot (11.11%) followed by Bt + Abamectin (17.64%). The highest infested twig was observed from control (44.44%). Similarly, at 15 DAS, the lowest infested twig was found at Bb + Abamectin sprayed plot (8.12%) followed by Bt +

Abamectin (14.29%). The highest infested twig was observed from control (50%) plots.

Table 1 - Effect of IPM modules on the twig infestation at different days after 1st spray

Treatments	5 DAS			10 DAS			15 DAS		
	No. of healthy twig plot^{-1}	No. of infested twig plot^{-1}	%infestation	No. of healthy twig plot^{-1}	No. of infested twig plot^{-1}	%infestation	No. of healthy twig plot^{-1}	No. of infested twig plot^{-1}	%infestation
T1	25.0c	5c	16.66	25c	7cd	21.87	26c	5d	16.13
T2	20.0d	9a	31.03	20d	9bc	31.03	21d	7c	25.00
T3	27.5b	6bc	17.91	28b	6de	17.64	30b	5d	14.29
T4	23.0c	8ab	25.80	23c	8bcd	25.81	26c	6cd	18.75
T5	18.0d	9a	33.33	18de	9bc	33.33	20d	7c	25.93
T6	30.0a	4c	11.76	32a	4e	11.11	34a	3e	8.12
T7	15.5e	9a	36.73	16ef	10ab	38.46	18e	12b	40.00
T8	13.0f	10a	43.47	15f	12a	44.44	16f	16a	50
Level of significance	**	*	-	*	**	-	*	*	-
CV%	6.12	10.83	-	5.36	10.61	-	7.82	10.91	-

T1 = Bt + Spinosad, T2= Bb + Lufenuron, T3 = Bt + Abamectin, T4 = Bt + Neem oil, T5 = Bt + Lufenuron, T6 = Bb+ Abamectin, T7= Bt + Buprofezin and T8= untreated control; In column, means followed by different letters are significantly different; * & ** Mean significant at 5% & 1% level of probability, respectively

Table 2 - Effect of IPM modules on the twig infestation at different days after 2nd spray

Treatments	5 DAS			10 DAS			15 DAS		
	No. of healthy twig plot^{-1}	No. of infested twig plot^{-1}	% infestation	No. of healthy twig plot^{-1}	No. of infested twig plot^{-1}	% infestation	No. of healthy twig plot^{-1}	No. of infested twig plot^{-1}	% infestation
T1	27.0 c	12.00b	20.34	27.00c	1.67ef	5.82	30.00c	2.00ef	6.25
T2	23.00d	5.66d	10.47	24.00e	5.00c	17.24	26.00e	3.67cd	12.37
T3	30.33b	4.00ef	11.65	31.00b	3.00de	8.82	32.00b	2.67de	7.70
T4	26.0c	4.66de	13.04	25.67d	4.00cd	13.48	27.67d	3.33de	10.74
T5	21.0d	5.66d	21.23	21f	4.67c	18.19	23.00f	5.00c	17.86
T6	35.0a	3.00f	7.89	35.67a	1.00f	2.73	38.00a	1.00f	2.56
T7	18.0e	10.00c	35.71	17g	8.00b	32.00	20.67g	7.67b	27.72
T8	14.0f	17.00a	54.84	13.33h	17.67a	57.00	13.00h	18.00a	58.06
Level of significance	**	*	-	**	**	-	**	**	-
CV%	4.71	10.03	-	5.02	5.76	-	5.68	10.27	-

T1 = Bt + Spinosad, T2= Bb + Lufenuron, T3 = Bt + Abamectin, T4 = Bt + Neem oil, T5 = Bt + Lufenuron, T6 = Bb+ Abamectin, T7= Bt + Buprofezin and T8= untreated control; In column, means followed by different letters are significantly different; * & ** Mean significant at 5% & 1% level of probability, respectively

After 2nd spray, at 5 DAS, the lowest infested twig was found from Bb +Abamectin sprayed plot (7.89%) followed by Bb + Lufenuron (10.47%) but the highest infested twig was in control (54.84%) (Table2). AT 10 DAS, the lowest infested twig was recorded at Bb + Abamectin sprayed plot (2.73%) followed by Bt + Abamectin (8.82%).The highest infested twig was observed from control (57.00%) (Table 2). Similarly, at 15 DAS, the lowest infested twig was observed in Bb + Abamectin sprayed plot (2.56%) followed by, Bt + Spinosad (6.25%). The highest infested twig was found from control (58.06%).

In case of 3rd spray, at 5 DAS the lowest infested twig was seen at Bb + Abamectin sprayed plot (2.78%) followed by Bt + Spinosad (5.27%). The highest infested twig was observed from control (62.96%) (Table 3). AT 10 DAS, the lowest infested twig was seen at Bb + Abamectin sprayed plot (1.99%) followed by Bt + Abamectin (4.69%). The highest infested twig was observed from control (68.97%) (Table3). AT 15 DAS, the lowest infested twig was seen at Bb + Abamectin sprayed plot (1.08%) followed by Bt + Abamectin (5.05%). The highest infested twig was observed from control (65.38%).

