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Research Article

Using Some Promising Insecticides as A Management Tool Against The Major Sucking Pests of Country Bean

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Abstract

An experiment has been conducted to know the efficiency of some promising pyrethroids and bio-rational insecticides for controlling the major sucking pests of country beans under field conditions during the winter season September 2020 – March 2021. The different treatments were Cypermethrin 10 EC (T_1), Lambda-Cyhalothrin 2.5 EC (T_2), Emamectin benzoate 5 SG (T_3), Abamectin 1.8 EC (T_4), Spinosad 45 SC (T_5), and untreated control (T6). The rate of leaf infestation at the lower, middle, and top stages of country bean ranged from 8.82–17.78, 13.89–36.39, and 13.72–33.33% in T_5 treated and untreated control plots, respectively. The rate of shoot infestation at the middle and top stages of country bean ranged from 18.67–34.33 and 17.00–39.27% in T_5 treated and untreated control plots, individually. The lowest and highest inflorescence infestation of 29.15% and 46.67% was recorded in T_5 treated and untreated control plots, separately. The lowest fruit infestation of 8.84% by number and 8.32% by weight was recorded in the treated plot T_5. The rate of reduction of pod infestation over control was 48.58, 24.02, 23.39, 21.81, and 19.92% by number and 73.53, 61.76, 58.82, 52.94, and 41.18% by weight in the treated plot T_5, T_4, T_1, T_3, and T_2, respectively. The yield in different treatments ranged from 1.35-2.50 t ha^{-1}. The highest adjusted net return and BCR of Tk. 52220.00 and 2.42, respectively were obtained from T_2 treated plots. The second highest BCR of 2.16 was calculated from T_4 treated plot. The lowest BCR of 1.05 was found in T_2 treated plot. The treatments T_5, T_4, and T_3 were effective to suppress the major sucking pests of the country bean.

Keywords: Country bean (*Lablab purpureus*), sucking pests, BCR, pyrethroids, and bio-rational insecticides

1. INTRODUCTION

The country bean (*Lablab purpureus* Lin.) is one of the most popular vegetable-cum-pulse crops in Bangladesh and belongs to the family Leguminosae and sub-family Papilionaceae [1]. The bean is commonly known as "seam" in Bangladesh [2]. It is the most important leguminous crop and it has important value for its atmospheric nitrogen fixation [3]. The fresh pods and green seeds are eaten after boiling or used in curries. Mature seeds are occasionally sun-dried and stored for use as vegetables. This bean is also grown for fodder and as a cover crop [4]-[6]. In Bangladesh, the bean is usually grown in winter, but in recent times, several photo-insensitive and summer varieties are developed, which helped to promote the cultivation of country beans year-round including in summer [7]-[9]. Bangladesh's country bean, *Lablab purpureus* (L.), is a widely produced vegetable and it contains high in protein (20-30% protein by dry weight). Thiamin, riboflavin, niacin, vitamin C, and iron (0.1, 0.06, 0.7, 9.0, and 41.7 mg/100g, respectively) are all present in significant amounts [10]. The entire land area under bean cultivation in Bangladesh is 49,192 acres; with a yield of 122,091 metric tons in 2014-2015 [11].

The high incidence of insect pests deteriorates the yield and quality of the pod of country beans. A report revealed that eighteen species of insect cause an infestation in the country bean field [6][12][13]. The various types of sucking pests include Aphid (*Aphis craccivora*), Jassid (*Amrasca devastas*), bean bug (*Coptosoma cribrarium*), Whitefly (*Bemisia argentifolii*), and thrips (*Sericothrips occipitalis*) are commonly found in a country bean field. Aphid and Jassid are the major sucking pests of country bean that causes damage directly by sucking the cell sap of the plant and indirectly by transmitting several viral diseases [14][15]. Both the nymph and adult phases of the sucking pests of country bean cause injury by sucking sap from flowers, buds, pods, and tender shoots of the plants and reduce the vitality of the bean and leguminous crops [2].

Effective controlling practices to manage these menacing sucking pests are much more difficult because they introduce their toxic saliva while they suck the plant sap as well, they act as a vector to

Table 1. Treatments, and components of this study.

Treatments of pyrethroids and rational pesticides for 10 days interval	Dose of water (mL/L)
T_1: Cypermethrin 10 EC	2.0
T_2: Lambda-Cyhalothrin 2.5 EC	3.0
T_3: Emamectin Benzoate 5 SG	1.0
T_4: Abamectin 1.8 EC	1.2
T_5: Spinosad 45 SC	0.4
T_6: Untreated Control	0

disseminate the plant disease and create secondary infection of the plants. Farmers of Bangladesh, particularly rely only on some common chemical insecticides to control the insect pest population. The frequent, over and misuse of this chemical insecticide has created a lot of detrimental effects on our environment like; pest resistance, resurgence, increase in the mortality rate of beneficial insects as the natural enemies, and finally enhanced environmental pollution. To avoid complete dependence on chemical pesticides, alternative tools are needed. There are many effective botanicals and bio-rational components available in the country which may be exploited side by side with the chemical components. Singh [16] described that foliar application of Lambda-Cyhalothrin at flowering and fruit initiation stages was the most effective against the different sucking insects. Cypermethrin, a synthetic pyrethroid is popularly used for its quick knockdown action with the quality of non-phytotoxic and almost non-toxic effect on mammals [17]-[19]. However, excessive and blind use of synthetic pesticides has created many problems for the environment.

Bio-based pesticides are effective in reducing the use of common chemical pesticides and controlling pests in a safe and eco-friendly manner. They have minimal effect on non-target organisms and similarly, the potential human health effects are not known so far. There is little study on synthetic pyrethroids and rational insecticides for bean-sucking pests in Bangladesh. With this in mind, the current research was conducted to determine the level of bean-sucking pest damage and its control with several pyrethroids and bio-rational pesticides.

