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ASSESSMENT OF SUSTAINABLE APPROACHES TO COMBAT BRINJAL SHOOT AND FRUIT BORER (*LEUCINODES ORBONALIS* GUENEE) INFESTATION

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ABSTRACT

A study was conducted to evaluate different treatment modules against the brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee, in the AKLB-9 variety of brinjal crops. The research took place in the field at the Department of Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *Kharif* season of 2019-20. The primary objectives were to assess the performance of various modules against the major insect pests of brinjal and to determine the relative safety of botanicals, bio-pesticides, bioagents and chemicals to natural enemies. Four treatment modules were tested using a randomized block design. These modules involved actions such as seedling dipping, removal of infested shoots, release of beneficial insects and application of different substances at specific intervals. The first application of each module occurred on Days After Transplanting (DAT) 20 and 60, with subsequent applications at 10-day intervals. Observations were made on the infestation of brinjal shoot borer and its natural enemies, including cumulative percentages of shoot and fruit infestation, at 3, 7 and 10 days after each spray. Average population of natural enemies per plant was also recorded. Additionally, the study evaluated the yield and Incremental Cost-Benefit Ratio (ICBR) of the different treatment modules for cost-effectiveness. Results indicated that Treatment Module 2 was the most effective against brinjal shoot and fruit borer, while Treatment Module 3 showed promise in minimizing shoot infestation. Modules 1 and 4 were observed to be safer for natural enemies like ladybird beetles. Treatment Modules 2 and 3 were found promising in minimizing fruit infestation, with Module 1 found to be safer for spiders. Treatment Module 2 emerged as the most effective and economically viable, recording an ICBR of 1:60.98. These findings contribute valuable insights into sustainable pest management practices for brinjal cultivation.

Key words : Brinjal, Integrated Pest Management, *Leucinodes orbonalis*, Modules.

Introduction

Botanically identified as *Solanum melongena* L. (2n=24), brinjal, commonly known as eggplant, belongs to the Solanaceae family. Its origin and diversity center in India (Bahaduri, 1951). Brinjal holds a vital position among vegetables in South and Southeast Asia, particularly during the hot and wet seasons when other vegetables are scarce (Thapa, 2010; Hanson *et al*., 2006). It serves as an affordable staple for both rural and urban populations, earning its reputation as the "poor man's crop." Not only is it economically accessible, but it also boasts high nutritive value, containing essential minerals, vitamins and amino acids.

Cultivated in India for over 4000 years, brinjal is a prevalent vegetable in warmer climates, including the Mediterranean and the Middle East. Among solanaceous vegetables, it is a favoured and economically significant crop for small-scale farmers, acting as a crucial cash crop for those in need. South Asia, comprising Bangladesh, India, and Pakistan, contributes about 50% of the global area dedicated to eggplant cultivation (Alam *et al*., 2003). In India, where approximately 4.5 million hectares are under vegetable cultivation, brinjal plays a pivotal role, especially considering the predominantly vegetarian population with a per capita consumption of 135 g per day, falling short of the recommended 300 g per day

(Dhandapani *et al*., 2003).

Brinjal cultivation faces significant challenges due to the infestation of various insect pests, acting as a limiting factor for profitable growth. Approximately 140 species of insect and non-insect pests from 50 families target brinjal, with notable culprits including the shoot and fruit borer (*Leucinodes orbonalis* Guenee), leaf hopper (*Amrasca biguttula biguttula*), aphid (*Aphid gossypii*), hadda beetle (*Epilachna* spp.) and brinjal stem borer (*Euzophera particrlla* Rag) (Butani and Jotwani, 1984).

The brinjal shoot and fruit borer, *Leucinodes orbonalis*, stands out as a destructive key pest across Asia, posing a major hurdle in both quantitative and qualitative brinjal fruit production (Purohit and Khatri, 1973; Kupuswamy and Balasubramanian, 1980; Latif *et al*., 2010; Chakraborti and Sarkar, 2011; Saimandir and Gopal, 2012; Hussain *et al*., 2020). Active during the grand growth period, this pest inflicts the highest damage on shoots, followed by flowers, flower buds, fruits, and midribs of leaves (Alpuruto, 1994). Larvae bore into tender shoots, flowers, or fruits, causing wilting, dropping, and withering of young shoots, leading to delayed crop maturity and reduced yield. Fruit tissue destruction and rotting may occur in severe cases (Neupane, 2001).

