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Ghodake RD
M.Sc. (Agriculture) Scholar, Division of Agricultural Entomology, RCSM, College of Agriculture, Kolhapur, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Hole UB
Professor, Department of Entomology, College of Agriculture, Nandurbar, Nandurbar, Maharashtra, India

Kharbade SB
Head of Division of Agricultural Entomology, RCSM College of Agriculture, Kolhapur, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Bagde AS
RCSM College of Agriculture, Kolhapur, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Galande SM
RCSM College of Agriculture, Kolhapur, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Corresponding Author:
Ghodake RD
M.Sc. (Agriculture) Scholar, Division of Agricultural Entomology, RCSM, College of Agriculture, Kolhapur, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Efficacy of bio-rational pesticides for the management of *Leucinodes orbonalis* Guenee, infesting Brinjal

Ghodake RD, Hole UB, Kharbade SB, Bagde AS and Galande SM

Abstract
A field experiment was conducted at the research farm in RCSM College of Agriculture, Kolhapur, during the *summer* 2022-23. The experiment followed a randomized block design with three replications and included eight treatments: T_1- *Metarhizium anisopliae* @ 6 g/L, T_2- *Beauveria bassiana* @ 6 g/L, T_3 -*Lecanicillium lecanii* @ 4 g/L, T_4- *B thuringiensis* @ 2 ml/L, T_5 -Spinosad @ 0.4 ml/L, T_6-Azadirachtin @ 1500 ppm, 5 g/L, T_7- *Heterorhabditis indica* @ 10 g/L and T_8 -untreated control. The objective was to study the efficacy of bio-rational pesticide for management of *Leucinodes orbonalis* Guenee, infesting brinjal. Three sprays were applied at 21 day intervals and data on shoot and fruit infestation, recorded at each spraying and picking, included the per cent of shoot infestation. The results revealed that the initial population of the pest before the spray indicated a non-significant distribution. However, after spray, the result revealed that the T_5 -Spinosad @ 0.4 ml/L was found to be a significantly effective treatment against shoot and fruit borer, which was comparable to T_6-Azadirachtin @ 1500 ppm, at 3, 7, and 14 days post-spraying Following closely in efficacy were *B thuringiensis* and *Metarhizium anisopliae.* The highest cost benefit ratio was recorded- T_5-spinosad @ 0.4 ml/L, followed by T_6-Azadirachtin @1500 ppm. The highest incremental cost-benefit ratio (ICBR) were recorded- T_4 -*Bacillus thuringiensis* @ 2 ml/L followed by T_6-Azadirachtin @1500 ppm *i.e* Spinosad > Azadirachtin at 1500 ppm > *B thuringiensis* > *Metarhizium anisopliae* > *Beauveria bassiana* > *Lecanicillium lecanii* > *Heterorhabditis indica* > Untreated control

Keywords: *Metarhizium anisopliae, Beauveria bassiana, Lecanicillium lecanii, Heterorhabditis indica*

1. Introduction
Vegetables play a vital role in sustaining human existence, contributing significantly to food security and meeting the nutritional needs of a growing global population. They provide essential vitamins, minerals, dietary fiber, and phytochemicals, each contributing uniquely to overall health. Different vegetable groups offer distinct combinations of these phytonutrients, imparting diverse health benefits, including improved gastrointestinal health, enhanced vision, and reduced risks of cardiovascular diseases, strokes, diabetes, and certain cancers (Joao Silva Dias, 2012) [1].

Brinjal (*Solanum melongena* Linnaeus), commonly known as eggplant, belongs to the Solanaceae family, encompassing over 2,450 species across 95 genera (Mabberley, 2008) [2]. With a chromosome number of 2n=24, brinjal has historical significance in India, dating back over 4,000 years, and is considered indigenous to the Indian subcontinent It holds a prominent status as the "Monarch of Vegetables," with India being the second-largest global producer after China. Despite its colloquial label as the "poor man's" food, eggplant is commercially important, contributing significantly to both kitchen gardens and market prices (Abhishek, 2021) [3].