2. MATERIALS AND METHODS

2.1. Experimental Site and Design

The experiment was performed in an open field of Entomology, at Sylhet Agricultural University, Sylhet, Bangladesh. The land belongs to the Khadimnagar soil series Eastern Surma-Kushiara Floodplain under the Agroecological Zones-20. The experiment is laid out in a randomized complete block design (RCBD) with three replications in the

Table 2. Effect of different treatments applied against the major sucking pests of country bean in terms of percent (%) of leaves infestation grown during the winter season.

Treatments	Percent (%) of leaves infestation			
	Lower leaves infestation	Middle leaves infestation	Top leaves infestation	Total leaves infestation
Cypermethrin 10 EC	12.80^{b}	18.12^{bc}	20.40^{bc}	19.28^{b}
Lambda-Cyhalothrin 2.5 EC	15.38^{ab}	20.55^{b}	25.30^{ab}	21.92^{b}
Emamectin benzoate 5 SG	9.34^{c}	17.54^{c}	19.07^{bc}	18.63^{b}
Abamectin 1.8 EC	8.80^{c}	16.33^{cd}	19.10^{bc}	17.63^{b}
Spinosad 45 SC	8.82^{c}	13.89^{d}	13.72^{c}	11.67^{c}
Control	17.78^{a}	36.39^{a}	33.33^{a}	28.80^{a}
CV (%)	7.34	18.51	14.46	19.56

Note: *Means within the same letter (s) within a column do not differ significantly (P=0.05) according to DMRT.*

Table 3. Effect of different treatments applied against the major sucking pests of country bean in terms of percent (%) of shoot infestation grown during the winter season.

Treatments	Percent (%) of shoot infestation		
	Middle shoot infestation	Top shoot infestation	Total shoot infestation
Cypermethrin 10 EC	24.35^{bc}	25.33^{bc}	24.50^{bc}
Lambda-Cyhalothrin 2.5 EC	33.11^{ab}	29.00^{b}	30.83^{ab}
Emamectin benzoate 5 SG	24.10^{bc}	21.96^{bc}	23.33^{bc}
Abamectin 1.8 EC	22.45^{c}	21.67^{bc}	23.67^{bc}
Spinosad 45 SC	18.67^{c}	17.00^{c}	20.50^{c}
Control	34.33^{a}	39.27^{a}	38.16^{a}
CV (%)	19.43	19.57	3.27

Note: *Means within the same letter (s) within a column do not differ significantly (P=0.05) according to DMRT.*

winter season September 2020 – March 2021.

2.2. Planting material

Seeds of cultivated local variety of Goalgadda were used in the experiment during the period from the winter season in September 2020 – March 2021.

2.3. Land preparation

The land was prepared by spade and stubble, and weeds were removed. Experimental land was divided into unit plots following the design of the experiment. During final land preparation, 10 t ha^{-1} decomposed cow dung was mixed with soil. In each plot measuring 3.0 m × 2.0 m, 4 pits were prepared for seedling transplantation.

2.4. Manures and fertilizers application

Recommended doses of fertilizer comprising Urea, TSP, and MoP at the rate of 30, 90, and 65 kg ha^{-1}, respectively, were applied. The entire dose of TSP and half the amount of MoP were applied to the soil of the pit 4-5 days before the seedling transplanting. The rest amount of the Urea and MoP were top-dressed at 30 and 45 days after transplanting.

2.5. Seedling raising and transplantation

A small seed bed measuring 2 × 1 m was prepared and seeds were sown in the nursery bed at Entomology field, SAU, Sylhet on 13, September 2020. The plots were lightly irrigated regularly to ensure proper germination and growth of the

Table 4. Effect of different treatments applied against the major sucking pests of country bean in terms of the number of inflorescences plot^{-1} grown during the winter season.

Treatments	Number of inflorescence infestation plot^{-1}		
	Number of healthy inflorescences	Number of infested inflorescences	% Infestation
Cypermethrin 10 EC	6.07^{bc}	3.85^{abc}	36.54^{bc}
Lambda-Cyhalothrin 2.5 EC	6.10^{bc}	4.02^{ab}	39.43^{ab}
Emamectin benzoate 5 SG	6.03^{bc}	3.34^{bcd}	34.53^{bc}
Abamectin 1.8 EC	6.23^{ab}	3.06^{cd}	33.51^{bc}
Spinosad 45 SC	6.47^{a}	2.94^{d}	29.15^{c}
Control	5.86^{c}	4.19^{a}	46.67^{a}
CV (%)	12.71	13.99	7.03

Note: *Means within the same letter (s) within a column do not differ significantly (P=0.05) according to DMRT.*

Table 5. Effect of different treatments applied against the major sucking pests of country bean in terms of the number of pods/fruits plot^{-1} grown during the winter season.

Treatments	Number of pods plot^{-1}			
	Number of healthy pods	Number of in-fested pods	Total Number of pods	% Infestation
Cypermethrin 10 EC	62.07^{cd}	9.73^{ab}	71.80^{ab}	13.66^{bc}
Lambda-Cyhalothrin 2.5 EC	54.70^{de}	10.17^{ab}	64.87^{bc}	19.54^{ab}
Emamectin benzoate 5 SG	68.53^{ab}	9.93^{ab}	78.46^{a}	12.74^{bc}
Abamectin 1.8 EC	63.97^{bc}	9.65^{ab}	73.62^{a}	12.62^{bc}
Spinosad 45 SC	72.87^{a}	6.53^{b}	79.40^{a}	8.84^{c}
Control	49.97^{e}	12.70^{a}	62.67^{c}	21.59^{a}
CV (%)	12.11	6.59	16.18	17.30

Note: *Means within the same letter (s) within a column do not differ significantly (P=0.05) according to DMRT.*

seedlings. Fifteen days old seedlings were transplanted into the well-prepared experimental plots. A total of 3 seedlings were planted in 1 pit @ 12 seedlings plot^{-1}.

