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Efficacy of bio-rational pesticides for the management of *Leucinodes orbonalis* Guenee, infesting brinjal (On Fruit)

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Abstract

In the summer of 2022-23, a field experiment was conducted at the research farm in RCSM College of Agriculture Kolhapur, employing a randomized block design with three replications and encompassing 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 - *Bacillus 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 assess the efficacy of bio-rational pesticides for managing *Leucinodes orbonalis* Guenee infestations in brinjal. Three sprays were applied at 21days intervals, recording data on shoot and fruit infestation at each spraying and picking, including the percentage of fruit infestation. The initial pest population before the spray showed a non-significant distribution. However, post-spray, T_5 - Spinosad @ 0.4 ml/L proved significantly effective against shoot and fruit borers, comparable to T_6 - Azadirachtin @ 1500 ppm at 3, 7, and 14 days post-spraying. Following closely in efficacy were *Bacillus thuringiensis* and *Metarhizium anisopliae*. The highest cost-benefit ratios were recorded for T_5 - Spinosad @ 0.4 ml/L, followed by T_6 - Azadirachtin @ 1500 ppm. The highest incremental cost-benefit ratios (ICBR) were recorded for T_4 - *Bacillus thuringiensis* @ 2 ml/L, followed by T_6 - Azadirachtin @ 1500 ppm, i.e., Spinosad > Azadirachtin at 1500 ppm > *Bacillus thuringiensis* > *Metarhizium anisopliae* > *Beauveria bassiana* > *Lecanicillium lecanii* > *Heterorhabditis indica* > untreated control.

Keywords: *Leucinodes orbonalis,* integrated pest management, field experiment

Introduction

Vegetables play a crucial role in sustaining human existence, significantly contributing to food security and meeting the nutritional needs of a growing global population. They offer essential vitamins, minerals, dietary fiber, and phytochemicals, each uniquely contributing to overall health. Different vegetable groups provide distinct combinations of these phytonutrients, delivering diverse health benefits such as 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, comprising over 2,450 species across 95 genera (Mabberley, 2008) [2]. With a chromosome number of 2 n = 24, brinjal holds historical significance in India, dating back over 4,000 years, and is considered indigenous to the Indian subcontinent. It is referred to as the "Monarch of Vegetables," with India being the second-largest global producer after China. Despite its colloquial label as "poor man's" food, eggplant is commercially important, significantly contributing to both kitchen gardens and market prices (Abhishek, 2021) [3].

As a summer crop, eggplant is susceptible to frost and climatic factors, particularly low temperatures during the cooler season, leading to abnormal ovary growth and deformed fruits. It thrives in hot and humid conditions for optimal fruit development and is cultivated year-round under irrigated conditions (Nothmann *et al*., 1973) [5]. 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, being rich in minerals (calcium, iron, phosphorous) and vitamins (A, B, C) (Yasir, 2019) [6].

Used in various dishes like baigan bharta and baigan curry, brinjal has medicinal uses, serving as a remedy for liver complaints and an Ayurvedic treatment for diabetes. It functions as an appetizer, aphrodisiac, cardio tonic, laxative, and anti-inflammatory agent (Health Line by Rachael Link, 2017) [7].

Brinjal faces challenges from 140 insect pests, with the shoot and fruit borer being the most destructive, causing economic damage up to 89%. Widely distributed in India, this pest causes significant losses due to its rapid reproductive capacity and prevalence in both wet and dry seasons. Farmers predominantly resort to chemical techniques, leading to issues like pesticide resistance, environmental pollution, and disruptions in natural population balance (Sharma and Tayde, 2017) [8]. Sustainable pest management practices are crucial to mitigate these challenges and ensure the continued cultivation and nutritional value of this vital vegetable.

Material and Methods

The study on the efficacy of bio-rational pesticides in managing *Leucinodes orbonalis* Guenee infestation in brinjal took place at the experimental field of RCSM College of Agriculture, Kolhapur, during the summer season of 2022-23. The following materials and methods were employed for the current investigation.

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)	

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

The assessment of Brinjal Shoot and Fruit Borer (BSFB) populations involved recording observations before the initial day of spraying and on the 3rd, 7th, and 14th days following insecticidal application. For each plot, five randomly selected and tagged plants were utilized to document BSFB populations. The collected data were subsequently transformed into a percentage of infestation through the application of specific formulas. (Soulakhe *et al.*, 2021) [9].