Table 3 - Effect of IPM modules on the twig infestation at different days after 3rd spray

Treatments	5 DAS			10 DAS			15 DAS		
	No. of healthy twig plot^{-1}	No. of infested twig plot^{-1}	%infestation	No. of healthy twig plot^{-1}	No. of infested twig plot^{-1}	%infestation	No. of healthy twig plot^{-1}	No. of infested twig plot^{-1}	%infestation
T1	30.00c	1.67ef	5.27	29.00b	1.67e	5.45	27.00b	2.33de	7.94
T2	25.00e	3.33cd	11.75	23.00e	3.33cd	12.65	20.00e	2.67cd	11.78
T3	31.00b	2.33def	6.99	27.00c	1.33e	4.69	25.00c	1.33f	5.05
T4	27.00d	3.00cde	10.00	25.00d	3.00d	10.71	22.67d	1.67ef	7.05
T5	20.00f	4.00c	16.67	17.67f	4.33c	20.3	16.00f	3.33c	17.23
T6	35.00a	1.00f	2.78	33.00a	0.67e	1.99	30.00a	0.33g	1.09
T7	18.00g	6.67b	27.04	17.00f	8.00b	32	15.00f	5.00b	25.00
T8	10.00h	17.00a	62.96	9.00g	20.00a	68.97	9.00g	17.67a	65.38
Level of significance	*	**	-	**	*	-	**	*	-
CV%	6.95	7.26		8.14	10.06		8.45	12.59	-

T1 = Bt + Spinosad, T2= Bb + Lufenuron, T3 = Bt + Abamectin, T4 = Bt + Neem oil, T5 = Bt + Lufenuron, T6 = Bb+ Abamectin, T7= Bt + Buprofezin and T8= untreated control; In column, means followed by different letters are significantly different; * & ** Mean significant at 5% & 1% level of probability, respectively

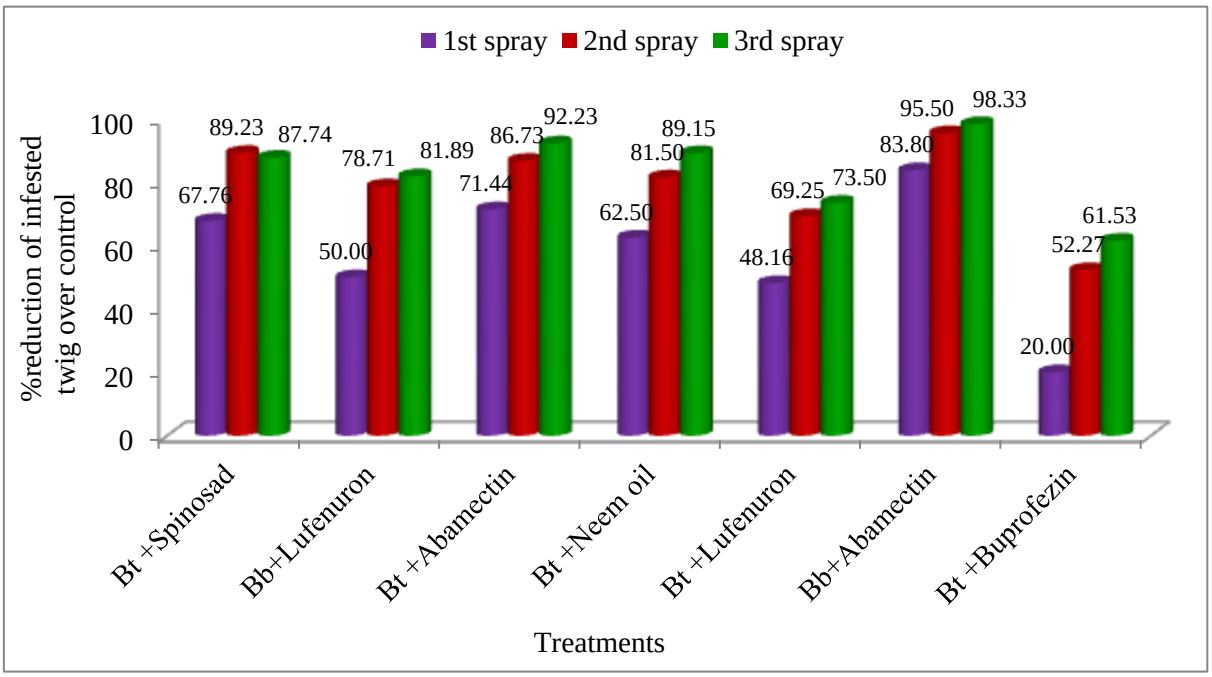

Figure 1 - Effect of IPM modules on the reduction (%) of infested twig over control at 1st, 2nd, and 3rd sprays

The highest percentage reduction of infested twig over control was observed from the plots treated with Bb + Abamectin (83.8%) in the first spray. However, Bt + Buprofezin (20%) provided the least percentage reduction of infested twig infested by bean aphid (Fig. 1). The efficacy rank of the IPM modules on (%) reduction of infested twig over control was as follows-Bb + Abamectin > Bt + Abamectin > Bt + Spinosad > Bb + Neem oil > Bb + Lufenuron > Bt + Lufenuron > Bt + Buprofezin in first spray. In case of second spray the highest percentage reduction of infested twig over control was observed from the plots treated with Bb + Abamectin (95.5%). However Bt + Buprofezin (52.27%) provided the least percentage reduction of infested twig affected by bean aphid (Fig.1). The efficacy rank of the IPM modules on (%) reduction of infested twig over control was as follows-

Bb + Abamectin > Bt+ Spinosad > Bt + Abamectin > Bt + Neem oil> Bb + Lufenuron > Bt + Lufenuron> Bt + Buprofezin. Similarly in the third spray, the highest percentage reduction of infested twig over control was observed from the plots treated with Bb + Abamectin (98.33%). However Bt + Buprofezin (61.53%) provided the least percentage reduction of infested twig affected by bean aphid (Fig. 1). The efficacy rank of the IPM modules on (%) reduction of infested twig over control was as follows- Bb + Abamectin > Bt + Abamectin > Bt + Neem oil > Bt + Spinosad > Bb + Lufenuron > Bt + Lufenuron > Bt + Buprofezin.

