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Efficacy of Bio-pesticides against spotted pod borer (*Maruca testulalis* (*Geyer*)) on green gram (*Vigna radiata* L.)

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Abstract
The materials and methods used in this study are described under the following sections: *Efficacy of bio-pesticides against spotted pod borer* (*Maruca testulalis* (*Geyer*)) *on green gram* (*Vigna radiata L.*). The experiment was carried out during the Kharif season of 2022 at Koirengei, Imphal, Manipur, India, using a randomized block design with eight treatments, each replicated three times. Green gram variety *Arka Anamika* was sown in plots measuring 2 m × 2 m, with a spacing of 30 cm × 10 cm, following the recommended agronomic practices except for plant protection. The experimental site had well-drained, medium-high fertility soil.

The area was prepared with good tilth and divided into three main blocks, each further subdivided into eight subplots of 2 m × 2 m with 30 cm bunds as borders. Treatments were assigned randomly to the subplots.

The study concluded that biopesticides are widely used to manage pest problems in agriculture, though conventional pesticide use has caused issues such as ecosystem contamination, soil and water pollution, pesticide residues in food, pest resurgence, and impacts on non-target organisms. Biopesticides with short residual activity—specifically formulations of *Beauveria bassiana, Metarhizium anisopliae*, 5ml/l NSKE, and Karanj oil—can be effectively applied under field conditions to control spotted pod borer (*Maruca testulalis* (*Geyer*)).

Keywords: Bio-pesticides, spotted pod borer, *Maruca testulalis* (Geyer), green gram, *Vigna radiata* L.,

Introduction

Pulses are an excellent source of protein and complement staple cereals in providing essential amino acids, vitamins, and minerals. They contain 22-24% protein, nearly twice that of wheat and three times that of rice. Pulses offer significant nutritional and health benefits, including reducing the risk of several non-communicable diseases such as colon cancer and cardiovascular disorders. Often referred to as “poor man’s meat,” pulses play a vital role in human diets. Although India is the world’s largest producer of pulses, average productivity remains low due to abiotic and biotic stresses, with an estimated 2.5 to 3.0 million tonnes lost annually to pests.

Greengram [*Vigna radiata* (L.) Wilczek], also known as mungbean or moong, is a leguminous crop belonging to the Fabaceae family. It is a self-pollinated diploid (2n = 2x = 22) with typical papilionaceous flowers comprising five sepals, five petals, ten diadelphous (9+1) stamens, and a monocarpellary ovary with a hairy style. In India, mungbean is cultivated over approximately 4.5 million hectares, producing 2.64 million tonnes with a productivity of 548 kg/ha.

Bio-pesticides are considered ideal alternatives to chemical pesticides because they are efficient, target-specific, and environmentally safe. Microbial pesticides, when compatible with commonly used biopesticides, can be applied simultaneously or sequentially to enhance pest management. However, potential inhibitory effects of chemical insecticides on entomopathogenic fungi must be carefully considered, as incompatible insecticides may reduce the development and reproduction of these beneficial organisms, affecting integrated pest management (IPM) strategies. Microbial pathogens thus offer an eco-friendly approach for pest control.

To evaluate their efficacy against gram pod borer, a field trial was conducted using various bio-pesticides, including *Beauveria bassiana*, *Metarhizium anisopliae*, *Paecilomyces fumosoroseus*, *Verticillium lecanii*, and *Bacillus thuringiensis* var. *kurstaki*. Treatments were compared with a control, and among them, *Beauveria bassiana* at 1 liter/ha (1×10^{12} spores/ml) proved most effective, recording the lowest larval population (Pandey and Das, 2017) [7].

Materials and Methods

The materials and methods used in this study are described under the following section: *Efficacy of bio-pesticides against spotted pod borer* (*Maruca testulalis* (*Geyer*)) *on green gram* (*Vigna radiata L*.). The experiment was conducted during the Kharif season of 2022 at Koirengei, Imphal, Manipur, India, using a randomized block design with eight treatments, each replicated three times. Green gram variety *Arka Anamika* was sown in 2 m × 2 m plots, with a spacing of 30cm × 10cm, following recommended agronomic practices except for plant protection. The experimental soil was well-drained and of medium-high fertility.