Being a summer crop, eggplant is vulnerable to frost and climatic factors, particularly low temperatures during the cooler season, leading to abnormal ovary growth and deformed fruits. It requires hot and humid conditions for optimal fruit development and is cultivated year-round under irrigated conditions (Nothmann et al., 1973) [4]. Recognized for its therapeutic attributes in Ayurveda, eggplant benefits individuals with diabetes, helps maintain blood sugar, reduces the risk of heart disease, aids in weight loss, and is considered beneficial in cancer prevention.

It is also suggested as a treatment for liver disorders, rich in minerals (calcium, iron, phosphorous) and vitamins (A, B, C) (Yasir, 2019) [5].

Used in various dishes like baigan bharta and baigan curry, brinjal has medicinal uses, acting as a remedy for liver complaints and an Ayurvedic treatment for diabetes. It serves as an appetizer, aphrodisiac, cardio tonic, laxative, and anti-inflammatory agent (Health Line by Rachael Link, 2017) [6].

Brinjal faces challenges from 140 insect pests, with the shoot and fruit borer being the most destructive, causing economic damage up to 89%. This pest is widely distributed in India, causing significant losses due to its rapid reproductive capacity and prevalence in both wet and dry seasons. Chemical techniques are predominantly employed by farmers, leading to issues such as pesticide resistance, environmental pollution, and disruptions in natural population balance (Sharma and Tayde, 2017) [7] Sustainable pest management practices are essential to mitigate these challenges and ensure the continued cultivation and nutritional value of this vital vegetable.

2. Materials and Methods

The investigation on the efficacy of bio-rational pesticides for managing *Leucinodes orbonalis* Guenee infesting brinjal was conducted at the experimental field of RCSM College of Agriculture, Kolhapur, during the *summer* season of 2022-23. The following material and methods were employed for the present investigations.

Experimental detail

Design of experiment	Randomized Block Design
Replications	: Three
Treatments	: Eight
Variety	: Shirgaon kata
Spacing	: 60 cm x 45 cm
Plot size	: 8 m x 4 m
Date of sowing	26/01/2023
Season	*Summer* 2022-23
RDF (kg/ha)	: 50:75:75 NPK

Table 1: Details of bio rational pesticides used in experiment

Sr. No.	Treatments	Dose (ml or g/L)	Trade Name	Source of supply
1	*Metarhizium anisopliae*	6	Phule Metarrhizium (1.15%WP)	MPKV, Rahuri
2	*Beauveria bassiana*	6	Phule Beauveria (1.15% WP)	MPKV, Rahuri
3	*Lecanicillium lecanii*	4	Phule Bugicide (1.15% WP)	MPKV, Rahuri
4	*B. thuringiensis*	2	Dipel (3.5% ES)	M/s. Wockhard India Ltd., Mumbai
5	Spinosad	0.4	Tracer (45% SC)	Sygenta Pvt. Ltd. Mumbai
6	Azadirachtin 1500 ppm	5	Econeem 1500 ppm	Margo biocontrol Pvt. Ltd.
7	*Heterorhabditis indica*	10	Sniper –WP (75,000-1,00,000 IJs/g)	Nimal Seed Pvt. Ltd,
8	Untreated Control		Phule Metarrhizium (1.15%WP)	

2.1 Methods of recording observations for the efficacy of bio rational pesticide

Brinjal shoot and fruit borer (BSFB) populations were assessed before the first day of spraying and on the 3rd, 7th, and 14th days after insecticidal application. Five randomly selected and tagged plants from each plot were used to record BSFB populations. The data were then converted into a percentage of infestation using specific formulas.