With a life cycle completed in 3-6 weeks, the brinjal shoot and fruit borer exhibits five overlapping generations in a year. Infestations and losses vary based on location, season, environmental factors, cultivars and plant age. Fruit infestation has been reported to range from 31-90% in Bangladesh, 37-63% in India, and 50-70% in Pakistan, resulting in yield reduction of up to 90% (Raheman, 1997; Dhanker, 1988; Saeed and Khan, 1997). Controlling this pest proves challenging as it resides within the shoot or fruit, making direct pesticide application difficult (Alam *et al*., 2003). Despite reliance on pesticides by farmers, increasing tolerance of the insect to chemicals complicates control efforts (Talekar, 2002). Moreover, the indiscriminate use of toxic pesticides poses health risks to farmers and consumers and contributes to environmental contamination.

In response to these challenges, alternative non-chemical approaches have been emphasized. The present study aims to evaluate different modules, including the removal of infested terminal shoots, the release of the bio control agent *Trichogramma chilonis* and the application of botanicals and biopesticides, against the brinjal shoot and fruit borer, offering potential solutions that are both effective and environmentally friendly.

Materials and Methods

An experiment was conducted on brinjal crops, specifically the AKLB-9 variety, in the field at the Department of Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during the *Kharif* season of 2019-20. The primary objective was to evaluate the effectiveness of various botanicals, biopesticides, bioagents and chemicals in managing the major insect pests affecting brinjal. Additionally, the study aimed to assess the impact of these substances on the population of beneficial insects, specifically natural enemies. Four treatment modules were tested using a randomized block design. The investigation involved the use of different materials, including botanicals, biopesticides, bioagents, and chemicals, to determine their performance in pest management. The relative safety of these substances towards beneficial insects, essential for natural pest control was also a focal point of the research.

Information regarding the materials employed in this study, including botanicals, biopesticides, bioagents and chemicals, is provided in Table 1. This table specifies details such as common names, formulations, concentrations, chemical names, trade names and their respective sources of supply.

Four distinct treatment modules were employed, incorporating botanicals such as Neem Seed Extract (NSE) at 5%, Azadirachtin at 1500 ppm and Neem cake, along with bio-pesticides like *Beauveria bassiana* at 1x109 CFU, *Metarhizium anisopliae* at 1×10^8 CFU, and *Trichogramma chilonis* at 1.5 lakh/ha. Additionally, various chemicals such as Dimethoate 30 EC, Imidacloprid 17.8% SL, Chlorantroniliprole 18.5% SC, Chloropyriphos 20 EC, Diafenthiuron 50% WP, Cypermethrin 25% EC, Fenpropathrin 30% EC and Emamectin benzoate 5% SG were included. The evaluation of these treatments occurred at different days after transplanting (DAT) within each module to assess their effectiveness in managing major insect pests affecting brinjal. The specific details of each treatment module can be found in Table 2.

Preparation of Neem Seed Extract (NSE) : A quantity of 5 kg of dried crushed neem seeds was taken for every 100 liters of water. The weighed seeds were ground and soaked overnight in a vessel with sufficient water. The next day, the extract was filtered through muslin cloth, and the process was repeated with water washing until complete extraction was ensured. The obtained suspension was adjusted for volume by adding the remaining quantity of water. To this extract, soap powder at 0.2% (200 gm/100 liters of water) was added

Table 1 : Details of botanicals, bio-pesticides, bioagent and chemicals used in the experiments.