Table 4 - Effect of IPM modules on the infestation of flower at different days after 1st spray

Treatments	5 DAS			10 DAS			15 DAS		
	No. of healthy flower plot^{-1}	No. of infested flower plot^{-1}	%infestation	No. of healthy flower plot^{-1}	No. of infested flower plot^{-1}	%infestation	No. of healthy flower plot^{-1}	No. of infested flower plot^{-1}	%infestation
T1	55.00c	7 f	11.29	57.00c	6e	9.52	58.00c	5e	7.94
T2	52.00d	10d	16.13	53.00e	10c	15.87	54.00e	9c	14.29
T3	58.00b	6g	9.38	59.00b	5e	7.81	60.00b	4ef	6.25
T4	54.00c	8e	12.90	56.00d	8d	12.5	57.00d	7d	10.94
T5	50.00e	12c	19.35	51.00f	11c	17.74	50.00f	10c	16.67
T6	60.00a	4h	6.25	62.00a	3f	4.62	63.00a	3f	4.55
T7	48.00f	13b	21.31	49.00g	13b	20.97	49.00g	11b	18.33
T8	45.00g	14a	23.73	46.00h	16a	25.81	47.00h	18a	27.69
Level of significance	*	**		**	**		*	*	-
CV%	5.41	9.00		11.87	7.85		10.64	8.10	-

T1 = Bt + Spinosad, T2= Bb + Lufenuron, T3 = Bt + Abamectin, T4 = Bt + Neem oil, T5 = Bt + Lufenuron, T6 = Bb+ Abamectin, T7= Bt + Buprofezin and T8= untreated control; In column, means followed by different letters are significantly different; * & ** Mean significant at 5% & 1% level of probability, respectively.

Effect of IPM modules on the infestation of flower caused by *A. craccivora*

After 1st spray, the lowest percentage of infested flower was found at Bb + Abamectin sprayed plot (6.25%) followed by Bt + Abamectin (9.38%) at 5 DAS. The highest percentage of infested flower was observed from control (23.73%) (Table 4). At 10 DAS, the lowest percentage of infested flower was seen at Bb + Abamectin sprayed plot (4.62%) followed by Bt + Abamectin (7.81%). The highest percentage of infested flower was observed from control (25.81%) (Table 4). AT 15

DAS, the lowest percentage of infested flower was seen at Bb + Abamectin sprayed plot (4.55%) followed by Bt + Abamectin (6.25%). The highest percentage of infested flower was observed from control (27.69%).

After 2nd spray, the lowest percentage of infested flower was observed at Bb + Abamectin sprayed plot (2.33%) followed by Bt + Abamectin (5.37%) at 5 DAS. The highest percentage of infested flower was observed from control (34.12%) (Table 5). At 10 DAS, the lowest percentage of infested flower was recorded at Bb + Abamectin sprayed plot (1.81%) followed by Bt + Abamectin (3.79%). The highest percentage of infested flower was observed from control (38.82%) (Table 5). Similarly at 15 DAS, the lowest percentage of infested flower was seen at Bb + Abamectin sprayed plot (1.73%) followed by Bt + Abamectin (4.29%). The highest percentage of infested flower was observed from control (43.39%).

Table 5 - Effect of IPM modules on the infestation of flower at different days after 2nd spray

Treatments	5 DAS			10 DAS			15 DAS		
	No. of healthy flower plot^{-1}	No. of infested flower plot^{-1}	%infestation	No. of healthy flower plot^{-1}	No. of infested flower plot^{-1}	%infestation	No. of healthy flower plot^{-1}	No. of infested flower plot^{-1}	%infestation
T1	62.66c	4.67f	6.93	67.00b	3.67e	5.19	69.00b	4.33cd	5.90
T2	53.00e	6.00e	10.17	56.00d	5.00d	8.19	58.00e	4.00d	6.45
T3	64.67b	3.67g	5.37	67.67b	2.67e	3.79	67.00c	3.00d	4.29
T4	57.67e	9.00c	13.49	60.33c	8.00b	11.71	60.67d	7.00b	10.34
T5	48.00f	7.67d	13.78	49.67e	6.67c	11.83	52.00f	5.67bc	9.83
T6	70.00a	1.67h	2.33	72.00a	1.33f	1.81	75.33a	1.33e	1.73
T7	43.00g	10.00b	18.87	45.00f	7.33bc	14.00	47.00g	7.00b	12.96
T8	38.00h	19.67a	34.12	34.67g	22.00a	38.82	30.00h	23.00a	43.39
Level of significance	*	**	-	**	**	-	**	*	-
CV%	6.91	6.64	-	6.75	9.80	-	8.24	12.47	-

T1 = Bt + Spinosad, T2= Bb + Lufenuron, T3 = Bt + Abamectin, T4 = Bt + Neem oil, T5 = Bt + Lufenuron, T6 = Bb+ Abamectin, T7= Bt + Buprofezin and T8= untreated control; In column, means followed by different letters are significantly different; * & ** Mean significant at 5% & 1% level of probability, respectively

After 3rd spray, the lowest percentage of infested flower was noticed at Bb + Abamectin sprayed plot (1.29%) followed by Bt + Abamectin

(3.03%) at 5 DAS. The highest percentage of infested flower was observed from control (45.12%) (Table 6). At 10 DAS, the lowest percentage of infested flower was seen at Bb + Abamectin sprayed plot (0.91%) followed by Bt + Abamectin (2.17%).