On Shoot

Number basis

The total number of shoots and number of infested shoots of five selected plants from each treatment replication wise was recorded. (Soulakhe *et al*, 2021) [8].

$$\% \text{ Shoot infestation} = \frac{\text{No. of shoot infested}}{\text{Total No. of shoot}} \times 100$$

On Fruit

Number basis

At each picking the total number of fruits and number of infested fruits of five selected plants from each treatment replication wise was recorded. (Gowrish *et al*, 2015) [9].

$$\% \text{ Fruit infestation} = \frac{\text{No. of fruit infested}}{\text{Total No. of fruit}} \times 100$$

Weight basis

At each picking the total weight of fruits and infested weight of fruits of five selected plants from each treatment replication wise was recorded. (Navale J.A *et al*, 2018) [10].

$$\% \text{ Damage} = \frac{\text{Wt. of infested fruit}}{\text{Total Wt. of fruit}} \times 100$$

2.2 Incremental Cost-Benefit Ratio (ICBR) and statistical analysis

Incremental Cost-Benefit Ratio (ICBR) was determined by dividing the net monetary return (B) by the total additional cost due to treatments (C). For statistical analysis, the percentage of fruit damage caused by borers underwent angular transformation using the ARCSIN method. The data were then subjected to standard analysis of variance as recommended by Panse and Sukhatame (1985) [11].

3. Results and Discussions

3.1 To study the efficacy of bio- rational pesticide for management of *Leucinodes orbonalis* Guenee, Infesting brinjal

3.1.1 First Spray against Shoot Borer Infestation

3.1.2 Pre-Spray Percentage of Shoot Borer (One day before the first spray)

Table No. 9 reveals uniformity in the pre-treatment population of L. orbonalis across the experimental area, showing infestation percentages ranging from 6.47% to 7.37%. The data were determined to be statistically non-significant (NS).

3.1.3. 3rd days after first spraying

Three days after the first spraying, all biopesticides proved significantly superior to the untreated control in reducing brinjal shoot borer incidence. Notably, T_5 (Spinosad @ 0.4 ml/L) exhibited the lowest shoot infestation at 3.00%, matching T_6 (Azadirachtin 1500 ppm @ 5g/L) at 3.50%. Other treatments included T_4 (*B. thuringiensis* @ 2ml/L) at

5.60%, T_1 (*Metarhizium anisopliae* @ 6 g/L) at 6.40%, T_2 (*Beauveria bassiana* @ 4 g/L) at 6.80%, T_3 (*Lecanicillium lecanii* @ 4 g/L) at 7.00%, and T_7 (*Heterorhabditis indica* @ 10 g/L) at 7.10%. Control (T_8) recorded the highest shoot infestation at 7.20%, significantly inferior to all tested biopesticides.

3.1.4 7th day after the first spraying

On the 7th day after the first spraying, a consistent reduction in shoot infestation was observed across all treatments. T_5 (Spinosad @ 0.4 ml/L) demonstrated superior efficacy with the lowest shoot infestation at 2.73%, statistically comparable to T_6 (Azadirachtin 1500 ppm @ 5 g/L) at 3.20%. The remaining treatments followed a sequential pattern, with T_4 (*B. thuringiensis* @ 2 ml/L) at 5.20%, T_1 (*Metarhizium anisopliae* @ 6 g/L) at 5.80%, T_2 (*Beauveria bassiana* @ 4 g/L) at 6.70%, T_3 (*Lecanicillium lecanii* @ 6 g/L) at 6.90%, and T_7 (*Heterorhabditis indica* @ 10 g/L) at 7.00%. Control (T_8) recorded the highest shoot infestation at 7.23%, significantly inferior to all tested biopesticide treatments.

3.1.5. 14th day after the first spraying

Fourteen days post the first biopesticide spray, T_5 (Spinosad @ 0.4ml/L) displayed the lowest shoot infestation at 2.50%, statistically comparable to T_6 (Azadirachtin 1500 ppm @ 5 g/L) at 2.80%. The remaining treatments followed a sequential pattern with statistically comparable results. Specifically, T_4 (*B. thuringiensis* @ 2 ml/L) showed 3.80% shoot infestation, T_1 (*Metarhizium anisopliae* @ 6 g/L) recorded 4.10%, T_2 (*Beauveria bassiana* @ 4 g/L) demonstrated 4.77%, T_3 (*Lecanicillium lecanii* @ 4 g/L) had 5.50%, and T_7 (*Heterorhabditis indica* @ 10 g/L) exhibited 6.80% shoot infestation. These treatments were statistically comparable. The control group (T_8) recorded the highest shoot infestation at 7.27%, significantly inferior to all tested biopesticide treatments.

