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Comparative Efficacy of Different Biopesticides against the Tobacco Caterpillar [*Spodoptera litura* (Fabricius)]

Rishabh Kumar [a*], S. K. Sharma [a], Jigyasa, Kiran Kumari [a] and Ankit Anand [a]

[a] Department of Entomology, Bihar Agricultural College, Bihar Agricultural University, Sabour, Bhagalpur – 813210, Bihar, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Tobacco caterpillar, *Spodoptera litura* (Fabricius) is an economically important polyphagous pestinflicting significant economic damage to numerous field and horticultural crops. Overreliance of chemical insecticides to manage the pest has led to the development of resistance, resurgence and residue problem in the crop ecosystems, in addition to high operating costs. Biopesticides have been reported to be effective for managing this pest in ecofriendly manner. Hence, the present study was conducted to assess the efficacy of different bio pesticides against *S. litura* under laboratory conditions at Bihar Agricultural College, Sabour, Bhagalpur during the *rabi* of 2022-23*.* It was conducted in completely randomized design (CRD) with eight treatments and three replications. Among the various biopesticides evaluated, *Steinernema carpocapsae*- 500 IJs/Petri

**Corresponding author;*

Plate and *Metarhizium anisopliae* 1×10^8 spores/ml -5g/l were most effective treatments and at par each other with 93.00 and 82.50 per cent larval mortality, respectively. They had performed equally with chemical check, Emmamectin benzoate 5 SG- 0.4 g/l which recorded with 95.63 % larval mortality. Neem oil 1500 ppm- 5 ml/litre and *Beauveria bassiana* 1×10^8 @5ml/l were the next best treatments with 78.31 and 59.38 % larval mortality respectively. The order of efficiency was Emamectin benzoate 5 SG (0.4g/l) > EPNs (500 IJs) >*Metarhizium anisopliae* 1% WP (5g/l) >Neem oil 1500 ppm (5 ml/litre) >*Beauveria bassiana*1 % WP (5 g/l) >*Metarhizium anisopliae* 1 % WP (2.5 g/l) >*Beauveria bassiana* 1 % WP (2.5 g/l).

Keywords: Polyphagous; entomo-pathogenic nematodes; bio-pesticides; eco-friendly; emamectin benzoate.

1. INTRODUCTION

Spodoptera litura (Fabricius) is a highly polyphagous insect that significant threat to agriculture and many other countries [1]. This insect has a wide range of host plants and has been reported to damage over 112 plant species from 44 different families [2]. In India alone, it has been observed affecting about 40 plant species Chari and Patel [3]. Various crops are known to serve as host plants for *Spodoptera litura*, and researchers [4-6] have documented its presence and damage in several agricultural crops. Some of the crops known to be affected by *Spodoptera litura viz.,* maize, castor, cauliflower, tobacco and several grasses etc. *Spodoptera litura's* ability to infest such a wide range of crops and plant species makes it an important agricultural pest that requires efficient management strategies to mitigate its impact on crop yields. Other hosts include ornamental plants, native vegetation, unwanted plants, and shade trees, such as *Leucaena leucocephala*, which serves as a shade tree in Indonesian cocoa plantations [7].

The damage inflicted by *S. litura* on tomatoes is significantly more pronounced. This pest has been documented to initiate leaf skeletonization in the early stages and extensive defoliation in later stages, thereby diminishing the plants' photosynthetic capability [8]. Entomopathogenic nematodes (EPNs) are beneficial organisms that parasitize insect pests and are increasingly employed as a biopesticide against a wide array of such pests [9]. Their remarkable qualities have sparked considerable commercial interest in utilizing nematodes as biological insecticides, presenting a promising alternative to chemical approaches in integrated pest management (IPM) strategies. EPNs possess numerous attributes that render them effective biocontrol agents. They exhibit behavior akin to insecticides or conventional plant protection chemicals, and they can be seamlessly integrated into IPM programs. Cultivating and applying EPNs is straightforward, utilizing established methods and equipment. Moreover, they demonstrate compatibility with various chemical pesticides, making them a valuable addition to IPM initiatives [10].