Table 6 - Effect of IPM modules on the infestation of flower at different days after 3rd spray

Treatments	5 DAS			10 DAS			15 DAS		
	No. of healthy flower plot^{-1}	No. of infested flower plot^{-1}	%infestation	No. of healthy flower plot^{-1}	No. of infested flower plot^{-1}	%infestation	No. of healthy flower plot^{-1}	No. of infested flower plot^{-1}	%infestation
T1	67.00b	3.00cd	4.29	60.00b	1.33c	2.17	58.00b	2.00c	3.33
T2	55.00e	4.33bc	7.29	50.00d	3.00b	5.66	47.00e	2.67bc	5.38
T3	64.00c	2.00de	3.03	60.00b	1.33c	2.17	54.67c	0.67de	1.21
T4	57.00d	4.67b	7.57	52.00c	3.67b	6.59	50.00d	3.33b	6.24
T5	48.00f	4.0bc	7.69	45.00e	3.00b	6.25	42.67f	2.67bc	5.88
T6	76.33 a	1.00e	1.29	73.00a	0.67c	0.91	70.00a	0.33e	0.47
T7	44.67g	5.00b	10.07	39.67f	3.00b	7.03	37.00g	1.67cd	4.32
T8	30.00h	24.67a	45.13	25.00g	20.00a	44.44	22.67h	17.00a	42.85
Level of significance	**	**	-	**	*	-	**	*	-
CV%	10.0	8.83	-	7.83	6.45	-	8.67	9.52	-

T1 = Bt + Spinosad, T2= Bb + Lufenuron, T3 = Bt + Abamectin, T4 = Bt + Neem oil, T5 = Bt + Lufenuron, T6 = Bb+ Abamectin, T7= Bt + Buprofezin and T8= untreated control; In column, means followed by different letters are significantly different; * & ** Mean significant at 5% & 1% level of probability, respectively

The highest percentage of infested flower was observed from control (44.44%) (Table 6). Similarly, at 15 DAS, the lowest percentage of infested flower was seen at Bb + Abamectin sprayed plot (.47%) followed by Bt + Abamectin (1.21%). The highest percentage of infested flower was observed from control (42.85%) (Table 6).

The highest percentage reduction of infested flower over control was observed from the plots treated with Bb + Abamectin (83.6%) in first spray. However Bt + Buprofezin (33.8%) provided the least percentage reduction of infested flower over control (Fig. 2). The efficacy rank of the IPM modules on (%) reduction of infested flower over control was as follows- Bb + Abamectin Bt + Abamectin >Bt + Spinosad > Bt + Neem oil> Bb + Lufenuron> Bt + Lufenuron > Bt + Buprofezin. After second spray, the highest percentage reduction of infested flower over control

was observed from the plots treated with Bb + Abamectin (96.01%). However, Bt + Buprofezin (70.13%) provided the least percentage reduction of infested flower over control (Fig. 2). The efficacy rank of the IPM modules on (%) reduction of infested flower over control was as follows- Bb + Abamectin > Bt + Abamectin > Bt + Spinosad > Bb + Lufenuron > Bt + Lufenuron > Bt + Neem oil > Bt + Buprofezin.