The experimental area was divided into three main blocks, each subdivided into eight subplots of 2m × 2m, separated by 30cm bunds. Treatments were randomly assigned to the subplots to ensure a randomized complete block design with three replications.

Table 3.1: Details of insecticides treatment used for field assessment against (*Maruca testulalis*) in green gram

Treatment no	Treatment details	Dosage
T_1	*Beauveria bassiana*	2.5ml/l
T_2	*Verticillium lecanii*	5g/l
T_3	*Metarhizium anisopliae*	5g/l
T_4	*Karanj oil*	2ml/l
T_5	*Neem oil*	0.5ml/l
T_6	*Azadirachtin*	5ml/l
T_7	*NSKE*	5ml/l
T_0	Con Control	

Method of Recording Observations

Co- relation of pod damage by (*Maruca testulalis*) Gram pod borer and incidence with weather factors to know the severity of the seasonal incidence. Data pertaining to maximum and minimum temperatures, rainfall and relative humidity in relation to the percent pod damage was presented here.

$$\text{Percentage reduction in pod damage over control (\%)} = \frac{\text{Pod damage in control} - \text{Pod damage in treatment}}{\text{Pod damage in control}} \times 100$$

$$\text{Percentage increase in yield over control (\%)} = \frac{\text{Grain yield in treatment} - \text{Grain yield in control}}{\text{Grain yield in control}} \times 100$$

Benefit cost ratio

The value of B: C of a different treatment are calculated by following formula.

$$\text{B:C ratio} = \frac{\text{Net return}}{\text{Cost of treatment}}$$

Where,

BC - Benefit Cost Ratio

Sireesha and Kumar the collected data were analyzed using analysis of variance (ANOVA). The F-test was employed to assess the significance of differences among treatments. The following table presents the framework of the analysis of variance applied in this study:

Results and Discussion

The Bio efficacy of biopesticide against spotted pod borer (*Maruca testulalis* (*Geyer*) on green gram

Pretreatment population

The data showing the mean larval population per plant under different treatments at various intervals after the first spray are presented in Table 4.1 and the corresponding figure. The variation in pre-treatment populations of *Maruca testulalis* (Geyer) on green gram across the different plots was statistically non-significant, indicating a uniform distribution of the pest before treatments were applied. The mean larval population measured 24 hours prior to treatment application ranged from 5.47 to 5.87 larvae per plant.

Post treatment population

The percent mean larval population across different treatments at various intervals after the first spray is presented in Table 4.1 and Figure 4.1. Statistical analysis of the data indicated that all treatments were significantly more effective in reducing the larval population of spotted pod borer (*Maruca testulalis* (Geyer)) compared to the control.

Per cent reduction of (*Maruca testulalis* (*Geyer*) larval population due to application of selected biopesticide in green gram on third day after spray.

The efficacy of the selected biopesticides at different intervals after the first spray is presented in Table 4.1 and Figure 4.1. On the third day after application, all treatments were significantly more effective than the control in reducing the larval population of *Maruca testulalis* (Geyer). Among them, *Beauveria bassiana* (2.5 ml/l) achieved the highest larval reduction (30.13%), followed by *Metarhizium anisopliae* (5 g/l, 28.11%), NSKE (5 ml/l, 24.16%), and Karanj oil (2 ml/l, 18.76%). Treatments T_1, T_3, T_4; T_7, T_4; and T_4, T_6, T_5 were statistically at par with each other.

On the seventh day after spraying, all treatments continued to show significant superiority over the control. *Beauveria bassiana* (2.5 ml/l) again recorded the highest reduction (43.42%), followed by *Metarhizium anisopliae* (5 g/l, 40.45%), NSKE (5 ml/l, 35.64%), and Karanj oil (2 ml/l, 30.72%). Treatments T_1, T_3; T_3, T_7; T_7, T_4; T_4, T_5; and T_5, T_6, T_2 were statistically comparable.