2. MATERIALS AND METHODS

Various bio-pesticides were evaluated against the *S.litura* under controlled laboratory conditions at Department of Entomology, Bihar Agricultural College, Sabour, Bhagalpur during the *rabi* 2022-23*.* Biopesticides included were *viz., Beauveria bassiana* and *Metarhizium anisopliae* at two different doses, Neem oil 1500 ppm and *Steinernema carpocapse. The* other two were chemical check*,* Emamectin benzoate 5 SG and untreated control, distilled water spray. Details of treatments evaluated are given in the Table 1.

Table 1. Treatment details

Treatments	Biopesticide Name	Dose
T1	*Beauveria bassiana* (1×10^8 spores/ml)	*2.5ml/l*
T2	*Beauveria bassiana* (1×10^8 spores/ml)	*5ml/l*
T3	*Metarhizium anisopliae* (1×10^8 spores/ml)	*2.5g/l*
T4	*Metarhizium anisopliae* (1×10^8 spores/ml)	*5g/l*
T5	Neem oil 1500 PPM	5 ml/litre
T6	*Steinernema carpocapse*	500 IJs/10 Larvae
T7	Emmamectin benzoate 5 SG	0.4g/l
T8	Untreated/Control	-

The present experiment was performed using completely randomized design (CRD) with eight treatments and three replications using leaf dip bioassay method. Leaves of tomato were properly cleaned and dipped for 30 seconds in the prepared treatment solutions. Observations were taken at 24 hrs, 48 hrs, 72 hrs, 96 hrs, 120 hrs, 144 hrs, 168 hrs, 192 hrs after application. A total of 10 of uniformly aged 3rd instar larvae were used in each replication. Per cent mortality was calculated by using the following formula 1 Karthi *et al.* [11] and per cent control calculated by using Abbott's [12] formula (2).

Percentage of mortality =

$$\frac{Numbers\ of\ dead\ larvae}{Numbers\ of\ larvae\ introduced} \times 100 \ldots\ldots\ldots\ldots \qquad \ldots(1)$$

$$Percent\ control = 100 \times \left(\frac{X-Y}{X}\right) \ldots\ldots\ldots\ldots\ldots\ldots. \ (2)$$

Where,
X =percent living in the check.
Y = percent living in the treated.
X-Y= percent killed by the treatment.

3. RESULTS AND DISCUSSION

After 24 hrs. of Application: The results of the experiment presented in Table 2, which focused on the mortality percentage of Tobacco caterpillar (*Spodoptera litura*), data revealed that, within the period of 24-hour,the larval mortality varied between 11.67 to 73.33 per cent when subjected to different treatments. The maximum per cent mortality was observed in the treatment with Emmamectin benzoate 5SG@0.4g/l (73.33) followed by the treatment, application of 500 infective juvenile units (IJs) of *Steinernema carpocapsae* (68.33). The larvae treated with Neem oil 1500ppm@5ml/litre resulted in 40.00 per cent mortality. The lowest percentage of mortality was observed in *Beauveria bassiana* @ 2.5 ml/l was 11.67 .

After 48 hrs. of Application: The data presented in Table 2 clearly indicates that the mortality percentage of Tobacco caterpillar larvae ranged from 20.00 to 91.67 per cent after 48-hour exposure to various treatments. The treatment Emmamectin benzoate 5SG @ 0.4g/l recorded the highest mortality of 91.67%, followed by the treatment, 500 IJs of *Steinernema carpocapsae* caused 80% mortality. The treatment *Metarhizium anisopliae* @ 5 g/l, caused mortality of 60.00%. The treatment, *Beauveria bassiana* @ 2.5 ml/l demonstrated lowest percentage of mortality 20.00.

After 72 hrs. of Application: The data presented in Table 2 revealed range of mortality percentage, spanning from 28.33% to 100 % within 72-hour period after application of different treatments. 100 per cent mortality was observed in the treatment Emmamectin benzoate 5SG @ 0.4g/l at the exposure of 72hrs duration which was followed by the treatment of 500 infective juvenile units (IJs) of *Steinernema carpocapsae*, which resulted 95.67 percent mortality. Meanwhile, the treatment *Metarhizium anisopliae @ 5* g/l led to 76.67 percent larval mortality. On the other hand, the treatments *Metarhizium anisopliae* @ 2.5 g/l and *Beauveria bassiana* @ 2.5 ml/l recorded lowest percentage of mortality, 35.00 and 28.33 per cent mortality, respectively.