S. no.	Common name	Common name/ Scientific name	Formulation	Trade name	Conc. (%) used	Sources of supply
1	Neem Seed Extract (NSE)	In crude form (*Azadirachta indica* A. Juss)		NSE	5%	Jay Bajrang Krushi Sewa Kendra, Akola
2	Azadirachtin	*Azadirachtin*	1500 ppm	EAZYFERT	0.15 %	MIDC Khamgaon
3	Neem cake		-	Neem cake		MIDC Khamgaon
4	*Beauveria bssiana*	*Beauveria bssiana*	1×10^9 CFU			Dept. of Plant Pathology, Dr. PDKV,Akola
5	*Metarhizium anisopliae*	*Metarhizium anisopliae*	1×10^9 CFU			Dept. of Plant Pathology, Dr. PDKV, Akola
6	Trichocard	*Trichogramma chilonis*				Biocontrol Laboratory, Dept. of Entomology, Dr. P.D.K.V., Akola
7	Dimethoate 30 EC	N-methyl-2-sulfanyiacetamide	660 (gm/ml)	TAFGOR	200 gm	TATA
8	Imidacloprid 17.8% SL	1-(6-chloro-3-pyridinyl methyl)N-nitro-2-imidazolinmine	150-175 (gm/ml)	Confider	30-35 gm	M/S Bayer Crop Sciences Ltd., Mumbai
9	Chloropyriphos 20 EC	(3,5,6 trichloro2-pyridinyl) phosphothioate	1000 (gm/ml)	STAMPEDE	40 gm	Sudarshan Pvt. LTD.
10	Diafenthiuron 50%WP	1-tetra-butyl-3-(2,6-di-isopropyl-4-penoxyphenyl) thiourea	3000 (gm/ml)	Pegasus	3000 gm	Syngenta Ltd., Mumbai
11	Cypermethrin 25% EC	(R,S)-alpha-cyano-3-phenoxybenzyl(1RS)-cis, trans-3-92,2-dichlorovinyl)-2,2-dimethylcyclopropane-carboxylate	150-200 (gm/ml)	superkillar	37-50 gm	Dhanuka Agritech Limited
12	Fenpropathrin 30%EC	2,2,3,3-tetramethylcyclo-propane-carboxylic acid	250-340 (gm/ml)	Meothrin	75-100 gm	Sumitomo chemicals limited
13	Emamectin benzoate 5%SG	Natural fermentation product of soil bacterium *Streptomyces avermittis*	200 (gm/ml)	Proclaim	10 gm	Syngenta Ltd., Mumbai
14	Chlorantronili-prole 18.5%SC		200 (gm/ml)	Coragen	40 gm	FMC India Private Ltd.

to enhance material coverage on the crop.

Preparation of Bio-Pesticide Suspension : The required quantity of *B. bassiana* and *M. anisopliae* for treatment was determined based on the plot area to be treated.

Method of application of Bio-pesticides, Botanicals

Method of Dipping the Seedling Tip during transplanting : During transplanting, the tips of seedlings were immersed in an insecticide-fungicide solution, specifically dimethoate 30 EC at 10 ml/10 liters combined with sulphur 40 WP at 20 gm/10 liters of water.

Method of applying botanicals and bio-pesticides : The application of bio-pesticides, including *B. bassiana*, *M. anisopliae*, and botanicals like Azadirachtin and NSE, commenced at 50 days after transplanting (DAT) of brinjal seedlings, following the schedule outlined in each

Table 2 : Details of treatment Modules.

Module-1	a. Dipping of seedlings in Dimethoate 30 EC @ 10 ml/L of water before transplanting. b. Removal of infested terminal shoot at 20, 30 and 40 DAT. c. Release of *Trichogramma chilonis* 1.5 lakh/ha at 50 and 60 DAT. d. Application of Azadirachtin 1500 ppm (3 ml/L) at 70 and 80 DAT. e. Application of *Metarhizium anisopliae* 1×10^9cfu @ 4 g/L 90 and 100 DAT.
Module-2	a. Dipping of seedlings in Imidacloprid 17.8% SL @ 0.5 ml/l of water before transplanting. b. Removal of infested terminal shoots at 20, 30 and 40 DAT. c. Application *of Beauveria bassiana* 1×10^9cfu @ 4 g/L at 50 and 60 DAT. d. Application of *Metarhizium anisopilae* 1×10^9cfu @ 4 g/L at 70 and 80 DAT. e. Spraying of Chlorantroniliprole 18.5% SC @ 0.3 ml/L at 90 and 100 DAT.
Module-3	a. Soil application of neem cake @ 250 kg/ha. b. Removal of infested terminal Shoots at 20, 30 and 40 DAT. c. Release of *Trichogramma chilonis* @ 1.5 lakh/ha at 50 60 and 70 DAT. d. Application of NSE 5% at 80 and 90 DAT. e. Application *Beauveria bassiana* 1×10^9cfu @ 4 gm/L at 100 DAT.
Module-4 (Farmer's practice)	a. Chloropyriphos 20 EC @ 2 ml/L at 20 DAT. b. Diafenthiuron 50% WP @ 0.80 ml/L at 30 and 40 DAT. c. Cypermethrin 25% EC @ 0.5 ml at 50 and 60 DAT. d. Fenpropathrin 30% EC @ 0.5 ml/L at 70 DAT. e. Emamectin benzoate 5% SG @ 0.5 gm/L at 80 and 90 DAT. f. Chlorantraniliprole 18.5% SC @ 0.3 ml/L at 100

DAT = Days after transplanting.

treatment module. Subsequent applications were made at 10-day intervals.