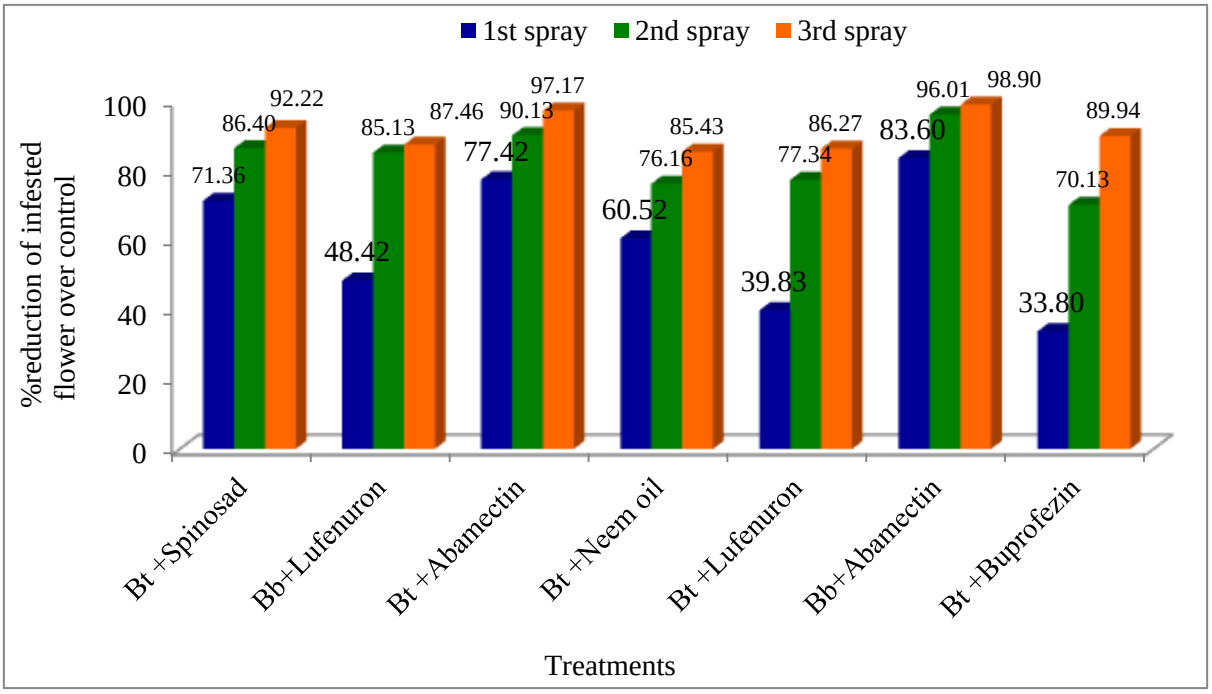

Figure 2 - Effect of IPM modules on the reduction (%) of infested flower over control at 1st, 2nd, and 3rd sprays

The highest percentage reduction of infested flower over control was observed from the plots treated with Bb + Abamectin (98.9%). However Bt + Neem oil (85.43%) provided the least percentage reduction of infested flower over control (Fig. 2). The efficacy rank of the IPM modules on (%) reduction of infested flower over control was as follows- Bb + Abamectin > Bt + Abamectin > Bt + Spinosad > Bb + Lufenuron > Bt + Lufenuron > Bt + Neem oil > Bt + Buprofezin.

Effect of IPM modules on the infestation of pod caused by *A. craccivora*

In case of 1st spray, at 5 DAS, the lowest percentage of infested pod was seen at Bb + Abamectin sprayed plot (7.89%) followed by Bt + Abamectin (11.76%). The highest percentage of infested pod was observed from control (24.53%) (Table 7). At 10 DAS, the lowest percentage of infested pod was seen at Bb + Abamectin sprayed plot

(6.49%) followed by Bt + Abamectin (10.14%). The highest percentage of infested pod was observed from control (24.07%) (Table 7). Similarly, at 15 DAS the lowest percentage of infested pod was seen at Bb + Abamectin sprayed plot (5.13%) followed by Bt + Abamectin (8.57%). The highest percentage of infested pod was observed from control (27.08%)

Table 7 - Effect of IPM modules on the infestation of pod at different days after 1st spray

Treatments	5 DAS			10 DAS			15 DAS		
	No. of healthy pod plot^{-1}	No. of infested pod plot^{-1}	%infestation	No. of healthy pod plot^{-1}	No. of infested pod plot^{-1}	%infestation	No. of healthy pod plot^{-1}	No. of infested pod plot^{-1}	%infestation
T1	56.00c	9.00e	13.85	56.00c	9.00e	13.85	56.00c	9.00e	13.85
T2	50.00e	10.00d	16.67	50.00e	10.00d	16.67	50.00e	10.00d	16.67
T3	60.00b	8.00f	11.76	60.00b	8.00f	11.76	60.00b	8.00f	11.76
T4	52.00d	10.00d	16.13	52.00d	10.00d	16.13	52.00d	10.00d	16.13
T5	48.00f	11.00c	18.64	48.00f	11.00c	18.64	48.00f	11.00c	18.64
T6	70.00a	6.00g	7.89	70.00a	6.00g	7.89	70.00a	6.00g	7.89
T7	45.00g	12.00b	21.05	45.00g	12.00b	21.05	45.00g	12.00b	21.05
T8	40.00h	13.00a	24.53	40.00h	13.00a	24.53	40.00h	13.00a	24.53
Level of significance	**	**	-	**	**	-	**	**	-
CV%	6.98	4.68	-	6.98	4.68	-	6.98	4.68	-

T1 = Bt + Spinosad, T2= Bb + Lufenuron, T3 = Bt + Abamectin, T4 = Bt + Neem oil, T5 = Bt + Lufenuron, T6 = Bb+ Abamectin, T7= Bt + Buprofezin and T8= untreated control; In column, means followed by different letters are significantly different. * & ** Mean significant at 5% & 1% level of probability, respectively

After 2nd spray, at 5DAS, the lowest percentage of infested pod was seen at Bb + Abamectin sprayed plot (2.56%) followed by Bt + Abamectin (5.72%). The highest percentage of infested pod was observed from control (29.62%) (Table8). At 10 DAS, after 2nd spray, the lowest percentage of infested pod was observed at Bb + Abamectin sprayed plot (2.42%) followed by Bb + Lufenuron (2.98%). The highest percentage of infested pod was noticed from control (40%) (Table 8). And again, the lowest percentage of infested pod was found from Bb + Abamectin sprayed plot (2.16%) followed by Bt + Spinosad (4.26%) at 15 DAS. The highest percentage of infested pod was observed from control (48%)

Table 8 - Effect of IPM modules on the infestation of pod at different days after 2nd spray