By the fourteenth day after spraying, the trend remained similar, with all treatments significantly reducing larval populations compared to the control. *Beauveria bassiana* (2.5 ml/l) recorded the highest reduction (41.42%), followed by *Metarhizium anisopliae* (5 g/l, 38.66%), NSKE (5 ml/l, 33.82%), and Karanj oil (2 ml/l, 30.22%). Treatments T_1, T_3; T_3, T_7; T_7, T_4; T_4, T_5; and T_5, T_6, T_2 were statistically at par with one another.

Mean of 3rd, 7th and 14th days after spraying (first spray)

The mean larval population recorded on the 3rd, 7th, and 14th days after spraying showed that all treatments were significantly more effective than the untreated control. Among the treatments, *Beauveria bassiana* (2.5 ml/l) achieved the highest larval reduction (38.32%), followed by *Metarhizium anisopliae* (5 g/l, 35.74%), NSKE (5 ml/l, 31.36%), and Karanj oil (2 ml/l, 26.57%). Treatments T_1, T_3; T_3, T_7; T_7, T_4; T_4, T_5; and T_5, T_6, T_2 were statistically at par with one another.

Table 4.1: Efficacy of biopesticide against spotted pod borer (*Maruca testulalis* (*Geyer*) on green gram (1st spray)

Treatment No.	Treatment combination	Dose	1DBS	Mean percent larval reduction over control			Overall mean
				Days after first spray			
				3rd Days	7th Days	14th Days	
T_1	*Beauveria bassiana*	2.5ml/l	5.47	30.13 33.17	43.42 41.20	41.42 40.03	38.32 38.20
T_2	*verticillium lecunii*	5g/l	6.13	10.32 18.09	20.61 26.74	21.58 27.52	17.50 24.45
T_3	*Metarhizium anisopliae*	5g/l	5.53	28.11 32.04	40.45 39.47	38.66 37.82	35.74 36.69
T_4	*Karanj oil*	2ml/l	5.67	18.76 25.66	30.72 33.65	30.22 33.33	26.57 31.02
T_5	*Neem oil*	0.5ml/l	6.33	12.47 20.59	26.68 30.96	26.43 30.88	21.86 27.78
T_6	*Azadirachtin*	5ml/l	6.20	11.50 22.39	23.82 29.17	22.67 28.42	19.33 26.06
T_7	*NSKE*	5ml/l	5.47	24.16 29.37	35.64 36.59	33.82 35.53	31.21 33.91
T_0	*Control*		5.87	0.00	0.00	0.00	0.00
	F-Test		NS	S	S	S	S
	C.D. at 0.5		0.739	5.547	6.71	5.50	5.56
	S.Ed.		0.345	2.58	3.11	2.56	2.59

The Bio efficacy of biopesticide against spotted pod borer (*Maruca testulalis* (*Geyer*) on green gram

Pretreatment population

The mean larval population per plant under different treatments at various intervals after the second spray is presented in Table 4.2 and Figure 4.2. The variation in pre-treatment populations of *Maruca testulalis* (Geyer) on green gram across the plots was statistically non-significant, indicating that the pest was uniformly distributed before treatments were applied. The mean larval population measured 24 hours prior to treatment application ranged from 4.13 to 7.07 larvae per plant.

Post treatment population

The percent mean larval population across different treatments at various intervals after the second spray is presented in Table 4.2 and Figure 4.2. Statistical analysis indicated that all treatments were significantly more effective than the control in reducing the larval population of spotted pod borer (*Maruca testulalis* (Geyer)).

4.2.2.1 Per cent reduction of (*Maruca testulalis* (*Geyer*) larval population due to application of selected biopesticide in green gram on third day second spray.

The efficacy of the selected biopesticides at different intervals after the second spray is presented in Table 4.2 and Figure 4.2. On the third day after application, all treatments were significantly more effective than the control in reducing the larval population of *Maruca testulalis* (Geyer). *Beauveria bassiana* (2.5 ml/l) recorded the highest larval reduction (52.73%), followed by *Metarhizium anisopliae* (5 g/l, 49.12%), NSKE (5 ml/l, 43.75%), and Karanj oil (2 ml/l, 41.89%). Treatments T_1, T_3; T_3, T_7; T_7, T_4; T_4, T_5; and T_5, T_6, T_2 were statistically at par with one another.