Table 2: Efficacy of bio pesticide against shoot borer infestation after 1st spray

Sr. No	Treatment	Dose (g or ml/L)	Shoot borer Infestation (%)				Mean
			DBS	3 DAS	7 DAS	14 DAS	
T_1	*Metarhizium anisopliae*	6	7.00 (15.32)	6.40 (14.60)	5.80 (13.92)	4.10 (11.64)	5.43 (13.42)
T_2	*Beauveria bassiana*	6	7.40 (15.71)	6.80 (15.05)	6.70 (14.94)	4.77 (12.50)	6.09 (14.24)
T_3	*Lecanicillium lecanii*	4	7.30 (15.64)	7.00 (15.33)	6.90 (15.22)	5.50 (13.53)	6.47 (14.71)
T_4	*B. thuringiensis*	2	6.50 (14.49)	5.60 (13.68)	5.20 (13.17)	3.80 (11.21)	4.87 (12.70)
T_5	Spinosad	0.4	7.27 (15.61)	3.00 (9.73)	2.73 (9.28)	2.50 (8.82)	2.74 (9.53)
T_6	Azadirachtin 1500 ppm	5	7.37 (15.68)	3.50 (10.66)	3.20 (10.11)	2.80 (9.31)	3.17 (10.24)
T_7	*Heterorhabditis indica*	10	7.20 (15.56)	7.10 (15.45)	7.00 (15.23)	6.80 (14.99)	6.97 (15.30)
T_8	Untreated Control		7.13 (15.47)	7.20 (15.56)	7.23 (15.58)	7.27 (15.62)	7.23 (15.60)
	S.E(m) ±		0.85	0.74	0.79	0.74	0.75
	CD at 5%		NS	2.26	2.40	2.27	2.31
	CV (%)		9.58	9.37	10.22	10.63	10.07

*Figures in parentheses are arc sin transformation values, DAS -days after spray

4. Second spray against shoot borer infestation

The information regarding the infestation of *L. orbonalis* on shoots following the second spray was illustrated in Table No.2 Following the second spray, all bio rational pesticides treatments exhibited significant superiority over the untreated control in reducing the infestation of brinjal shoot borer. The shoot infestation caused by *L. orbonalis* decreased on the 3rd, 7th and 14th days after spraying.

Table 10: Efficacy of bio pesticide against shoot borer infestation after 2nd spray

Tr. No.	Treatment	Dose (g or ml/L)	Shoot borer Infestation (%)			Mean
			3 DAS	7 DAS	14 DAS	
T_1	*Metarhizium anisopliae*	6	3.90 (11.36)	3.50 (10.76)	3.40 (10.59)	3.60 (10.93)
T_2	*Beauveria bassiana*	6	4.60 (12.34)	4.50 (12.11)	4.30 (11.93)	4.47 (12.20)
T_3	*Lecanicillium lecanii*	4	5.30 (13.31)	5.10 (13.01)	4.50 (12.18)	4.97 (12.87)
T_4	*B. thuringiensis*	2	3.70 (11.07)	3.60 (10.78)	3.30 (10.46)	3.53 (10.83)
T_5	Spinosad	0.4	2.40 (8.61)	2.27 (8.35)	2.00 (8.02)	2.22 (8.57)
T_6	Azadirachtin 1500 ppm	5	2.60 (9.02)	2.50 (8.83)	2.43 (8.70)	2.51 (9.11)
T_7	*Heterorhabditis indica*	10	6.50 (14.73)	6.00 (14.04)	5.40 (13.41)	5.97 (14.13)
T_8	Untreated Control	6	7.30 (15.64)	7.47 (15.83)	7.50 (15.87)	7.42 (15.81)
	S.E(m) ±		0.76	0.72	0.63	0.70