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) [10].

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

Weight basis: At each picking the total weight of fruits and infested weight of fruits of five selected plants from each treatment replication wisewasrecorded. (Navale J.A *et al.*, 2018) [11].

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

Incremental cost-benefit ratio (ICBR) and statistical analysis

The calculation of Incremental Cost-Benefit Ratio (ICBR) involved 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. Subsequently, the transformed data underwent standard analysis of variance, following the recommended approach by Panse and Sukhatame (1985) [19].

Results and Discussion

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

Table 2: Efficacy of bio- rational pesticides against fruit borer infestation (Weight basis)

Tr. No.	Treatment	Dose (g or ml/L)	Mean % fruit infestation after Different pickings (Weight basis)			Mean
			1st picking	2nd picking	3rd picking	
T_1	*Metarhizium anisopliae*		9.00 (17.42)	8.50 (16.86)	8.00 (16.36)	8.50 (16.95)
T_2	*Beauveria bassiana*	6	10.07 (18.36)	7.93 (16.20)	7.80 (16.21)	8.60 (17.03)
T_3	*Lecanicillium lecanii*	6	12.67 (20.83)	11.00 (19.36)	8.60 (17.02)	10.76 (19.09)
T_4	*B. thuringiensis*	4	9.17 (17.61)	6.63 (14.92)	7.00 (15.19)	7.60 (15.96)
T_5	Spinosad	2	5.47 (13.34)	3.93 (11.26)	3.60(10.62)	4.33 (11.97)
T_6	Azadirachtin 1500 ppm	0.4	5.80 (13.80)	4.00 (11.31)	3.90 (11.15)	4.57 (12.29)
T_7	*Heterorhabditis indica*	5	10.63 (21.89)	9.27 (17.66)	9.07 (17.50)	9.66 (18.09)
T_8	Untreated Control	10	11.37 (19.70)	12.00 (20.21)	15.30 (23.02)	12.89 (21.00)
	SE(m) ±		1.05	0.86	0.33	1.00
	CD at 5%		3.19	2.62	1.00	3.06
	CV (%)		10.41	9.36	11.14	10.63

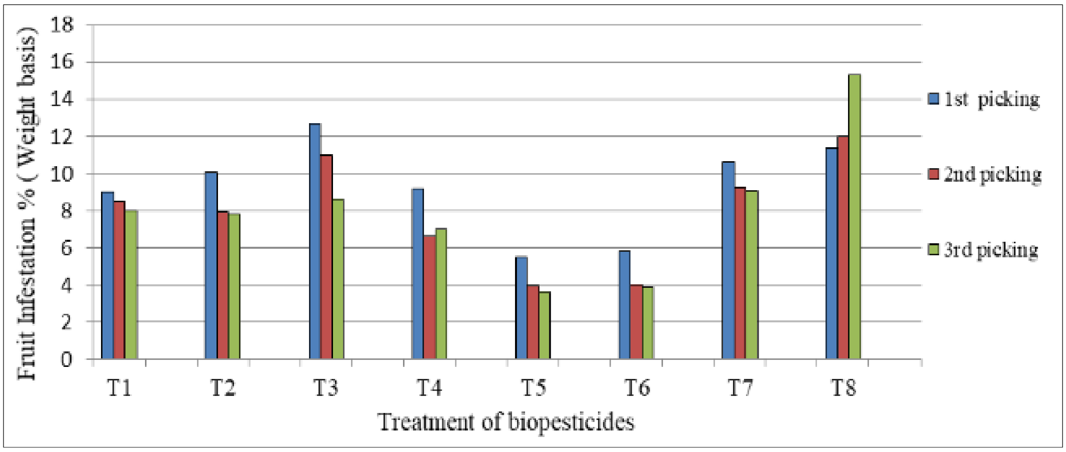

Fig 1: Efficacy of bio- rational pesticides against fruit borer infestation (Weight basis)

Percent fruit damage (Weight basis)

Table s2 reveals that all the biopesticide treatments exhibited significantly lower infestation of fruit borer on a numerical basis when compared to the untreated control