Treatments	5 DAS			10 DAS			15 DAS		
	No. of healthy pod plot^{-1}	No. of infested pod plot^{-1}	%infestation	No. of healthy pod plot^{-1}	No. of infested pod plot^{-1}	%infestation	No. of healthy pod plot^{-1}	No. of infested pod plot^{-1}	%infestation
T1	39.67c	2.67de	6.31	43.00d	2.67cde	5.85	45.00 c	2.00de	4.26
T2	35.00e	3.67cd	9.49	97.67a	3.00cd	2.98	40.67e	3.00cd	6.87
T3	44.00b	2.67de	5.72	48.33c	2.00de	3.97	50.67b	2.33de	4.39
T4	37.67d	4.00cd	9.60	40.00e	3.33cd	7.69	43.00d	2.67d	5.85
T5	27.33f	5.00bc	15.47	31.67f	4.00bc	11.21	35.00f	4.00bc	10.25
T6	50.67a	1.33e	2.56	53.67b	1.33e	2.42	60.00a	1.33e	2.16
T7	25.00g	6.00b	19.35	28.00g	5.33b	15.99	30.67g	4.67b	13.21
T8	19.00h	8.00a	29.62	15.00h	10.00a	40	13.00 h	12.00a	48
Level of significance	**	*	-	**	*	-	*	*	-
CV%	9.31	8.51	-	9.20	9.49	-	8.75	6.91	-

T1 = Bt + Spinosad, T2= Bb + Lufenuron, T3 = Bt + Abamectin, T4 = Bt + Neem oil, T5 = Bt + Lufenuron, T6 = Bb+ Abamectin, T7= Bt + Buprofezin and T8= untreated control; In column, means followed by different letters are significantly different. * & ** Mean significant at 5% & 1% level of probability, respectively.

Table 9 - Effect of IPM modules on the infestation of pod at different days after 3rd spray

Treatments	5 DAS			10 DAS			15 DAS		
	No. of healthy pod plot^{-1}	No. of infested pod plot^{-1}	%infestation	No. of healthy pod plot^{-1}	No. of infested pod plot^{-1}	%infestation	No. of healthy pod plot^{-1}	No. of infested pod plot^{-1}	%infestation
T1	35.0 c	1.33 bc	3.66	30.00 c	1.33 cd	4.25	28.00c	.33cde	4.53
T2	31.33d	2.33b	6.92	28.00 d	1.67bcd	5.63	24.67d	0.67de	2.64
T3	40.0 b	1.33bc	3.22	38.00 b	1.33cd	3.38	35.00b	0.67de	1.88
T4	35.0 c	0.67c	1.88	30.00c	1.33cd	4.25	27.67c	.67bcd	5.69
T5	29.0 e	1.67bc	5.45	28.00d	2.00bc	6.67	25.0d	2.33bc	8.53
T6	51.0 a	0.67c	1.29	44.67 a	0.33d	0.74	42.0a	0.33e	0.78
T7	21.0 f	2.33b	9.99	18.00e	3.00b	14.29	15.0e	2.67b	15.11
T8	8.0 g	9.67a	54.73	5.00f	11.00a	68.75	3.0f	10.0a	76.92
Level of significance	*	*	-	**	*	-	*	*	-
CV%	7.63	6.90	-	7.70	12.85	-	10.05	6.81	-

T1 = Bt + Spinosad, T2= Bb + Lufenuron, T3 = Bt + Abamectin, T4 = Bt + Neem oil, T5 = Bt + Lufenuron, T6 = Bb+ Abamectin, T7= Bt + Buprofezin and T8= untreated control; In column, means followed by different letters are significantly different. * & ** Mean significant at 5% & 1% level of probability, respectively

After 3rd spray, the lowest percentage of infested pod was recorded at Bb + Abamectin sprayed plot (1.29%) followed by Bt + Neem oil (1.88%) at 5 DAS. The highest percentage of infested pod was observed from control (54.73%) (Table 9). At 10 DAS, the lowest percentage of infested pod was seen at BB + Abamectin sprayed plot (0.74%) followed by Bt + Abamectin (3.38%) but the highest percentage of infested pod was observed from control (68.75%) (Table 9). Similarly at 15 DAS, the lowest percentage of infested pod was seen at Bb + Abamectin sprayed plot (0.78%) followed by Bt +Abamectin (1.88%). The highest percentage of infested pod was observed from control (76.92%).