	CD at 5%		2.33	2.21	1.94	2.16
	CV (%)		11.10	10.76	9.70	10.52

*Figures in parentheses are arc sin transformation values DAS -days after spray

4.1.3rd days after second spraying

On the 3rd day, T_5 (Spinosad @ 0.4ml/L) demonstrated the lowest shoot infestation at 2.40%, while T_6 (Azadirachtin 1500 ppm @ 5 g/L) showed 2.60%, both exhibiting superiority and statistical similarity. Other treatments followed a sequential pattern: T_4 (*B. thuringiensis* @ 2ml/L) at 3.70%, T_1 (*Metarhizium anisopliae* @ 6 g/L) at 3.90%, T_2 (*Beauveria bassiana* at 4 g/L) at 4.60%, T_3 (*Lecanicillium lecanii* @ 4 g/L) at 5.30%, and T_7 (*Heterorhabditis indica* @ 10 g/L) at 6.50%, increasing in shoot infestation. In contrast, T_8, the untreated control plot, recorded a significantly higher shoot infestation at 7.30%.

4.2.7th days after second spraying

The application of T_5 (Spinosad @ 0.4ml/L) resulted in the lowest shoot infestation at 2.27%, demonstrating significant superiority and statistical parity with T_6 (Azadirachtin 1500 ppm @ 5g/L) at 2.50%. T_4 (*B. thuringiensis* @ 2ml/L) showed a shoot infestation of 3.60%, T_1 (*Metarhizium anisopliae* @ 6g/L) recorded 3.50%, T_2 (*Beauveria bassiana* @ 4g/L) demonstrated 4.50%, T_3 (*Lecanicillium lecanii* @ 4g/L) had 5.10%, and T_7 (*Heterorhabditis indica* @ 10g/L) exhibited a shoot infestation of 6.0%, following an increasing order of shoot infestation. All these treatments were significantly superior to T_8, the untreated control plot, which showed a shoot infestation of 7.47%.

4.3.14th days after second spraying

On the 14th day after the second spray, T_5 (Spinosad @ 0.4ml/L) recorded the minimum shoot infestation at 2.00%, demonstrating superiority and statistical parity with T_6 (Azadirachtin 1500 ppm @ 5 g/L) at 2.43%, and T_4 (*B. thuringiensis* @ 2 ml/L) with a shoot infestation of 3.30%. T_1 (*Metarhizium anisopliae* @ 6 g/L) recorded 3.40%, T_2 (*Beauveria bassiana* @ 4 g/L) demonstrated 4.30%, T_3 *(Lecanicillium lecanii* @ 4 g/L) had 4.50%, and T_7 (*Heterorhabditis indica* @ 10 g/L) showed a shoot infestation of 5.40%, proving to be the second-best treatments. These treatments effectively reduced shoot infestation compared to T_8, the untreated control plot, which recorded 7.50% shoot infestation.

5. Third spray against shoot borer infestation

Information regarding the impact of various biopesticides on shoot borer infestation in brinjal after the third spray is available in Table No. 3. The data indicates that all the bio pesticides were significantly more effective than the untreated control.

Table 3: Third spray against shoot borer infestation

Tr. No	Treatment	Dose (g or ml/L)	Shoot borer Infestation (%)			Mean
			3 DAS	7 DAS	14 DAS	
T_1	*Metarhizium anisopliae*	6	3.20 (10.07)	3.10 (10.06)	3.00 (9.93)	3.10 (10.14)
T_2	*Beauveria bassiana*	6	4.10 (11.62)	3.80 (11.21)	3.60 (10.91)	3.83 (11.29)
T_3	*Lecanicillium lecanii*	4	4.30 (11.92)	4.00 (11.47)	3.90 (11.38)	4.07 (11.63)
T_4	*B. thuringiensis*	2	3.10 (10.06)	3.00 (9.88)	2.90 (9.71)	3.00 (9.97)
T_5	Spinosad	0.4	1.90 (7.81)	1.70 (7.43)	1.50 (6.97)	1.70 (7.48)
T_6	Azadirachtin 1500 ppm	5	2.10 (8.23)	1.90 (7.77)	1.70 (7.44)	1.90 (7.92)
T_7	*Heterorhabditis indica*	10	5.20 (13.12)	5.00 (12.92)	4.10 (11.45)	4.77 (12.59)
T_8	Untreated Control	6	7.57 (15.94)	7.60 (15.98)	7.70 (16.09)	7.62 (16.03)
	S.E(m) ±		0.66	0.55	0.69	0.63
	CD at 5%		2.02	1.68	2.94	2.21
	CV (%)		10.37	8.85	11.53	10.25