Method of recording observations

Observations were recorded in the field after transplanting, focusing on the following aspects:

Per cent Shoot infestation: Five randomly selected plants from each plot were labelled for observation. When pest infestation on shoots began, observations were made on the total number of shoots and the number of infested shoots for five selected plants from each treatment replication. The per cent shoot infestation was calculated using the formula:

$$\text{Per cent shoot infestation} = \frac{\text{Number of infested shoot}}{\text{Number of total shoots}} \times 100$$

Per cent Infested fruits on number basis : The number of infested and healthy fruits were recorded during each picking of five observational plants. The per cent fruit borer infestation on a number basis was calculated using the formula:

$$\text{Fruit borer infestation (number basis)} = \frac{\text{Number of infested fruits}}{\text{Total no. of fruits plucked}} \times 100$$

Observation on population of beneficial insects (Natural enemies) : The observation on the number of natural enemies was recorded on five randomly selected plants from each treatment plot at 3, 7 and 10 days after each treatment module spray during the season. The mean was calculated to represent the population of natural enemies.

Statistical analysis : In accordance with Gomez and Gomez (1984), the data collected from the field experiments for various parameters throughout the season underwent suitable transformations and were subjected to statistical analysis to assess the level of significance. Statistical analysis was also applied to the yield data to compare the impacts of different treatment modules. The pest-related and yield data, collected throughout the experimentation period, were subjected to appropriate statistical analysis after transformation, enhancing the interpretation of results for various parameters.

Results

Effect of treatment modules on brinjal shoot and fruit borer, after 20, 30, 40 and 50 DAT at 3, 7 and 10 days after spray (DAS)

Efficacy of treatment modules at 20 DAT (3, 7 and 10 days after spray)

At the 3 DAS mark, the treatment module M2 showed the lowest shoot infestation, with 7.06% and was comparable to M3, which had 8.28% shoot infestation per plant. Both M2 and M3 were significantly better than M1 and M4. M4 and M1 recorded the highest shoot damage, with 10.62% and 12.74% per plant, respectively (Table 3).

Table 3 : Efficacy of treatment modules on per cent shoot infestation by brinjal shoot and fruit borer after 20, 30, 40 and 50 DAT at 3, 7 and 10 days after spray.

Mo. No.	Treatment modules	Per cent fruit infestation of *L. orbonalis* /plant at 20 DAT			Per cent fruit infestation of *L. orbonalis* / plant at 30 DAT			Per cent fruit infestation of *L. orbonalis* /plant at 40 DAT			Per cent fruit infestation of *L. orbonalis* /plant at 50 DAT		
		3 DAS	**7 DAS**	**10 DAS**	**3 DAS**	**7 DAS**	**10 DAS**	**3 DAS**	**7 DAS**	**10 DAS**	**3 DAS**	**7 DAS**	**10 DAS**
M1	a. Dipping of seedlings in Dimethoate 30 EC @ 10 ml/L of water before transplanting. b. Removal of infested terminal shoots at 20, 30 and 40 DAT. c. Release of *Trichogramma chilonis* 1.5 lakh/ha at 50 and 60 DAT. d. Application of Azadirachtin 1500 ppm (3 ml/L) at 70 and 80 DAT. e. Application of *Metarhizium anisopliae* $1x10^9$ cfu @ 4 g/L 90 and 100 DAT	12.74 (3.69)	12.64 (3.59)	13.02 (3.72)	12.52 (3.65)	12.44 (3.64)	13.90 (3.82)	12.58 (3.66)	12.35 (3.63)	14.09 (3.86)	12.30 (3.61)	10.9 (3.42)	13.09 (3.72)
M2	a. Dipping of seedlings in Imidacloprid 17.8% SL @ 0.5 ml/l of water before transplanting. b. Removal of infested terminal shoots at 20, 30 and 40 DAT. c. Application *of Beauveria bassiana* 1×10^9 cfucfu @ 4 g/L at 50 and 60 DAT. d. Application of *Metarhizium anisopilae* 1×10^9 cfucfu @ 4 g/L at 70 and 80 DAT. e. Spraying of Chlorantroniliprole 18.5% SC @ 0.3 ml/L at 90 and 100 DAT.	7.06 (2.83)	6.44 (2.72)	7.12 (2.84)	6.72 (2.92)	7.02 (2.76)	7.14 (2.84)	6.90 (2.80)	6.38 (2.71)	6.96 (2.81)	6.66 (2.76)	6.16 (2.64)	6.82 (2.79)
M3	a. Soil application of neem cake @ 250 kg/ha. b. Removal of infested terminal shoots at 20, 30 and 40 DAT. c. Release of *Trichogramma chilonis* @ 1.5 lakh/ha at 50 60 and 70 DAT. d. Application of NSE 5% at 80 and 90 DAT.	8.28 (3.04)	7.54 (2.92)	8.30 (3.04)	8.96 (2.96)	8.02 (2.99)	9.05 (3.16)	8.12 (3.01)	7.99 (2.95)	9.54 (3.23)	7.78 (2.95)	6.82 (2.79)	8.84 (3.13)