After 96 hrs. of Application: The data presented in Table 2 illustrates the range of 35.00 to 100.00percent mortality observed after applying various treatments at 96-hour duration. The treatment *Beauveria bassiana* @ 2.5 ml/l exhibited the lowest per cent mortality (35.00). The treatment with the application of 500IJs of *Steinernema carpocapsae* resulted in 100% mortality within 96 hours which was followed by the treatment, *Metarhizium anisopliae @ 5 g/l*(85.00 percent mortality).

After 120 hrs. of Application: The information provided in Table 2 distinctly illustrated that the mortality percentage of Tobacco caterpillar larvae exhibited a span of 45.00 to 100.00 per cent at 120 hours exposure to diverse treatment regimens. The treatment *Metarhizium anisopliae @ 5* g/l, recorded 100.00 per cent mortality at 120 hrs after application. *Beauveria bassiana* @ 2.5 ml/l exhibited 45.00 per cent mortality.

After144 hrs. of Application: The data presented in Table 2 distinctly illustrated that the mortality percentage of Tobacco caterpillar larvae showed variance from 55.00 to 100.00 per cent following 144-hour exposure to different treatments.Neem extract 5% attained 100.00 per cent mortality at 144hrs of application. *Beauveria bassiana* @ 5 ml/lexhibited 80.00 per cent mortality followed by the treatment, *Metarhizium anisopliae* @ 2.5 g/l and *Beauveria bassiana* @ 2.5 ml/l (55.00 per cent mortality).

Table 2. Comparative bio-efficacy of *Steinernema carpocapsae* against *S .litura*

Treatment	**Mortality percentage of *S.litura***								
	24 hrs	**48 hrs**	**72 hrs**	**96 hrs**	**120 hrs**	**144 hrs**	**168 hrs**	**192 hrs**	**Mean**
T_1-*Beauveria bassiana 1×10^8@ 2.5ml/l*	11.67^g	20.00^g	28.33^f	35.00^e	45.00^d	55.00^c	65.00^c	70.00^c	41.25^c
T_2-*Beauveria bassiana 1×10^8@5ml/l*	25.00^e	30.00^e	35.00^e	51.67^c	65.00^c	80.00^b	88.33^b	100.00^a	59.38^{bc}
T_3-*Metarhizium anisopliae* 1×10^8@2.5g/l	20.00^f	26.67^f	35.00^e	40.00^d	45.00^d	55.00^c	60.00^d	80.00^b	45.21^c
T_4-*Metarhizium anisopliae*1×10^8@5g/l	38.33^d	60.00^c	76.67^c	85.00^b	100.00^a	100.00^a	100.00^a	100.00^a	82.50^a
T_5-Neem oil 1500 ppm@ 5 ml/litre	40.00^c	50.00^d	60.00^d	85.00^b	90.00^b	100.00^a	100.00^a	100.00^a	78.31^{ab}
T_6-Steinernemacarpocapsae 500 IJs/Petri Plate	68.33^b	80.00^b	95.67^b	100.00^a	100.00^a	100.00^a	100.00^a	100.00^a	93.00^a
T_7-Emmamectin benzoate 5SG@0.4g/l	73.33^a	91.67^a	100.00^a	100.00^a	100.00^a	100.00^a	100.00^a	100.00^a	95.63^a
T_8-Untreated/Control (dipped in water)	0^h	0^h	0^g	0^f	0^e	0^d	0^e	6.66^d	0.83^d
SEm (±)	**1.01**	**1.14**	**1.12**	**1.16**	**0.82**	**0.57**	**0.90**	**1.23**	**17.97**
CD(p=0.05)	**0.10**	**0.12**	**0.10**	**0.15**	**0.15**	**0.16**	**0.19**	**0.23**	
CV	**1.10**	**1.15**	**0.85**	**1.21**	**1.15**	**1.16**	**1.35**	**1.53**	

After 168 hrs. of Application: The data presented in Table 2 makes it evident that the percentage of mortality ranged from 65.00 to 100.00 after the application of treatments over 168-hour period. The treatment *Beauveria bassiana* @ 5 ml/l led to mortality of 88.33. The lowest mortality percentage (65.00) was observed with the treatment *Beauveria bassiana* @ 2.5 ml/l followed by the treatment *Metarhizium anisopliae* @2.5 g/l (60%).