*Figures in parentheses are arc sin transformation values

5.1.3rd days after third spraying

On the 3rd day after the third spray, T_5 (Spinosad @ 0.4ml/L) recorded the minimum shoot infestation at 1.90%, statistically similar to T_1 (Azadirachtin @ 1500 ppm, 5 g/L) with a shoot infestation of 2.10%. T_4 (B. thuringiensis @ 2 ml/L) showed a shoot infestation of 3.10%, T_1 (Metarhizium anisopliae @ 6 g/L) recorded 3.20%, T_2 (*Beauveria bassiana* @ 6 g/L) demonstrated 4.10%, T_3 (*Lecanicillium lecanii* @ 4 g/L) had 4.30%, and T_7 (*Heterorhabditis indica* @ 10 g/L) showed a shoot infestation of 5.20%, proving to be the second-best treatments. In contrast, T_8, the untreated control plot, recorded a higher shoot infestation at 7.57%.

5.2.7th days after third spraying

On the 7th day after the third spray, T_5 (Spinosad @ 0.4ml/L) recorded the minimum shoot infestation at 1.70%, statistically similar to T_1 (Azadirachtin @ 1500 ppm, 5 g/L) with a shoot infestation of 1.90%. T_4 (B. thuringiensis @ 2 ml/L) showed a shoot infestation of 3.0%, T_1 (Metarhizium anisopliae @ 6 g/L) recorded 3.10%, T_2 (Beauveria bassiana @ 4 g/L) demonstrated 3.80%, T_3 (*Lecanicillium lecanii* @ 4 g/L) had 4.0%, and T_7 (Heterorhabditis indica @ 10 g/L) showed a shoot infestation of 5.0%, proving to be the second-best treatments. In contrast, T_8, the untreated control plot, recorded a higher shoot infestation at 7.60%.

5.3.14th days after third spraying

On the 14th day after the third spray, T_5 (Spinosad @ 0.4 ml/L) recorded the minimum shoot infestation at 1.50%, statistically similar to Azadirachtin @ 1500 ppm (5 g/L) with a shoot infestation of 1.70%. Additionally, T_4 (B. thuringiensis @ 2ml/L) showed a shoot infestation of 2.90%, T_1 (Metarhizium anisopliae @ 6g/L) recorded 3.0%, T_2 (Beauveria bassiana @ 6 g/L) demonstrated 3.60%, T_3 (*Lecanicillium lecanii* @ 6 g/L) had 3.90%, and T_7 (Heterorhabditis indica @ 10 g/L) showed a shoot infestation of 4.10%, making it the second-best treatment. In contrast, T_8, the untreated control plot, recorded a higher shoot infestation at 7.70%.

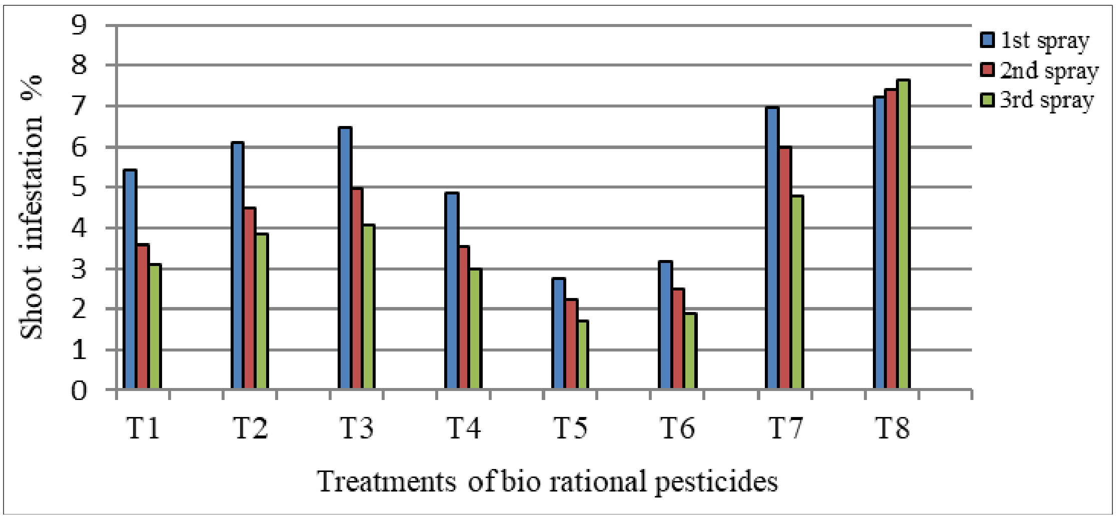
Table 4: Average shoot borer infestation at the 1st, 2nd and 3rd spray