Table 3 continued...

Table 3 continued...

	e. Application *Beauveria bassiana* 1×10^9 cfu @ 4 gm/L at 100 DAT.												
M4	a. Chloropyriphos 20 EC @ 2 ml/L at 20 DAT. b. Diafenthiuron 50% WP @ 0.80 ml/L at 30 and 40 DAT. c. Cypermethrin 25% EC @ 0.5 ml at 50 and 60 DAT. d. Fenpropathrin 30% EC @ 0.5 ml/L at 70 DAT. e. Emamectin benzoate 5% SG @ 0.5 gm/L at 80 and 90 DAT. f. Chlorantraniliprole 18.5% SC @ 0.3 ml/L at 100 DAT.	10.62 (3.40)	9.10 (3.17)	11.22 (3.49)	11.38 (3.37)	11.14 (3.47)	10.27 (3.35)	11.77 (3.56)	10.97 (3.45)	13.04 (3.74)	10.27 (3.35)	9.16 (3.22)	10.61 (3.39)
	F 'test'	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
	SE (m)±	0.10	0.09	0.11	0.15	0.11	0.15	0.14	0.16	0.15	0.13	0.10	0.15
	CD at 5%	0.33	0.30	0.35	0.48	0.36	0.46	0.45	0.52	0.49	0.41	0.32	0.46
	CV (%)	7.35	7.10	7.86	10.79	8.20	10.20	9.89	11.83	10.39	9.28	7.76	10.48

Figures in parenthesis are corresponding square root transformation values. DAT= Days after transplanting.

Moving on to the 7 DAS point, the treatment module M2 again exhibited the lowest shoot infestation, with 6.44%, similar to M3, which had 7.54% shoot infestation per plant. Both M2 and M3 were significantly superior to M1 and M4. M4 and M1 recorded the highest shoot damage, with 9.10% and 12.64% per plant, respectively.

At the 10 DAS, the treatment module M2 had the significantly lowest shoot infestation, with 7.12% and was comparable to M3, which had 8.30% shoot infestation per plant. Both M2 and M3 were significantly better than M1 and M4. M4 and M1 recorded the highest shoot damage, with 11.22% and 13.02% per plant, respectively.

Efficacy of treatment modules at 30 DAT (3, 7 and 10 days after spray)

At the 3 DAS, the treatment module M2 exhibited the significantly lowest shoot infestation, with a recorded 6.72 percent per plant. This result was comparable to the performance of treatment modules M3 and M4, which showed shoot infestations of 8.96 and 11.38 percent, respectively. On the other hand, the treatment module M1 demonstrated the highest shoot damage at 12.52 percent per plant, although it was statistically like the performance of treatment module M4 (Table 3).

Moving to the 7 DAS, the treatment module M2 continued to display the significantly lowest shoot infestation, with a recorded 7.02 percent per plant. Treatment module M3 also showed a low shoot infestation of 8.02 percent, and both these treatments outperformed the infestations observed in treatment modules M1 and M4. However, treatment modules M4 and M1 recorded the highest shoot damage at 11.14 and 12.44 percent per plant, respectively and were statistically similar to each other.

At 10 DAS, the treatment module M2 once again exhibited the significantly lowest shoot infestation, with a recorded 7.14 percent per plant. Treatment module M3 also showed a low shoot infestation of 9.05 percent, and both these treatments were significantly better than treatment module M1. However, treatment modules M4 and M1 recorded the highest shoot damage at 10.27 and 13.90 percent per plant, respectively, and were statistically similar to each other (Table 3).