On the seventh day after spraying, all treatments continued to show significant superiority over the control. *Beauveria bassiana* (2.5 ml/l) achieved the highest reduction (64.94%), followed by *Metarhizium anisopliae* (5 g/l, 63.22%), NSKE (5 ml/l, 60.62%), and Karanj oil (2 ml/l, 59.77%). Treatments T_1, T_3, T_7, T_4, T_5; T_4, T_5, T_6; and T_5, T_6, T_2 were statistically comparable.

By the fourteenth day after spraying, all treatments remained significantly effective compared to the control. *Beauveria bassiana* (2.5 ml/l) recorded the highest larval reduction (58.86%), followed by *Metarhizium anisopliae* (5 g/l, 57.25%), NSKE (5 ml/l, 54.48%), and Karanj oil (2 ml/l, 54.81%). Treatments T_1, T_3, T_4, T_7; T_3, T_4, T_7, T_5; and T_5, T_6, T_2 were statistically at par with each other.

Mean of 3rd, 7th and 14th days after spraying (second spray)

The mean larval population recorded on the 3rd, 7th, and 14th days after the second spray indicated that all treatments were significantly more effective than the untreated control. Among the treatments, *Beauveria bassiana* (2.5 ml/l) achieved the highest reduction in *Maruca testulalis* (Geyer) population (58.84%), followed by *Metarhizium anisopliae* (5 g/l, 56.53%), NSKE (5 ml/l, 52.95%), and Karanj oil (2 ml/l, 52.16%). Treatments T_1, T_3, T_7, T_4; T_7, T_4, T_5; and T_5, T_6, T_2 were statistically at par with one another.

Table 4.2: Efficacy of biopesticide against spotted pod borer (*Maruca testulalis* (*Geyer*) on green gram (2nd spray)

Treatment No.	Treatment combination	Dose	1DBS	Mean percent larval reduction over control			Overall mean
				Days after second spray			
				3rd Days	7th Days	14th Days	
T_1	*Beauveria bassiana*	2.5ml/l	4.13	52.73 46.56	64.94 52.89	58.86 50.10	58.84 50.14
T_2	*verticillium lecunii*	5g/l	5.53	30.88 33.73	45.28 42.26	40.30 39.38	38.82 38.59
T_3	*Metarhizium anisopliae*	5g/l	4.33	49.12 44.49	63.22 52.72	57.25 48.61	56.53 48.82
T_4	*Karanj oil*	2ml/l	4.93	41.89 40.32	59.77 50.67	54.81 47.78	52.16 46.32

T_5	*Neem oil*	0.5ml/l	5.20	35.42 36.46	55.83 48.38	47.94 43.81	46.40 43.01
T_6	*Azadirachtin*	5ml/l	5.47	34.54 35.99	49.08 44.47	44.38 41.76	42.67 40.85
T_7	*NSKE*	5ml/l	4.60	43.75 41.38	60.62 51.155	54.48 47.58	52.95 46.76
T_0	*Control*		7.07	0.00	0.00	0.00	0.00
	F-Test		S	S	S	S	S
	C.D. at 0.5		0.418	6.547	11.16	8.83	7.72
	S.Ed.		0.195	3.05	5.20	4.19	3.59

Overall performance of biopesticide treatment, on the mean percent reduction of spotted pod borer (*Maruca testulalis* (*Geyer*) (Observations on the 3rd, 7th and 14th mean of first and second spray).

Mean of 3rd, 7th and 14th days after spraying (first spray)

The mean larval population recorded on the 3rd, 7th, and 14th days after the first spray showed that all treatments were significantly more effective than the untreated control. Among the treatments, *Beauveria bassiana* (2.5 ml/l) achieved the highest reduction in *Maruca testulalis* (Geyer) population (38.32%), followed by *Metarhizium anisopliae* (5 g/l, 35.74%), NSKE (5 ml/l, 31.36%), and Karanj oil (2 ml/l, 26.57%). Treatments T_1, T_3; T_3, T_7; T_7, T_4; T_4, T_5; and T_5, T_6, T_2 were statistically at par with each other.