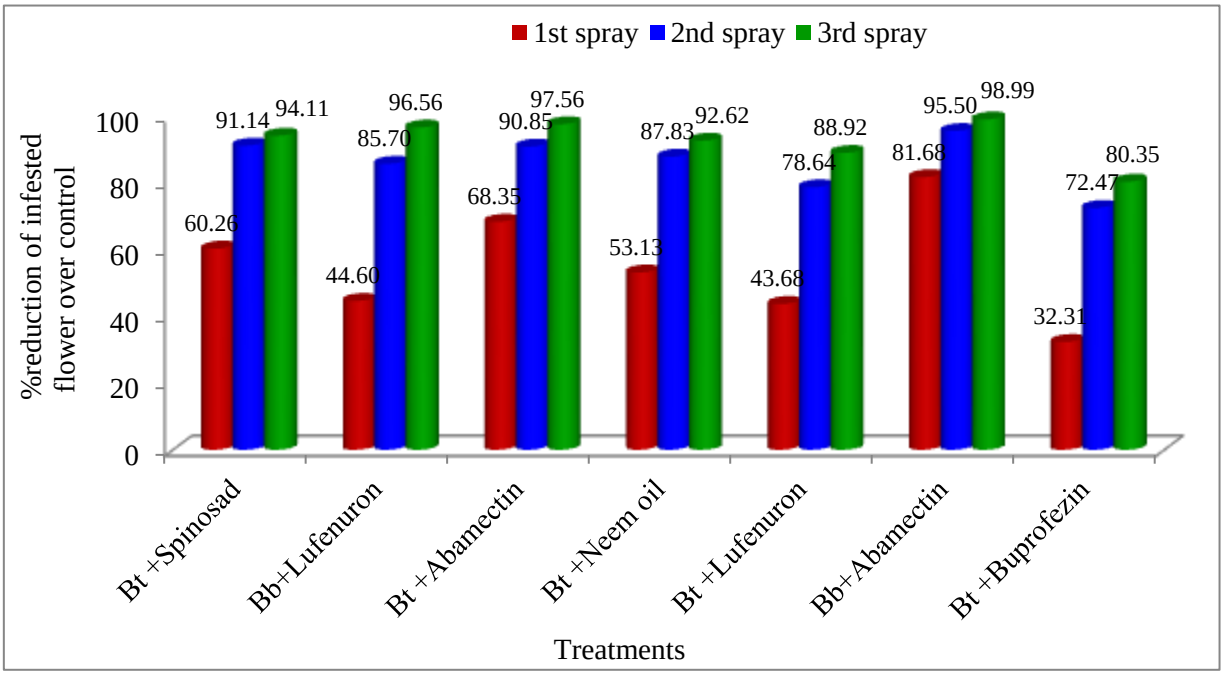

Figure 3 - Effect of IPM modules on the reduction (%) of infested pod over control at 1st, 2nd, and 3rd sprays

The highest percentage reduction of infested pod over control was observed from the plots treated with Bb + Abamectin (81.68%) in first spray. However Bt + Buprofezin (32.31%) provided the least percentage reduction of infested pod infested by bean aphid (Fig. 3). The efficacy rank of the IPM modules on (%) reduction of infested flower over control was as follows- Bb + Abamectin > Bt + Abamectin > Bt + Spinosad > Bt + Neem oil > Bb + Lufenuron > Bt + Lufenuron > Bt + Buprofezin. The highest percentage reduction of infested pod over control was observed from the plots treated with Bb + Abamectin (95.5%). However Bt + Buprofezin (72.47%) provided the least percentage reduction of infested pod infested by bean aphid (Fig. 3).

The efficacy rank of the IPM modules based on (%) reduction of infested flower over control was as follows-Bb + Abamectin > Bt + Spinosad > Bt + Abamectin> Bt + Neem oil > Bb + Lufenuron > Bt + Lufenuron > Bt + Buprofezin. The highest percentage reduction of infested pod over control was observed from the plots treated with Bb + Abamectin (98.99%). However Bt + Buprofezin (80.35%) provided the least percentage reduction of infested pod affected by bean aphid (Fig. 3).The efficacy rank of the IPM modules on (%) reduction of infested flower over control was as follows- Bb + Abamectin > Bt + Abamectin > Bb + Lufenuron > Bt + Spinosad > Bt + Neem oil > Bt + Lufenuron > Bt + Buprofezin.

Effect of IPM modules on the yield (ton ha-1) of marketable pod

Table 10 - Effect of IPM modules on the yield (ton ha-1) of marketable pod

Treatments	**Yield (ton ha^{-1})**	**Yield increase (%)**
T_1	7.63c	55.18
T_2	6.31e	45.80
T_3	9.43b	63.73
T_4	6.45d	46.98
T_5	5.39f	36.55
T_6	12.46a	72.55
T_7	4.65g	26.45
T_8	3.42h	-
Level of Significance	*	-
CV (%)	6.78	-
LSD	1.13	-

T1 = Bt + Spinosad, T2= Bb + Lufenuron, T3 = Bt + Abamectin, T4 = Bt + Neem oil, T5 = Bt + Lufenuron, T6 = Bb+ Abamectin, T7= Bt + Buprofezin and T8= untreated control; In column, means followed by different letters are significantly different. * Means significant at 5% level of probability.

The results revealed that all IPM modules could increase marketable pod yield (ton ha-1) of country bean significantly as compared to control. Statistically significant variation was observed in respect of yield at different modules in the present study. Bb +Abamectin showed the highest (12.46 ton ha-1) yield which was significantly different from other treatments used in the experiment whereas the lowest yield was recorded from untreated control plots (3.42 ton ha-1). The IPM module comprising Bt + Abamectin also showed a very good yield performance

among the modules tested.