2.6. Intercultural operations

After transplanting the plants were initially irrigated by water cane and later on regular irrigation was maintained. After one week of transplanting, the propping of each plant with bamboo sticks (1.50 m) was provided about 1.50 m high from ground level for additional support to allow normal creeping. All the bamboo sticks in each row were fastened strongly by a galvanized wire to allow the vines to creep along. Weeding and mulching in the plots were done, whenever necessary.

2.7. Treatments, concentration, and application time of the pyrethroids and rational pesticides

All treatments were applied 5 times at 10 days intervals starting from the first appearance of the infestation. All spray materials were applied on the upper and lower surfaces of the leaves and shoots to ensure complete coverage of the plants. The spray was always done in the afternoon to avoid scorching sun, and insecticidal drift, and to protect pollinating wild bees and other beneficial insects. Plants under the control plot were sprayed with clean tap water in the same manner. During the application of insecticides, precautions were taken to avoid drift to adjacent plots by using polythene sheets between plots (Table 1).

2.8. Data collection

The effect of different treatments in controlling bean-sucking pests and infestation was determined based on the infestation of leaves, shoots, inflorescences, and pods of country beans and yield per hectare.

2.8.1. Leaf, shoot, and inflorescence infestation

The total number of leaves, shoots, and inflorescences as well as the number of infested leaves, shoots, and inflorescences were recorded from each plot at weekly intervals. Leaf, shoot, and inflorescence infestation [20] was calculated in percent using the following formula 1:

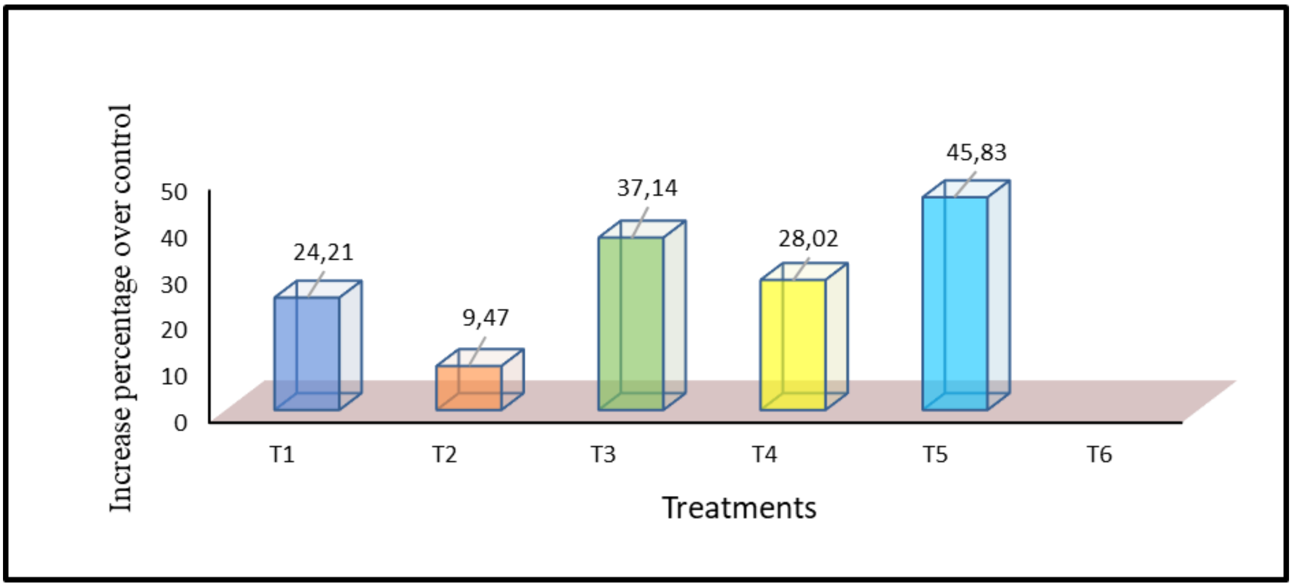
$$\%\ \text{leaf, shoot, and inflorescence} = \frac{\text{Number of infested leaves, shoots, and inflorescences}}{\text{Total number of leaves, shoots, and inflorescences}} \times 100\ \% \quad (1)$$

2.8.2. Pod infestation and yield per hectare

Fruits were harvested at 7-10 days intervals and the numbers of healthy and infested fruits and their weight were noted separately per plot per treatment. Harvests were done throughout the fruiting season and the percent pod/fruit infestation by number and weight was calculated [21] using the following formulas 2 and 3.

$$\%\ \text{Pod infestation number} = \frac{\text{Number of infested pods}}{\text{Total number of pods}} \times 100\ \% \quad (2)$$

$$\%\ \text{Pod infestation weight} = \frac{\text{Weight of infested pods}}{\text{Total weight of pods}} \times 100\ \% \quad (3)$$



Note: *T_1: Application of Cypermethrin 10 EC @ 2mL/L of water at 10 days interval; T_2: Application of Lambda-Cyhalothrin 2.5 EC @ 3mL/L of water at 10 days interval; T_3: Application of Emamectin Benzoate 5 SG @ 1 g/L of water at 10 days interval; T_4: Application of Abamectin 1.8 EC@ 1.2 mL/L of water at 10 days interval; T_5: Application of Spinosad 45 SC 0.4 mL/L of water at 10 days interval; and T_6: Untreated Control.*

Figure 1. Effect of different treatments applied against the major sucking pests of country bean in terms of % increase in the number of healthy pods plot^{-1} over control grown during the winter season

Percent increase or decrease over control was also computed using the following formula 4 and 5, respectively:

$$\%\ \text{Increase over control} = \frac{\text{No./Wt. of pod in treated plot} - \text{No/Wt. of pod in control plot}}{\text{No. or Wt. of pod in control plot}} \times 100\ \% \quad (4)$$

$$\%\ \text{Decrease over control} = \frac{\text{No./Wt. of pod in control plot} - \text{No/Wt. of pod in treated plot}}{\text{No. or Wt. of pod in control plot}} \times 100 \quad (5)$$

2.9. Economic analysis

Benefit-cost ratio (BCR) was analyzed by considering the total expenditure of growing the crop and the total return from that particular treatment. In this experiment, BCR was calculated for a hectare of land. Benefit-cost analysis was done through the following steps.