Mean of 3rd, 7th and 14th days after spraying (second spray)

The mean larval population recorded on the 3rd, 7th, and 14th days after the second spray indicated that all treatments were significantly more effective than the untreated control. Among the treatments, *Beauveria bassiana* (2.5 ml/l) achieved the highest reduction in *Maruca testulalis* (Geyer) population (58.84%), followed by *Metarhizium anisopliae* (5 g/l, 56.53%), NSKE (5 ml/l, 52.95%), and Karanj oil (2 ml/l, 52.16%). Treatments T_1, T_3, T_7, T_4; T_7, T_4, T_5; and T_5, T_6, T_2 were statistically at par with each other.

Table 4.3: Overall performance of biopesticide treatment, on the mean percent reduction of spotted pod borer (*Maruca testulalis* (*Geyer*) (Observations on the 3rd, 7th and 14th mean of first and second spray).

Treatment No.	Treatment combination	Dose	Mean percent larval reduction over control		
			1st spray	2nd spray	Pooled Mean
T_1	*Beauveria bassiana*	2.5ml/l	38.32	58.84	48.58
T_2	*verticillium lecunii*	5g/l	17.50	38.82	28.16
T_3	*Metarhizium anisopliae*	5g/l	35.74	56.53	46.14
T_4	*Karanj oil*	2ml/l	26.57	52.16	39.37
T_5	*Neem oil*	0.5ml/l	21.86	46.40	34.13
T_6	*Azadirachtin*	5ml/l	19.33	42.67	31.00
T_7	*NSKE*	5ml/l	31.21	52.95	42.08
T_0	*Control*		0.00	0.00	0.00
	F-Test		S	S	
	C.D. at 0.5		5.56	7.72	
	S.Ed.		2.59	3.59	

Bio efficacy of biopesticide against spotted pod borer (*Maruca testulalis* (*Geyer*) on pod yield (q ha-1) of green gram: The data indicated that all biopesticide treatments produced significantly higher yields compared to the control. The highest yield was recorded with *Beauveria bassiana* (2.5 l/l) at 17.10 q ha^{-1}, followed by *Metarhizium anisopliae* (5 g/l) at 14.81 q ha^{-1}, NSKE (5 ml/l) at 13.32 q ha^{-1}, and Karanj oil (2 ml/l) at 12.75 q ha^{-1}. The lowest yield was observed in the control plots (T0, water) at 6.59 q ha^{-1}.

Table 4.4: Bio efficacy of biopesticide against spotted pod borer (*Maruca testulalis* (*Geyer*) on pod yield (q ha-1) of green gram

Treatment No.	Treatment combination	Dose	Pod yield (q ha-1)	increase in yield over control
T_1	*Beauveria bassiana*	2.5ml/l	17.10	10.51
T_2	*verticillium lecunii*	5g/l	9.05	2.46
T_3	*Metarhizium anisopliae*	5g/l	14.81	8.22
T_4	*Karanj oil*	2ml/l	12.75	6.16
T_5	*Neem oil*	0.5ml/l	10.26	3.67
T_6	*Azadirachtin*	5ml/l	11.48	4.89
T_7	*NSKE*	5ml/l	13.32	6.73
T_0	*Control*	-	6.59	-
		F-Test	S	
		C.D. at 0.5	0.642	
		S.Ed.	0.299	

Conclusion

The study concluded that biopesticides are widely used for managing pest problems in agriculture. Unlike chemical pesticides, which can cause environmental contamination, water and soil pollution, pesticide residues in food, pest resurgence, and effects on non-target organisms, biopesticides offer a safer alternative. Short-residual biopesticides such as *Beauveria bassiana*, *Metarhizium anisopliae*, NSKE (5 ml/l), and Karanj oil can be effectively incorporated under field conditions to control the spotted pod borer (*Maruca testulalis* (Geyer)).

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