First picking infestation

During the initial picking, it was observed that the lowest percentage of fruit damage was recorded in T_5 - Spinosad @ 0.4 ml/L, with 5.47 percent fruit damage, which was statistically comparable to Azadirachtin @ 1500 ppm, 5 g/L, recording 5.80 percent fruit damage. The remaining treatments, namely T_1 - *Metarhizium anisopliae* @ 6 g/L, recorded 9.0 percent fruit infestation; T_4 - *Bacillus thuringiensis* @ 2 ml/L recorded 9.17 percent fruit infestation; T_2 - *Beauveria bassiana* @ 6 g/L recorded 10.07 percent fruit infestation; T_3 - Lecanicillium lecanii @ 4 g/L recorded 12.67 percent fruit infestation, and T_7 - *Heterorhabditis indica* @ 10 g/L recorded 10.63 percent fruit damage. The highest level of fruit damage, i.e., 11.37 percent, was found in T_8 - the untreated control.

Second picking infestation

The results of the second picking indicate that among the various treatments, T_5 - Spinosad @ 0.4 ml/L exhibited the lowest percentage of fruit damage, with only 3.93%. This result was statistically comparable to the performance of Azadirachtin @ 1500 ppm, 5 g/L, which recorded 4.00% fruit damage. The remaining treatments showed varying degrees of fruit damage. T_4 - *Bacillus thuringiensis* @ 2 ml/L had a fruit damage percentage of 6.63%, while T_2 - *Beauveria bassiana* @ 6 g/L recorded 7.93% fruit infestation. T_1 - *Metarhizium anisopliae* @ 6 g/L exhibited a higher level of fruit damage at 8.50%, T_4 - *Lecanicillium lecanii* @ 4 g/L recorded a fruit infestation rate of 11.0%, and T_7 - *Heterorhabditis indica* at 10 g/L had the highest fruit damage percentage at 9.27%. The untreated control group, T_8, which did not receive any treatment, showed the highest level of fruit damage at 12.0%. It's important to note that these observations suggest that Spinosad @ 0.4 ml/L and Azadirachtin at 1500 ppm @ 5g/L were the most effective treatments in minimizing fruit damage during the second picking, while the untreated control group had the highest fruit damage percentage.

Third picking infestation

Results indicate that during the third picking, T_5 - Spinosad @ 0.4 ml/L continued to exhibit the lowest percentage of fruit damage at 3.60%. This outcome remained statistically comparable to the performance of T_6 - Azadirachtin at 1500 ppm @ 5 g/L, which recorded 3.90% fruit damage. The other treatments showed varying levels of fruit damage, with T_4 - *Bacillus thuringiensis* @ 2 ml/L at 7.0%, T_2 - *Beauveria bassiana* @ 6 g/L at 7.80%, and T_1 - *Metarhizium anisopliae* at 6 g/Lit at 8.50%. Additionally, T_4 - *Lecanicillium lecanii* at 4 g/L recorded a fruit infestation rate of 8.60%, T_7 - *Heterorhabditis indica* @ 10 g/L had the highest fruit damage percentage at 9.07%, and the untreated control group, T_8, showed the highest level of fruit damage at 15.30%. The observations suggest that, similar to the first and second picking, Spinosad @ 0.4 ml/L and Azadirachtin at 1500 ppm @ 5 g/L were the most effective treatments in minimizing fruit damage during the third picking. The untreated control group again had the highest fruit damage percentage.

Mean of fruit infestation

Results indicate that the mean of all pickings, T_5 - Spinosad @ 0.4 ml/L, continued to exhibit the lowest percentage of fruit damage at 4.33%. This outcome remained statistically comparable to the performance of T_6 - Azadirachtin at 1500 ppm @ 5 g/Lit, which recorded 4.57% fruit damage. The other treatments showed varying levels of fruit damage, with T_4 - *Bacillus thuringiensis* @ 2 ml/L at 7.60%, T_2 - *Beauveria bassiana* @ 6 g/L at 8.60%, and T_1 - *Metarhizium anisopliae* @ 6 g/L at 8.50%. Additionally, T_4 - *Lecanicillium lecanii* @ 4 g/L recorded a fruit infestation rate of 8.60%, T_7 - *Heterorhabditis indica* @ 10g/L had the highest fruit damage percentage at 9.66%, and the untreated control group, T_8, showed the highest level of fruit damage at 12.89%. The observations suggest that in all three pickings, Spinosad @ 0.4 ml/L and Azadirachtin at 1500 ppm @ 5 g/L were the most effective treatments in minimizing fruit damage during all three pickings. The untreated control group again had the highest fruit damage percentage.