2.9.1. Treatment-wise cost of cultivation

This cost was calculated by adding all costs incurred for labor and inputs for each treatment including the control plot during the entire vegetative and fruiting period. The yield of each treatment was converted into tons per hectare.

2.9.2. Gross return and net return

The yield in terms of taka was calculated by multiplying the total yield by the unit price of the country bean at that time (Tk. 45 kg^{-1}). Net return was calculated by subtracting treatment-wise management cost from gross return.

2.9.3. Adjusted net return

The adjusted net return was determined by subtracting the net return of the control plot from the net return of a particular treatment [21].

$$\text{Adjusted net return} = \text{Net return of a particular treatment} - \text{Net return of control plot} \quad (6)$$

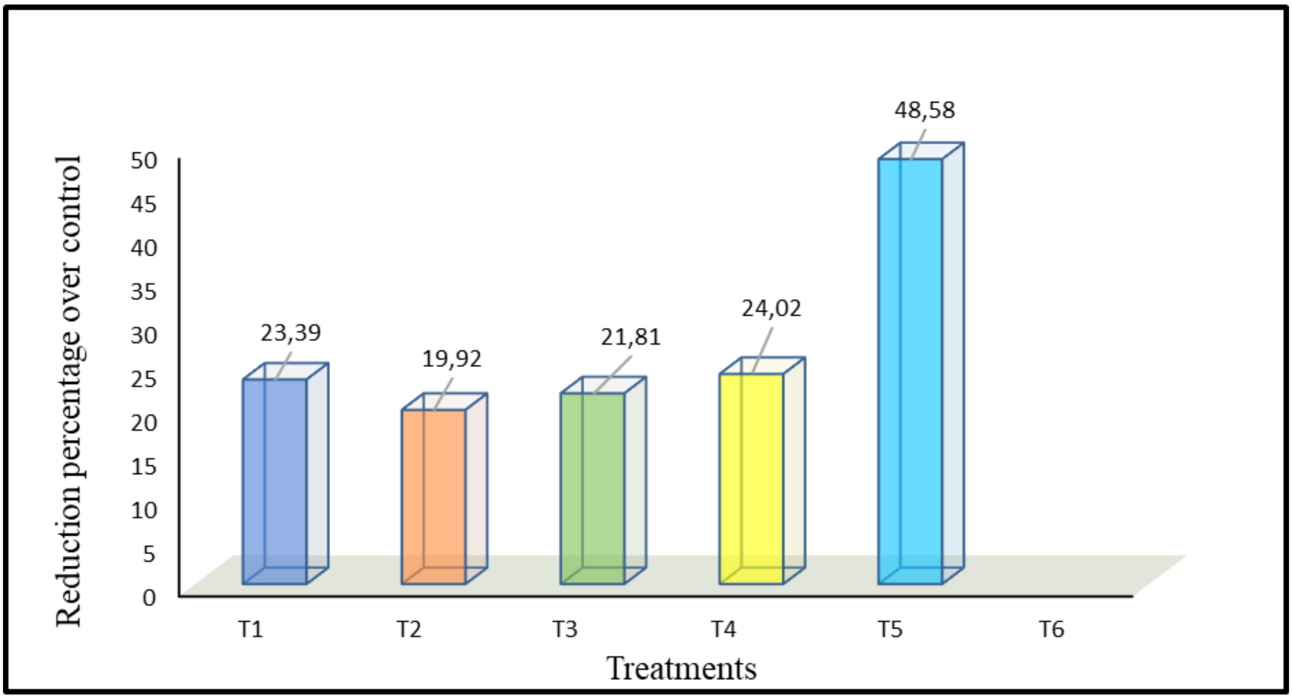
2.9.4. Benefit Cost Ratio Calculation

Finally, the Benefit Cost Ratio (BCR) [21] was calculated by dividing the adjusted net return by the respective total management cost for each treatment following the formula:

$$\text{Benefit cost ratio} = \frac{\text{Adjusted net return}}{\text{Total management cost}} \quad (7)$$

2.10. Data Analysis

All the data collected were double-checked, coded, and transferred from the preliminary note to a master sheet, summarized, categorized, and entered into a database with Microsoft Excel 2019. All the data collected and computed were analyzed statistically. Analysis of variance (ANOVA) was conducted for the parameters of leaf infestation (middle leaf infestation, top leaf infestation, total



Note: *T_1: Application of Cypermethrin 10 EC @ 2 mL/L of water at 10 days interval; T_2: Application of Lambda-Cyhalothrin 2.5 EC @ mL/L of water at 10 days interval; T_3: Application of Emamectin Benzoate 5 SG @ 1 g/L of water at 10 days interval; T_4: Application of Abamectin 1.8 EC@ 1.2 mL/L of water at 10 days interval; T_5: Application of Spinosad 45 SC 0.4 mL/L of water at 10 days interval; T_6: Untreated Control.*

Figure 2. Effect of different treatments applied against the major sucking pests of country bean in terms of % reduction of the number of infested pods plot^{-1} over control grown during the winter season**.**

leaf infestation, % leaf infestation,), shoot infestation (middle shoot infestation, top shoot infestation, total shoot infestation, % shoot infestation), inflorescence infestation (number of healthy inflorescences, number of infested inflorescences, % inflorescences infestation), pods infestation (number of healthy pods, number of infested pods, % pods infestation), pods weight (healthy pods weight, infested pods weight, weight of total pod, % pods weight), and country bean yield (marketable yield, infested yield, total yield) to identify the significant differences between the treatments using the R software 0.05% level. Then, DMRT (Duncan's multiple range tests) was performed for those parameters to compare the significant differences between the treatment means.