Efficacy of treatment modules at 40 DAT (3, 7 and 10 days after spray)

At the 3DAS stage, the treatment module M2 exhibited the lowest shoot infestation, recording 6.90 percent per plant. This was statistically comparable to the performance of treatment module M3, which showed a shoot infestation of 8.12 percent. Both treatment modules were significantly better than the infestations observed in treatment modules M1 and M4. Treatment modules M4 and M1 recorded the highest shoot damage at 11.77 and 12.58 percent per plant, respectively, and were statistically similar to each other (Table 3).

Moving to the 7 DAS point, the treatment module M2 once again displayed the lowest shoot infestation, recording 6.38 percent per plant. This result was comparable to the performance of treatment module M3, which showed a shoot infestation of 7.99 percent. Both treatment modules were significantly superior to treatment module M1. The treatment modules that followed in effectiveness were M4 and M1, recording the highest shoot damage at 10.97 and 12.35 percent per plant, respectively, and were statistically similar to each other (Table 3).

At the 10 DAS, the treatment module M2 once again demonstrated the lowest shoot infestation, recording 7.00 percent per plant. This was statistically comparable to the performance of treatment module M3, which showed a shoot infestation of 9.54 percent. Both of these treatment modules were significantly better than the infestations observed in treatment modules M1 and M4. Treatment modules M4 and M1 recorded the highest shoot damage at 13.00 and 14.09 percent per plant, respectively and were statistically similar to each other.

Efficacy of treatment modules at 50 DAT (3, 7 and 10 days after spray)

At the 3DAS stage, the treatment module M2 exhibited the significantly lowest shoot infestation, recording 6.66 percent per plant, and was on par with treatment module M3, which recorded 7.78 percent. Both of these treatment modules were significantly more effective in controlling shoot infestation compared to the treatment module of M1. However, the treatment modules of M4 and M1 recorded the highest shoot damage at 10.27 and 12.30 percent per plant, respectively and were statistically similar to each other.

Moving to the 7 DAS, the treatment module M2 once again demonstrated the significantly lowest shoot infestation, recording 6.16 percent per plant, and was on par with treatment module M3, which recorded 6.82 percent. Both of these treatment modules were significantly more effective in controlling shoot infestation compared to the treatment module of M1. Meanwhile, treatment modules M4 and M1 recorded the highest shoot damage at 9.16 and 10.9 percent per plant, respectively, and were statistically like each other (Table 3).

At the 10 DAS, the treatment module M2 continued to display the significantly lowest shoot infestation, recording 6.82 percent per plant and was on par with treatment module M3, which recorded 8.84 percent. Both of these treatment modules were significantly more effective in controlling shoot infestation compared to the treatment module of M1. However, treatment modules M4 and M1 recorded the highest shoot damage at 10.61 and 13.09 percent per plant, respectively and were statistically similar to each other.

Cumulative efficacy of treatment modules on per cent shoot infestation of brinjal shoot and fruit bore at 3, 7 and 10 DAS

At the 3 DAS stage, the cumulative data, as presented in Table 4, showed statistical significance. The treatment module M2 exhibited the least cumulative shoot infestation due to brinjal shoot and fruit borer, recording 6.83 percent. Following closely were treatment modules M3 and M4, with shoot infestations of 8.28 and 11.24 percent, respectively and both were statistically at par each other. In contrast, treatment module M1 recorded the highest shoot infestation at 12.53 percent.

Moving to the 7 DAS, the cumulative data remained statistically significant. Treatment module M2 displayed the least cumulative shoot infestation due to brinjal shoot and fruit borer, recording 6.50 percent. Following closely were treatment modules M3 and M4, with shoot infestations of 7.59 and 10.09 percent, respectively and both were statistically similar to each other. However, treatment module M1 recorded the highest fruit infestation at 12.08 percent across all treatments.

At the 10 DAS, the cumulative data continued to exhibit statistical significance. Treatment module M2 displayed the least cumulative shoot infestation due to brinjal shoot and fruit borer, recording 7.01 percent. Following closely were treatment modules M3 and M4, with shoot infestations of 8.93 and 11.28 percent, respectively and both were statistically like each other. Nevertheless, treatment module M1 recorded the highest fruit infestation at 13.52 percent.