The results align with studies such as Navale *et al.*, (2018) [11], where Emamectin benzoate and selected insecticides and bio-pesticides like Spinosad 45 SC showed good results against *Leucinodes orbonalis* and could be part of integrated pest management. Similarly, Machhindra *et al.*, (2023) [15] found good potential for controlling BSFB (*Leucinodes orbonalis*), with Spinosad 45% SC identified as the best treatment. In comparison, Sureshsing *et al.*, (2017) [17] reported that Spinosad exhibited the lowest percentage of infestation of shoot and fruit borer at 6.87%, significantly lower than the control (16.97%). Tayde *et al.*, (2010) [16] also demonstrated Spinosad's effectiveness in controlling fruit infestation, both numerically and on a weight basis, with statistically significant results compared to other treatments.

Percent Fruit Damage (Number Basis)

Table 3: Efficacy of bio- rational pesticides against fruit borer infestation (Number basis)

Tr. No	Treatment	Dose (g or ml/L	Mean % fruit infestation after different pickings (Number basis)			Mean
			1st picking	2nd picking	3rd picking	
T_1	*Metarhizium anisopliae*	6	10.00 (18.42)	9.40 (17.78)	6.10 (14.17)	8.50 (16.86)
T_2	*Beauveria bassiana*	6	10.20 (18.52)	7.60 (15.89)	6.30 (14.39)	8.03 (16.39)
T_3	*Lecanicillium lecanii*	4	10.00 (18.42)	9.10 (17.54)	8.50 (16.91)	9.20 (17.65)
T_4	*B. thuringiensis*	2	9.97 (18.26)	7.10 (15.31)	6.50 (14.75)	7.86 (16.21)
T_5	Spinosad	0.4	6.90 (15.15)	4.30 (11.78)	3.20 (10.30)	4.80 (12.50)
T_6	Azadirachtin 1500 ppm	5	7.10 (15.43)	4.50 (12.18)	3.60 (10.93)	5.07 (12.88)
T_7	*Heterorhabditis indica*	10	11.20 (19.40)	10.10 (18.47)	6.20 (14.33)	9.17 (17.50)
T_8	Untreated Control		12.10 (20.35)	12.50 (20.70)	13.00 (21.12)	12.53 (20.73)
	SE(m)+		0.88	0.80	0.89	0.85
	CD at 5%		2.70	2.44	2.72	2.62
	CV (%)		8.55	8.58	10.63	9.25

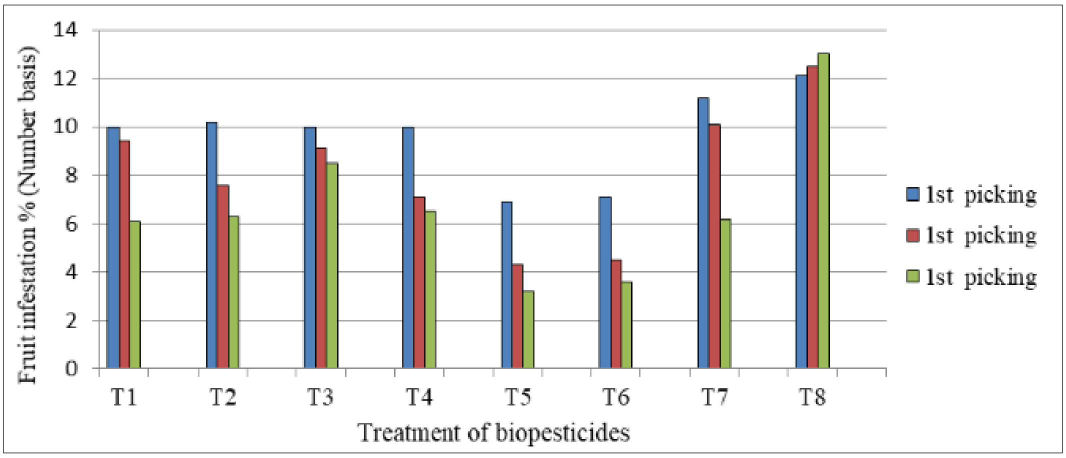

Fig 2: Efficacy of bio- rational pesticides against fruit borer infestation (Number basis)