3. RESULTS AND DISCUSSIONS

3.1. Effect of different treatments on leaves infestation

The effects of various treatments on percent leaf infestation by sucking pests of the country bean are presented in Table 2. The rate of leaf infestation at the lower, middle, and top stages of country bean ranged from 8.82-17.78, 13.89-36.39, and 13.72-33.33% in Spinosad 45 SC treated and untreated control plots, respectively. All the treatments showed a significant effect on the percent leaf infestation, the total leaves infestation ranged from 11.67-28.80%, the highest leaf infestation was recorded in the untreated control (28.80%) plot and the lowest infestation was obtained with Spinosad 45 SC (11.67%) sprayed plot, respectively. The second highest leaf infestation was found in Lambda-Cyhalothrin 2.5 EC (21.92%) treated plot and this was followed by Cypermethrin 10 EC (19.28%), Emamectin benzoate 5 SG (18.63%), and Abamectin 1.8 EC (17.63%) and they were statistically identical. Similar results were also observed by Das et al. [22] and the major pests include aphids, sap-sucking bugs, pod borers, leaf miners, and stem flies which cause a yield loss of about 37-100% in natural conditions.

3.2. Effect of different treatments on shoot infestation

Table 6. Effect of different treatments applied against the major sucking pests of country bean in terms of pods/fruits weight plot^{-1} during the winter season

Treatments	Pods/Fruits weight (kg) plot^{-1}			
	Healthy pods weight	Infested pods weight	Weight of total pod	%
Cypermethrin 10 EC	1.25^{ab}	0.16^{bc}	1.41^{ab}	15.29^{abc}
Lambda-Cyhalothrin 2.5 EC	1.27^{ab}	0.20^{b}	1.47^{ab}	23.11^{ab}
Emamectin benzoate 5 SG	1.24^{ab}	0.14^{bc}	1.38^{ab}	12.54^{bc}
Abamectin 1.8 EC	1.30^{ab}	0.13^{bc}	1.43^{ab}	11.79^{bc}
Spinosad 45 SC	1.34^{a}	0.09^{c}	1.53^{a}	8.32^{c}
Control	0.70^{b}	0.34^{a}	1.04^{c}	26.60^{a}
CV (%)	18.99	10.21	18.66	21.32

Note: *Means within the same letter (s) within a column do not differ significantly (P=0.05) according to DMRT.*

The effects of all treatments on percent shoot infestation by sucking pests of the country bean are presented in Table 3. The rate of shoot infestation at the middle and top stages of country bean ranged from 18.67-34.33 and 17.00-39.27% in Spinosad 45 SC treated and untreated control plots, individually. All the treatments exhibited a significant effect on the percent shoot infestation, the total shoot infestation ranged from 20.50-38.16%, the highest leaf infestation was recorded in the untreated control (38.16%) plot and the lowest infestation was obtained with Spinosad 45 SC (20.50%) treated plot, respectively. The second highest shoot infestation was found in Lambda-Cyhalothrin 2.5 EC (30.83%) treated plot and this was followed by Cypermethrin 10 EC (24.50%), Abamectin 1.8 EC (23.67%), and Emamectin benzoate 5 SG (23.33%) they were statistically identical but significantly different (Table 2). The current finding was fully supported by Sultana [23] who reported that 26.08% shoot/twig infestation was found in Spinosad 45 SC treated plot.

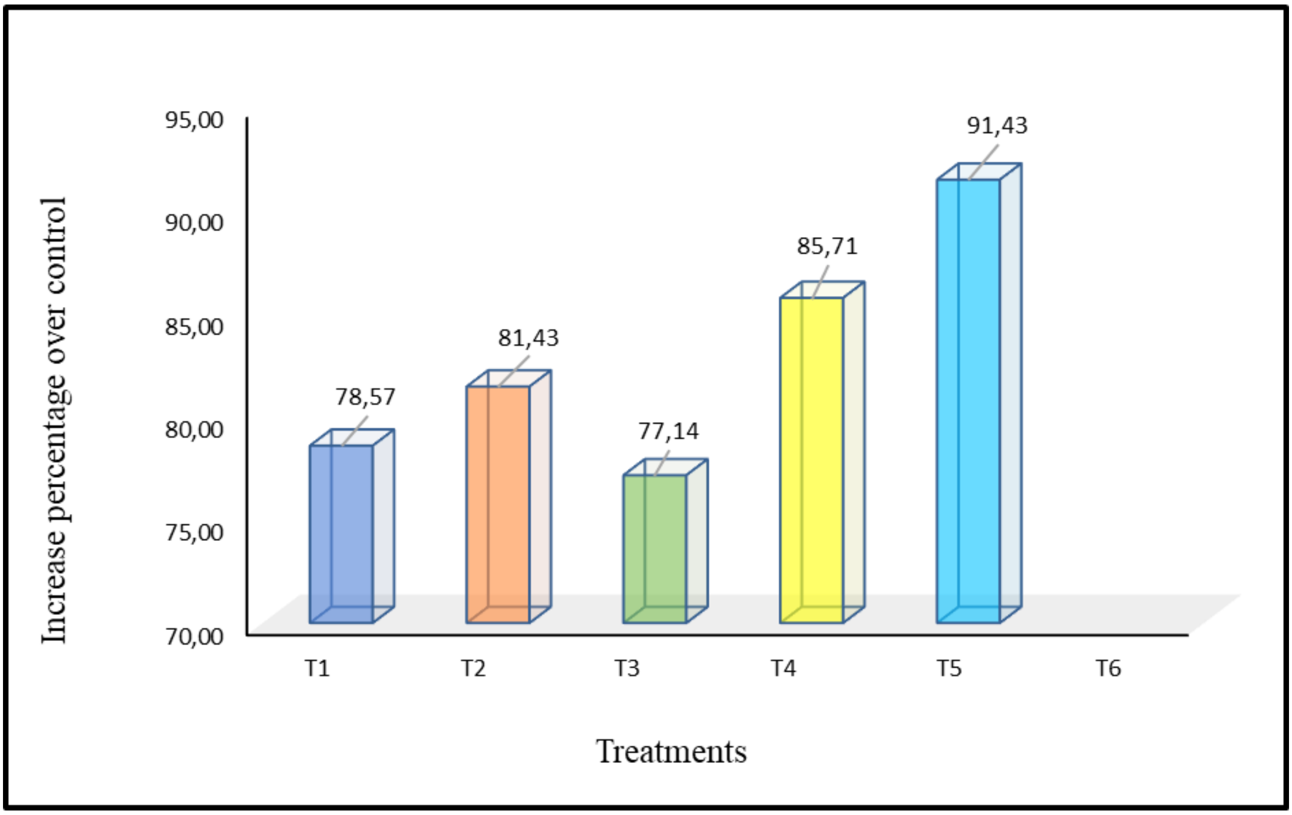
3.3. Effect of different treatments on inflorescence infestation