After 192 hrs. of Application: Results obtained from the experiment (Table 2) showed that 100 percent mortality with the treatment *Beauveria bassiana* @ 5ml/l was achieved during 192 hrs. However, Emamectin benzoate 5SG @ 0.4 g/l, EPN (500IJs),*Metarhizium anisopliae* @5g/l,Neem extract 5% attained 100 percent mortality within 168 hrs. The treatment *Metarhizium anisopliae* @ 2.5 g/l and *Beauveria bassiana* @ 2.5ml/l showed 80.00 and 70.00 per cent mortality, respectively. Only 6.66 percent mortality was recorded in untreated control during the entire period of investigation.

The comparative effectiveness of various biopesticides and EPNs were studied. Per cent mortality of *S. litura* was recorded after 24 hours, 48 hours, 72 hours, 96 hours, 120 hours, 144 hours, 168 hours, and 192 hours of application, it was revealed from the provided Table 2 related mortality of *S. litura*. The treatment Emmamectin benzoate@ 0.4 g/l achieved the highest mortality 73.33, 91.67 and 100 per cent after 24 hrs, 48 hrs and 72 hrs, respectively. Emamectin benzoate is a semi-synthetic biopesticide derived from avermectins, which are natural products produced by the bacterium *Streptomyces avermitilis*. The next most effective treatment was observed, using EPNs @ 500 IJs per petri plate, resulted 100 % mortality of *S. litura* within 96 hrs of application. Among fungal biopesticides, *Metarhizium anisopliae* @ 5 g/l, recorded 100.00 per cent mortality at 120 hrs after application. Neem extract 5 % attained 100.00 per cent mortality at 144 hrs of application. In case of *Beauveria bassiana* @ 5 ml/l, 100 percent mortality was achieved after 192 hrs. While *Metarhizium anisopliae* @ 2.5 g/l and *Beauveria bassiana* @ 2.5 ml/l showed 80.00 and 70.00 per cent mortality, respectively. Only 6.66 per cent mortality was recorded in untreated control during the period of investigation. Hence it was concluded that larval mortality enhanced with increase in doses and time interval. Emmamectin benzoate inhibits signal transmission at junction and act as (GABA) gamma aminobutyric acid antagonist in insects. *Beauveria bassiana* (White muscardine diseases) and *Metarhizium anisopliae* (Green muscardine diseases) produces endotoxin, causes death of insect larvae.The present findings are in relevant with Pragya and Das [13] who found that the fungal mycotoxin of *Beauveria bassiana* and *Metarhizium anisopliae* showed the reduced development of lepidopteran pests. Patel et al. (2020) tested the effectiveness of various native strains of entomopathogenic fungi, including *Beauveria bassiana, Metarhizium anisopliae*, and *Nomuraea rileyi*, as well as entomopathogenic bacteria such as *Bacillus thuringiensis*, was evaluated in comparison to non-native strains. Yadav et al. [14] conducted an experiment on bio-efficacy of *Steinernema carpocapsae* and found that *S. carpocapse* caused 100 per cent larval mortality.

4. CONCLUSION

The most effective treatment was Emamectin benzoate @ 0.4g/l with larval mortality of 100 percent within 72 hrs. whichwas followed by EPNs @ 500 IJs caused 100 per cent larval mortality within 96 hrs. The treatment Emamectin benzoate @ 0.4g/l achieved the highest larval mortality and appeared as the most effective insecticide to manage the pest. Emamectin benzoate is a semi-synthetic bio pesticide, which are natural products produced by the bacterium *Streptomyces avermitilis.* Itis also promising bio pesticides effective Lepidopteran insect pests. It is eco-friendly and no harmful effect on natural enemies biodegradable and can be more effective than chemical pesticides in the long term. Thus, this semi-bio pesticide may be incorporated in Integrated Pest management.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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