Effect of treatment modules on fruit damage by brinjal shoot and fruit borer, after 60, 70, 80 and 90 DAT

Efficacy of treatment modules on per cent fruit damage by brinjal shoot and fruit borer after 60 DAT at 3, 7 and 10 DAS

At the 3 DAS, the treatment module M2 exhibited the significantly lowest fruit infestation at 60 DAT,

Table 4 : Cumulative efficacy of treatment modules on per cent shoot infestation by brinjal shoot and fruit borer at 3, 7 and 10 DAT.

Mo. No.	Treatment modules	Percent shoot infestation of *L. orbonalis* / plant			Mean
		3 DAS	7 DAS	10 DAS	
M1	a. Dipping of seedlings in Dimethoate 30 EC @ 10 ml/L of water before transplanting. b. Removal of infested terminal shoot at 20, 30 and 40 DAT. c. Release of *Trichogramma chilonis* 1.5 lakh/ha at 50 and 60 DAT. d. Application of Azadirachtin 1500 ppm (3 ml/L) at 70 and 80 DAT. e. Application of *Metarhizium anisopliae* 1x10^9 cfu @ 4 g/L 90 and 100 DAT	12.53 (3.65)	12.08 (3.57)	13.52 (3.78)	12.71 (3.66)
M2	a. Dipping of seedlings in Imidacloprid 17.8% SL @ 0.5 ml/l of water before transplanting. b. Removal of infested terminal shoots at 20, 30 and 40 DAT. c. Application *of Beauveria bassiana* 1×10^9 cfu @ 4 g/L at 50 and 60 DAT. d. Application of *Metarhizium anisopilae* 1×10^9 cfu @ 4 g/L at 70 and 80 DAT. e. Spraying of Chlorantroniliprole 18.5% SC @ 0.3 ml/L at 90 and 100 DAT.	6.83 (2.82)	6.50 (2.70)	7.01 (2.82)	6.79 (2.78)
M3	a. Soil application of neem cake @ 250 kg/ha. b. Removal of infested terminal Shoots at 20, 30 and 40 DAT. c. Release of *Trichogramma chilonis* @ 1.5 lakh/ha at 50 60 and 70 DAT. d. Application of NSE 5% at 80 and 90 DAT. e. Application *Beauveria bassiana*1x10^9 cfu @ 4 gm/L at 100 DAT.	8.28 (2.99)	7.59 (2.91)	8.93 (3.14)	8.26 (3.01)
M4	a. Chloropyriphos 20 EC @ 2 ml/L at 20 DAT. b. Diafenthiuron 50% WP @ 0.80 ml/L at 30 and 40 DAT. c. Cypermethrin 25% EC @ 0.5 ml at 50 and 60 DAT. d. Fenpropathrin 30% EC @ 0.5 ml/L at 70 DAT. e. Emamectin benzoate 5% SG @ 0.5 gm/L at 80 and 90 DAT. f. Chlorantraniliprole 18.5% SC @ 0.3 ml/L at 100 DAT	11.01 (3.42)	10.09 (3.32)	11.28 (3.49)	10.79 (3.41)
	F 'test'	Sig	Sig	Sig	Sig
	SE (m)±	0.13	0.11	0.14	0.12
	CD at 5%	0.41	0.38	0.44	0.41
	CV(%)	9.32	8.72	9.73	9.25

Figures in parenthesis are corresponding square root transformation values. DAT= Days after transplanting.

recording 7.06 percent fruit damage per plant. This result was on par with the performance of treatment module M3, which showed a fruit damage of 8.28 percent. Both treatments were significantly more effective in controlling fruit damage compared to the treatment modules of M1 and M4. Treatment modules M4 and M1 recorded the highest fruit damage at 10.62 and 12.74 percent per plant, respectively and were statistically similar to each other (Table 5).

Moving to the 7 DAS point, the treatment module M2 once again displayed the significantly lowest fruit damage at 60 DAT, recording 6.56 percent fruit damage per plant. This result was on par with the performance of treatment modules M3 and M4, which showed fruit damage of 7.50 and 9.38 percent, respectively. In contrast, treatment modules M1 recorded the significantly highest fruit damage at 12.18 percent per plant, although it was statistically similar to the performance of treatment module M4.