First picking infestation

In the initial harvest, notable differences in fruit damage were observed among treatments. T_5 (Spinosad @ 0.4 ml/L) recorded the lowest percentage of fruit damage at 6.90%, statistically comparable to T_6 (Azadirachtin at 1500 ppm, @ 5 g/L) with 7.10% fruit damage. Other treatments exhibited varying degrees of fruit damage, with T_8 (untreated control) having the highest at 12.10%. Results suggest that T_5 and T_6 were particularly effective in minimizing fruit damage during this period.

Second picking infestation

During the second harvest, T_5 (Spinosad @ 0.4 ml/L) showed the least fruit damage at 4.30%, similar to T_6 (Azadirachtin at 1500 ppm, @ 5 g/L) with 4.50% fruit damage. T_8 (untreated control) had the highest fruit damage at 12.50%. T_5 and T_6 were effective in reducing fruit damage compared to other treatments during this time.

Third picking infestation

In the third harvest, T_5 (Spinosad @ 0.4 ml/L) again exhibited the least fruit damage at 3.20%, comparable to T_6 (Azadirachtin at 1500 ppm, @ 5 g/L) with 3.60% damage. T_8 (untreated control) had the highest fruit damage at 13.0%. T_5 and T_6 were particularly effective in minimizing fruit damage compared to other treatments during this period.

Mean of fruit infestation

Across all pickings, T_5 (Spinosad @ 0.4 ml/L) consistently exhibited the lowest fruit damage at 4.80%, comparable to T_6 (Azadirachtin at 1500 ppm, @ 5g/L) with 5.07% fruit damage. T_8 (untreated control) consistently showed the highest fruit damage at 12.53%. T_5 and T_6 were consistently the most effective treatments in minimizing fruit damage.

The results align with previous studies, such as Patra *et al.* (2009) [18], Mane *et al.* (2020) [20], Mohit Singh *et al.* (2015) [13], and Devi *et al.* (2015) [4], highlighting the effectiveness of Spinosad in minimizing fruit damage, making it a promising choice for pest management

Efficacy of different biopesticides on brinjal yield

Table 4 presents significant differences in brinjal fruit yield among treatments with applied biopesticides compared to the control. T_5 (Spinosad @ 0.4 ml/L) achieved the highest fruit production at 50 qt/ha, closely followed by T_6 (Azadirachtin @1500 ppm) with 43.75 qt/ha. Other treatments included T_4 (Bacillus thuringiensis @ 2 ml/L) at 40.62 qt/ha, T_1 (*Metarhizium anisopliae* @ 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 untreated control plot, T_7, exhibited the lowest yield at 17.18 qt/ha.

Table 4: Yield of Brinjal

Tr. No	Treatment	Dose (g or ml/L)	Total Yield n (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 5), 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 anisopliae* @ 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 5: 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/h)	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	-	-	-

Conclusion

The study's findings underscore the efficacy of various biopesticides in managing brinjal shoot and fruit borer infestations while also positively impacting brinjal yield. Throughout the harvesting periods, treatments T_5 (Spinosad @ 0.4 ml/L) and T_6 (Azadirachtin @ 1500 ppm, @ 5 g/L) consistently demonstrated superior performance in minimizing fruit damage compared to other treatments and the untreated control group. This aligns with previous research, emphasizing the effectiveness of Spinosad in particular for pest management in brinjal cultivation. Moreover, the application of biopesticides resulted in significantly higher brinjal fruit yields compared to the untreated control, with T_5 exhibiting the highest yield at 50 qt/ha.

These findings highlight the potential of biopesticides as sustainable alternatives for pest management in brinjal cultivation, offering both effective pest control and enhanced yield outcomes. Further research and field trials may be warranted to explore the long-term effectiveness and environmental impact of these biopesticides, as well as their economic feasibility for farmers. Overall, the study contributes valuable insights into integrated pest management strategies for brinjal cultivation, with implications for improving agricultural sustainability and food security.

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