The comparative effectiveness of various treatments on inflorescence infestation was presented in Table 3. All the treatments revealed a significant effect on inflorescence infestation. The lowest and highest inflorescence infestation of 29.15 and 46.67% was recorded in Spinosad 45 SC treated and untreated control plots, separately. The second highest inflorescence infestation was found in Lambda-Cyhalothrin 2.5 EC (39.43%) treated plot and this was followed by Cypermethrin 10 EC (36.54%), Emamectin benzoate 5 SG (34.53%) and Abamectin 1.8 EC (33.51%) they were statistically at par but significantly different (Table 4). Paul et al. [24] reported that 27.57% inflorescence infestation was found in Cypermethrin 10 EC @ 2mL/L treated plot which was strongly supported by the current study. On the other hand, Sultana [23] reported that 34.28% inflorescence/flower infestation was found in the Spinosad 45 SC treated plot, and these results were almost similar to the current finding.

3.4. Effectiveness of different treatments on the pod infestation by number

The comparative effectiveness of various treatments on pod infestation by number due to sucking. pests of country beans have been evaluated in percent (%) and were presented in Table 4. The lowest percent pod infestation by number was recorded in Spinosad 45 SC (8.84 %) treated plot and it was significantly lower compared to all other treated treatments. The second lowest pod infestation by number was found in Abamectin 1.8 EC (12.62%) followed by Emamectin benzoate 5 SG (12.74%) and Cypermethrin 10 EC (13.66%) they were statistically at par but significantly different (Table 5).

Paul et al. [24] reported that 5.38-7.45% pod infestation by number was recorded in Cypermethrin 10 EC @ 2mL/L treated plot which was partially (13.66%) supported by the current



Note: *T_1: Application of Cypermethrin 10 EC @ 2 mL/L of water at 10 days interval; T_2: Application of Lambda-Cyhalothrin 2.5 EC @ 3 mL/L of water at 10 days interval; T_3: Application of Emamectin Benzoate 5 SG @ 1 g/L of water at 10 days interval; T_4: Application of Abamectin 1.8 EC@ 1.2 mL/L of water at 10 days interval; T_5: Application of Spinosad 45 SC 0.4 mL/L of water at 10 days interval; T_6: Untreated Control.*

Figure 3. Effect of different treatments applied against the major sucking pests of country bean in terms of % increase in weight of healthy pod's plot^{-1} over control grown during the winter season.

research. Nur et al. [25] stated that Spinosad 45 SC and Emamectin benzoate 5 SG performed the best result by least infestation (4.50 and 6.00%, respectively) and this finding is fully supported by the current study.

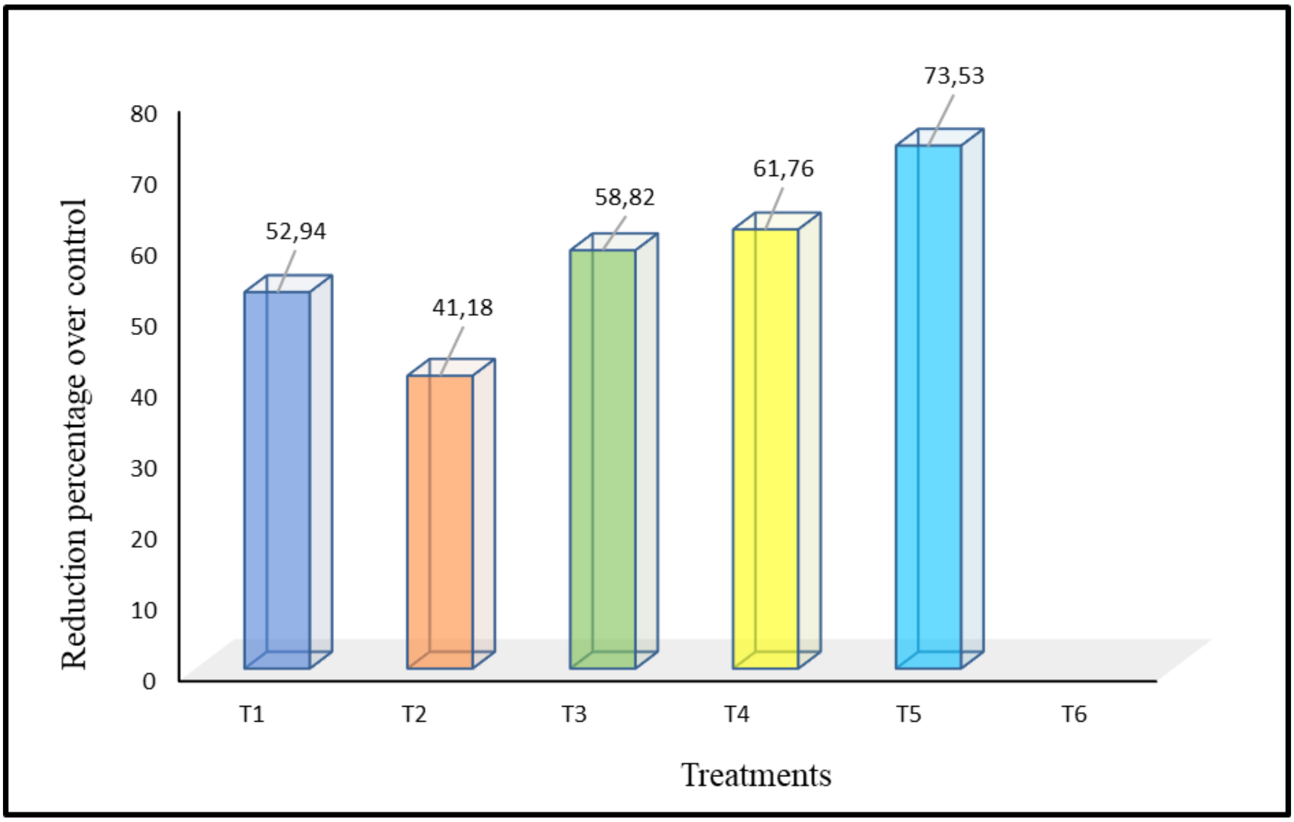
3.5. The percent increase in the number of healthy pods plot^{-1} over control