Tr. No	Treatment	Dose (g or ml/L)	Shoot borer Infestation (%)			Mean
			1st spray	2nd spray	3rd spray	
T_1	*Metarhizium anisopliae*	6	5.43 (13.42)	3.60 (10.93)	3.10 (10.14)	4.21 (11.72)
T_2	*Beauveria bassiana*	6	6.09 (14.24)	4.47 (12.20)	3.83 (11.29)	4.89 (12.71)
T_3	*Lecanicillium lecanii*	4	6.47 (14.71)	4.97 (12.87)	4.07 (11.63)	5.66 (13.68)
T_4	*B. thuringiensis*	2	4.87 (12.70)	3.53 (10.83)	3.00 (9.97)	3.81 (11.20)
T_5	Spinosad	0.4	2.74 (9.53)	2.22 (8.57)	1.70 (7.48)	2.22 (8.53)
T_6	Azadirachtin 1500 ppm	5	3.17 (10.24)	2.51 (9.11)	1.90 (7.92)	2.53 (9.10)
T_7	*Heterorhabditis indica*	10	6.97 (15.30)	5.97 (14.13)	4.77 (12.59)	5.92 (14.04)
T_8	Untreated Control		7.23 (15.60)	7.42 (15.81)	7.62 (16.03)	7.42 (15.81)
	S.E(m) ±		0.75	0.70	0.63	0.69
	CD at 5%		2.31	2.16	2.21	2.22
	CV (%)		10.07	10.52	10.25	10.28

*Figures in parentheses are arc sin transformation values

Average shoot borer infestation at the 1st, 2nd and 3rd spray

The data in Table No.4 indicated that T_5 (Spinosad @ 0.4ml/L) exhibited the minimum shoot borer infestation at 2.22%, demonstrating superiority and statistical parity with T_6 (Azadirachtin @ 1500 ppm, 5 g/L) with 2.53% shoot infestation. Among other treatments, T_4 (*B. thuringiensis* @ 2 ml/L) had 3.81%, T_1 (*Metarhizium anisopliae* @ 6 g/L) recorded 4.21%, T_2 (*Beauveria bassiana* @ 6 g/L) had 4.89%, T_3 (*Lecanicillium lecanii* @ 4 g/L) showed 5.66%, and T_7 (*Heterorhabditis indica* @ 10 g/L) had 5.92%, proving to be the second-best treatments in reducing shoot infestation. However, all these treatments were significantly superior in reducing shoot infestation compared to T_8, the untreated control (7.42 percent). A comprehensive examination showed that all the biopesticides were effective in decreasing order: Spinosad > Azadirachtin at 1500 ppm > *B. thuringiensis* > *Metarhizium anisopliae* > *Beauveria bassiana* > *Lecanicillium lecanii* > *Heterorhabditis indica.* Their significance in reducing shoot infestation was evident when evaluated against the untreated control. The current findings closely align with previous research Mohit Singh *et al*, (2015) [12], The utilization of Spinosad 45 SC @ 200 ml/ha proved to be the most effective treatment in mitigating shoot and fruit damage across all observational intervals. Sharma and Tayde, (2017) [13] the least percentage of shoot infestation, fruit infestation, and the best benefit-to-cost ratio were observed in cypermethrin (control) with values of 6.69%, 9.33%, and 1:8.01, respectively. This was followed by spinosad, which recorded figures of 13.2%, 10.66%, and 1:7.63, respectively.