Discussion

From the present study of developing microbial insecticide based IPM modules on the aphid infestation it was observed that aphid infestation changed significantly on the twig, flower, and pod at different sprays and time intervals. The highest percentage of reduction of infestation over control was found in Bb + Abamectin treated plants which was followed by Bt + Abamectin . Similarly, the highest yield and percentage yield increase of marketable pod were also found from the plots treated with Bb + Abamectin which was also followed by Bt + Abamectin . Based on different parameters was clearly observed that *Beauveria bassiana* and Abamectin were very effective to manage the bean aphid in the field. Similar findings were reported by 11 where they stated that Abamectin could control aphids about 98.90% after five days of spraying. Similarly, it was reported that Abmectin 1.8EC @ 0.5ml/l was highly effective against aphid and thrips on chilli in the field12. Besides, it has been explained that Abamectin showed the good performance against aphid infestation in the field13. It was stated that nano-formulated Abamectin had very good effect against the pea aphid. They also explained that these results are expected to contribute to the application of solvent-free nano-formulated pesticides that comply with the integrated pest management (IPM) strategies14. Abamectin was found very effective to reduce the aphid (Aphis gossypii) infestation on tomato in the field and subsequently to increase the yield of tomato 15. These above reports are more or less in the line with the findings of the present research which support the toxic effect of Abamectin for managing aphid and increase of marketable pod yield of the country bean. In another report it has been stated that *Beauveria bassiana* @ 3.33 ml/l was very effective on the mortality of mustard aphid both in leaf dip and spray methods in the laboratory16. This finding supports the results of the present research where *Beauveria bassiana* was also very effective in IPM module to manage the aphid infestation and subsequently the yield of marketable pod of country bean.

Conclusion

All the biorational insecticides based IPM modules tested were significantly effective against the aphid infesting country bean. But the module comprising Bb + Abamectin showed the best performance based on the efficacy against the aphid infestation as well as yield of marketable pod. Therefore, this module might be recommended for the management of bean aphid by the farmers after regional trial throughout the country.

Acknowledgments

The authors would like to thanks to the Ministry of Education, Government of the People's Republic of Bangladesh for providing the fund to conduct this nice research work under a project.

References

1. Schaffhausen, RV. *Dolichos lablab* or Hyacinth bean-its use for feed, food and soil improvements. Econ Botany**.** 1963 17**:** 146-153.
2. BBS. Statistical Year book of Bangladesh, Bangladesh Bureau of Statistics, Government of the People's Republic of Bangladesh, Dhaka, 2017.
3. Alam MZ, Ahmed A, Alam S, Islam MA. A review of Research Division of Entomology (1947-1964). Agriculture Information Service, 3, R. K. Mission Road, Dhaka-3,1964 76p.
4. Minks AK, Harrewijn P. Aphid pathogens. In: Minks AK. Harrewijn P (eds) Aphids their biology, natural enemies and control.Vol.2B. Elsevier. Amsterdam, Netherlands. 1988 pp 5-7.
5. Dixon AFG. Parthenogenetic reproduction and rate of increase in aphid. 1987 pp. 269-287.
6. Singh SR, Allen DJ. Pests, diseases, resistance and protection of *Vigna unguiculata* (L.) Walp. Advances in legumes science. R. J. Summerfield and H. A. Bunting. (eds.) London: Royal Botanical Gardens, and Ministry of Agriculture, Fisheries and Food. 1980 419-443
7. Attle AA, El- heneidy AH, Elkady EA. Studies on the aphid, *Aphis craccivora* in Egypt. *Bull.* De-la-Societe Entomologique-d'Egypte, 1987 66: 319-324.

8. Islam MS. Genetic diversity, combining ability and heterosis in Hyacinth bean [(*Lablab purpureus* (L) Sweet]. A PhD dissertation submitted to Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur. Bangladesh, 2008 190 p.

9. Sharma HC, Singh M, Residual toxicity of insecticides on cabbage caterpillar (*Pieris brasicae*) and their dissipation on cauliflower. Indian J Agric Sci. 1993 63(1): 59-63.

10. Rahman MM, Sampa MSA. Combined effects of Bradyrihizobial strain municipal solid waste compost and fertilizers on nodulation, N content and uptake of soybean. J Environ Sci Nat Res. 2012 5(2): 85-90.

11. Sun Y, Xue M, Zhang X, Zhao HP, Li ZX. Population dynamics and control techniques of aphids on honeysuckle. Zhongguo Zhong Yao Za Zhi. 2013 8(21): 3676-80.

12. Sujay YH, Giraddi1 RS, Udikeri SS. Efficacy of new molecules and botanicals against chilli (*Capsicum annuum* L.) pests. Madras Agric J. 2015 102 (10-12): 348-352.

13. Saad AS, Massoud MA, Abdel-Mgged AA, Mourad AK, et al. An approach for IPM programme to control sucking pests infesting garden bean plants (*Phaseolus vulgaris*) in Egypt. Commum Agric Appl Biol Sci. 2007 72(3): 565-581.

14. Sun C, Yu M, Zeng Z, Francis F, et al. Biocidal activity of polylactic acid-based nano-formulated Abamectin on *Acyrthosiphon pisum* (Hemiptera: Aphididae) and the aphid predator *Adalia bipunctata* (Coleoptera: Coccinellidae). PLoS ONE 2020 15(2): e0228817. https://doi.org/10.1371/journal.pone.0228817.

15. Wagh BM, Pagire KS, Thakare DP, Birangal AB. Management of sucking pests by using newer insecticides and their effect on natural enemies in tomato (*Lycopersicon esculentum* Mill.). Int J Curr Microbiol App Sci. 2017 6(4): 615-622.

16. Khanal D, Maharjan S, Lamichhane J, Neupane P, et al. Efficacy of biorational compounds against mustard aphid (*Lipaphis erysimi* Kalt.) and English grain aphid (*Sitobion avenae* Fab.) under laboratory conditions in Nepal. Adv Agric. 2020 pp1-7.