The percent increase in the number of healthy pods plot^{-1} over control of all treatment results was shown in Figure 1. The increase in the number of healthy pods over control was calculated as 45.83, 37.34, 28.02, 24.21, and 9.47% due to spray with Spinosad 45 SC, Emamectin benzoate 5 SG, Abamectin 1.8 EC, Cypermethrin 10 EC, and Lambda-Cyhalothrin 2.5 EC, respectively. Results of the present study revealed that all treatments have a significant role in the percent increase in the number of healthy pods plot^{-1} over control. The most effective treatment was Spinosad 45 SC and the least effective was Lambda-Cyhalothrin 2.5 EC against sucking pests of country beans. Similar results were found in dry beans in Brazil [26].

3.6. The percent reduction in the number of infested pods plot^{-1} over control

The percent reduction in the number of infested pods plot^{-1} over control was the highest in Spinosad 45 SC treated plot (48.58%) and the lowest in Lambda-Cyhalothrin 2.5 EC plot (19.92%). The second highest reduction was found in Abamectin 1.8 EC (24.02%) sprayed plot (Figure 2). The findings of the present study revealed that Cypermethrin 10 EC @ 2 mL/L of water at 10 days interval spray resulted in a substantial reduction (23.39%) in the number of infested pods over the control. A similar study was conducted Paul et al. [24] and found an almost similar reduction (20.28%) in pod infestation over control.

3.7. Effectiveness of different treatments on pod infestation by weight



Note: *T_1: Application of Cypermethrin 10 EC @ 2 mL/L of water at 10 days interval; T_2: Application of Lambda-Cyhalothrin 2.5 EC @ 3 mL/L of water at 10 days interval; T_3: Application of Emamectin Benzoate 5 SG @ 1 g/L of water at 10 days interval; T_4: Application of Abamectin 1.8 EC@ 1.2 mL/L of water at 10 days interval; T_5: Application of Spinosad 45 SC 0.4 mL/L of water at 10 days interval; T_6: Untreated Control.*

Figure 4. Effect of different treatments applied against the major sucking pests of country bean in terms of % increase in weight of healthy pod's plot^{-1} over control grown during the winter season.

The comparative effectiveness of various treatments on pod infestation by weight due to sucking pests of country beans has been evaluated in percent and was presented in Table 6. The lowest percent pod infestation by weight was recorded in Spinosad 45 SC (8.32 %) treated plot and it was significantly lower compared to all other treated treatments. The second lowest pod infestation by weight was found in Abamectin 1.8 EC (11.79%) followed by Emamectin benzoate 5 SG (12.54%) and Cypermethrin 10 EC (15.29%) they were statistically similar but significantly different. Paul et al. [24] reported that 6.55-6.89% pod infestation by weight was recorded in Cypermethrin 10 EC @ 2 mL/L treated plot which was much below the current finding (15.29%). Uddin et al. [27] reported that Cypermethrin 10 EC, Lambda-Cyhalothrin 2.5 EC, Emamectin benzoate 5 SG, and Spinosad 45 SC performed significant results by inhibiting the pod infestation (12.78, 13.54, 10.77 and 11.79%, respectively) and this finding is strongly supported by the current research.

3.8. The percent increase in weight of healthy pods plot^{-1} over control

The percent increase in weight of healthy pods plot^{-1} over control of all treatment consequences is shown in Figure 3. The increase in weight of healthy pods plot^{-1} over control was calculated as 91.43, 85.71, 81.43, 78.57, and 77.14% due to spray with Spinosad 45 SC, Abamectin 1.8 EC, Lambda-Cyhalothrin 2.5 EC, Cypermethrin 10 EC, and Lambda-Cyhalothrin 2.5 EC, respectively. Results of the present study revealed that all treatments have a significant role in the percent increase in weight of healthy pods plot^{-1} over control. The most effective treatment was Spinosad 45 SC and the least effective was Lambda-Cyhalothrin 2.5 EC against sucking pests of country beans. Paul et al. [24] reported that an 18.42-46.93% increase in

Table 7. Effect of different treatments applied against the major sucking pests of country bean in terms of yield ton ha^{-1} during the winter season

Treatments	Country bean yield ton ha^{-1}		
	Marketable Yield (t ha^{-1})	**Infested Yield (t ha^{-1})**	**Total Yield (t ha^{-1})**
Cypermethrin 10 EC	1.69^{bc}	0.28^{bc}	1.97^{b}
Lambda-Cyhalothrin 2.5 EC	1.64^{bc}	0.34^{b}	1.98^{b}
Emamectin benzoate 5 SG	2.13^{ab}	0.24^{bc}	2.37^{ab}
Abamectin 1.8 EC	2.27^{a}	0.23^{bc}	2.50^{ab}
Spinosad 45 SC	2.47^{a}	0.18^{c}	2.65^{a}
Control	0.83^{c}	0.52^{a}	1.35^{c}
CV (%)	16.57	15.45	14.11

Note: *Means within the same letter (s) within a column do not differ significantly (P=0.05) according to DMRT.*

weight of healthy pods plot^{-1} over control was recorded in Cypermethrin 10 EC @ 2mL/L treated plot which was much lower than the current finding (78.57%).