Average shoot borer infestation at the 1st, 2nd and 3rd spray

Efficacy of different biopesticide on yield of brinjal

The data in Table No.5 regarding the yield of brinjal fruit show significant differences in treatments with applied bio pesticides compared to the control. T_5 (Spinosad @ 0.4 ml/L) yielded the highest fruit production at 50 qt/ha, followed closely by T_6 (Azadirachtin @1500 ppm) with 43.75 qt/ha. Other treatments included T_4 (Bacillus *thuringiensis* @ 2 ml/L) with 40.62 qt/ha, T_1 (*Metarhizium anisoplae* @ 6 g/L) at 34.37 qt/ha, T_2 (*Beauveria bassiana* @ 6 g/L) at 32.81 qt/ha, T_4 (*Lecanicillium lecanii* @ 4 g/L) at 29.06 qt/ha, and T_7 (*Heterorhabditis indica* @10 g/L) at 25 qt/ha. The lowest yield was observed in T_7, the untreated control plot, at 17.18 qt/ha.

Table 5: Efficacy of different biopesticide on yield of brinjal

Tr. No	Treatment	Dose (g or ml/L)	Total Yield (kg/plot)	Yield (q/ha)
T_1	*Metarhizium anisopliae*	6	11	34.37
T_2	*Beauveria bassiana*	6	10.5	32.81
T_3	*Lecanicillium lecanii*	4	9.3	29.06
T_4	*B. thuringiensis*	2	13	40.62
T_5	Spinosad	0.4	16	50
T_6	Azadirachtin 1500 ppm	5	14	43.75
T_7	*Heterorhabditis indica*	10	8	25
T_8	Untreated Control	6	5.5	17.18

Incremental cost benefit ratio

In the economic analysis of various bio-pesticide treatments against major pests of brinjal (Table No.6), T_4 (*Bacillus thuringiensis* @ 2 ml/L) exhibited the most favorable incremental cost-benefit ratio (ICBR) of 1:32.32, followed by T_6 (Azadirachtin @ 1500 ppm) with a ratio of 1:27.51, T_1 (*Metarhizium anisoplae* @ 6 g/L) with a ratio of 1:24.69, T_2 (*Beauveria bassiana* @ 6 g/L) with a ratio of 1:22.45, T_4 (*Lecanicillium lecanii* @ 4 g/L) with a ratio of 1:17.06, T_5 (Spinosad @ 0.4 ml/L) with a ratio of 1:16.78, and T_7 (*Heterorhabditis indica* @ 10 g/L) with a ratio of 1:4.99.

Table 6: Economics and ICBR of different bio rational pesticides used in brinjal

Tr. No.	Yield q/ha	Cost of cultivation except cost of bio pesticides Rs/ha	Total cost of Cultivation	Value additional Yield over untreated control (Rs/ha)	Gross Marginal return Rs/ha	Net Profit Rs/ha	B:C Ratio	ICBR
1	34.37	32231	33971	42975	85925	51954	2.52	24.69
2	32.81	32231	33971	39075	82025	48054	2.41	22.45
3	29.06	32231	33971	29700	72650	38679	2.13	17.06
4	40.62	32231	34044	58600	101550	67506	2.98	32.32
5	50	32231	37118	82050	125000	87882	3.36	16.78
6	43.75	32231	34645	66425	109375	74729	3.15	27.51
7	25	32231	36144	19550	62500	26356	1.72	4.99
8	17.18	32231	-	-	42950	-	-	-

Rate of Brinjal: 25 Rs/kg

6. Conclusion

Based on the results and discussion of the present investigation, the following conclusions are proposed-

1. T_5 (Spinosad @ 0.4 ml/L) was found to be a significantly effective treatment against shoot and fruit borer, which was comparable to T_6 (Azadirachtin @ 1500 ppm)
2. The highest cost benefit ratio were recorded- T_5-spinosad @ 0.4 ml/L, followed by T_6-Azadirachtin @1500 ppm
3. The highest incremental cost-benefit ratio (ICBR) were recorded- T_4-*Bacillus thuringiensis* @ 2 ml/L followed by T_6-Azadirachtin @1500 pp

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