3.9. The percent reduction in weight of infested pods plot^{-1} over control

The reduction in weight of infested pods over control ranged from 41.17-73.53%. The percent reduction in weight of infested pods plot^{-1} over control was the highest in Spinosad 45 SC treated plot (73.53%) and the lowest in Lambda-Cyhalothrin 2.5 EC plot (41.18%). The second highest reduction was found in Abamectin 1.8 EC (61.76%) sprayed plot followed by Emamectin Benzoate 5 SG (37.55%), Cypermethrin 10 EC (38.58), and Lambda-Cyhalothrin 2.5 EC (34.05%) (Figure 4). Similar results were observed by Ahmed et al. [28] in the research field of the department of Entomology BSMRAU campus, Bangladesh.

3.10. Effect of different treatments on the yield (t ha^{-1}) of country bean

The effect of different treatments on yield has been evaluated in terms of total fruit yield, healthy fruit yield or marketing yield, and infested fruit yield obtained in each treatment during the entire period of the crop (Table 7). Significantly the highest marketable yield (2.47 t ha^{-1}) was recorded from Spinosad 45 SC treated plot which was higher than any other treatments and followed by Abamectin 1.8 EC (2.27 t ha^{-1}) and Emamectin benzoate 5 SG (2.13 t ha^{-1}) and they were statistically similar. The lowest yield of healthy fruits (0.83 t ha^{-1}) was recorded from the untreated control plot which was followed by Lambda-Cyhalothrin 2.5 EC (1.64 t ha^{-1}) and Cypermethrin 10 EC (1.69 t ha^{-1}) and the later two were statistically identical. Significantly the least infested yield (0.18 t ha^{-1}) was recorded from Spinosad 45 SC treated plot and the highest (0.52 t ha^{-1}) was in the untreated control. The second highest infested yield was found in Lambda-Cyhalothrin 2.5 EC (0.34 t ha^{-1}) followed by Cypermethrin 10 EC (0.28 t ha^{-1}), Emamectin benzoate 5 SG (0.24 t ha^{-1}) and Abamectin 1.8 EC (0.23 t ha^{-1}) and later three all were statistically identical but significantly different. The total yield was the highest (2.65 t ha^{-1}) in Spinosad 45 SC treated plot and the lowest (1.35 t ha^{-1}) in the untreated control plot. The total yield of Abamectin 1.8 EC (2.50 t ha^{-1}) was statistically at par with Emamectin benzoate 5 SG (2.37 t ha^{-1}) treated plot and the second lowest yield (1.97 t ha^{-1}) was recorded in Cypermethrin 10 EC treated plots and which was statistically similar with Lambda-Cyhalothrin 2.5 EC (1.98 t ha^{-1}) treated plot.

The performance of the different treatments against the sucking pests of country beans in different aspects, such as percent leaf, shoot, inflorescence and pod infestation, reduction of infestation over control, healthy and total fruit yield as found in the present study were more or less in conformity with the findings of several other similar studies. Khan et al. [14] reported that in the winter season under natural conditions (in an

Table 8. Economic analysis of different treatments applied against the major sucking pests of the country bean during the winter season

Treatment	Cost of control	Marketable yield (t ha^{-1})	Gross return	Net return	Adjusted net return	BCR
Cypermethrin 10 EC	18500	1.69	76050	57550	20200	1.09
Lambda-Cyhalothrin 2.5 EC	17800	1.64	73800	56000	18650	1.05
Emamectin benzoate 5 SG	19300	2.13	95850	76550	39200	2.03
Abamectin 1.8 EC	20495	2.27	102150	81655	44305	2.16
Spinosad 45 SC	21580	2.47	111150	89570	52220	2.42
Control	0	0.83	37350	37350	-	-

untreated control plot) Goalgadda country bean produced 0.81 t ha^{-1} and this finding was most similar to the current research. Conversely, Paul et al. [24] recorded in the range of total yield 9.55-11.60 t ha^{-1} in Cypermethrin 10 EC treated plots. On the other hand, Uddin et al. [27] reported the total yield in Cypermethrin 10 EC, Lambda-Cyhalothrin 2.5 EC, Emamectin benzoate 5 SG, and Spinosad 45 SC treated plots were obtained 3.47, 14.80, 14.75 and 15.78 t ha^{-1}, respectively, and those findings have fully differed from the performance of the different treatments of the current research and it might be happened due to different agro-ecological zone, soil characters, and bean varietal difference.

3.11. Economic analysis of different pyrethroids and bio-rational insecticide treatments

The benefit-cost ratio (BCR) has worked out based on the expenses incurred and the value of crops obtained against the treatment used in the present study for the control of sucking pests of the country bean are presented in Table 8. It is to be noted here that expenses incurred referred to those only on pest control. Thus, it is revealed that the BCR was the highest at 2.42 in treatment 5 Spinosad 45 SC followed by BCR 2.16 and 2.03 in treatments 4 Abamectin 1.8 EC and 3 Emamectin benzoate 5 SG and the lowest BCR 1.05 in treatment 2 Lambda-Cyhalothrin 2.5 EC, respectively. Similar results were also noted in a study and the BCR was found to be 1.371 which implies that the investment of one taka in country bean production generated a BDT of 1.371 [29].

4. CONCLUSIONS

In respect of five treatments of pyrethroids and bio-rational insecticides, Spinosad 45 SC showed the highest efficacy against the sucking pests and it might be an effective, suitable, and workable tool for suppressing the sucking pest of country beans. Treatment Abamectin 1.8 EC@ 1.2 mL/L of water at 10 days intervals would be better next to the Spinosad 45 SC. Emamectin Benzoate 5 SG @ 1g/L of water at 10 days intervals would be the third effective and amendment intervention against the sucking pests for economic country bean production in Bangladesh.

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Conflicts of Interest

The authors declare no conflict of interest.

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