At the 10 DAS, the treatment module M2 continued to exhibit the significantly lowest fruit damage at 60 DAT, recording 7.74 percent fruit damage per plant. This result was on par with the performance of treatment module M3, which showed fruit damage of 8.20 percent. Both treatment modules were significantly more effective in controlling fruit damage compared to the treatment modules of M1 and M4. Treatment modules M4 and M1 recorded the highest fruit damage at 11.70 and 13.04 percent per plant, respectively, and were statistically like each other (Table 5).

Table 5 : Efficacy of treatment modules on per cent shoot infestation by brinjal shoot and fruit borer after 60, 70, 80 and90 DAT at 3,7 and 10 days after spray.

Mo. No.	Treatment modules	Per cent fruit infestation of *L. orbonalis* /plant at 60 DAT			Per cent fruit infestation of *L. orbonalis* /plant at 70 DAT			Per cent fruit infestation of *L. orbonalis* /plant at 80 DAT			Per cent fruit infestation of *L. orbonalis* /plant at 90 DAT		
		3 DAS	**7 DAS**	**10 DAS**	**3 DAS**	**7 DAS**	**10 DAS**	**3 DAS**	**7 DAS**	**10 DAS**	**3 DAS**	**7 DAS**	**10 DAS**
M1	f. Dipping of seedlings in Dimethoate 30 EC @ 10 ml/L of water before transplanting. g. Removal of infested terminal shoots at 20, 30 and 40 DAT. h. Release of *Trichogramma chilonis* 1.5 lakh/ha at 50 and 60 DAT. i. Application of Azadirachtin 1500 ppm (3 ml/L) at 70 and 80 DAT. j. Application of *Metarhizium anisopliae* $1x10^9$ cfu @ 4 g/L 90 and 100 DAT	12.74 (3.68)	12.18 (3.62)	13.04 (3.73)	12.30 (3.61)	11.34 (3.49)	13.09 (3.72)	12.58 (3.67)	11.16 (3.47)	13.02 (3.72)	12.40 (3.64)	11.00 (3.45)	12.82 (3.70)
M2	f. Dipping of seedlings in imidacloprid 17.8% SL @ 0.5 ml/l of water before transplanting. g. Removal of infested terminal shoots at 20, 30 and 40 DAT. h. Application *of Beauveria bassiana* 1×10^9 cfucfu @ 4 g/L at 50 and 60 DAT. i. Application of *Metarhizium anisopilae* $1x10^9$ cfucfu @ 4 g/L at 70 and 80 DAT. j. Spraying of Chlorantroniliprole 18.5% SC @ 0.3 ml/L at 90 and 100 DAT.	7.06 (2.83)	6.56 (2.74)	7.74 (2.95)	6.66 (2.76)	6.12 (2.67)	6.82 (2.79)	6.50 (2.73)	5.88 (2.62)	7.12 (2.84)	6.66 (2.76)	6.12 (2.66)	7.20 (2.85)
M3	f. Soil application of neem cake @ 250 kg/ha. g. Removal of infested terminal shoots at 20, 30 and 40 DAT. h. Release of *Trichogramma chiloni*s @ 1.5 lakh/ha at 50 60 and 70 DAT. i. Application of NSE 5% at 80 and 90 DAT.	8.28 (3.04)	7.50 (2.88)	8.20 (3.02)	7.96 (2.98)	7.45 (2.90)	8.84 (3.13)	8.12 (3.01)	7.32 (2.88)	8.30 (3.04)	8.02 (2.99)	7.08 (2.83)	8.24 (3.01)

Table 5 continued...

Table 5 continued...

	j. Application *Beauveria bassiana* 1×10^{9} cfu @ 4 gm/L at 100 DAT.												
M4	g. Chloropyriphos 20 EC @ 2 ml/L at 20 DAT. h. Diafenthiuron 50% WP @ 0.80 ml/L at 30 and 40 DAT. i. Cypermethrin 25% EC @ 0.5 ml at 50 and 60 DAT. j. Fenpropathrin 30% EC @ 0.5 ml/L at 70 DAT. k. Emamectin benzoate 5% SG @ 0.5 gm/L at 80 and 90 DAT. l. Chlorantraniliprole 18.5% SC @ 0.3 ml/L at 100 DAT.	10.62 (3.40)	9.38 (3.21)	11.70 (3.56)	10.27 (3.35)	9.22 (3.19)	10.61 (3.39)	10.77 (3.40)	10.14 (3.32)	11.22 (3.49)	11.14 (3.47)	9.72 (3.26)	11.60 (3.54)
	F 'test'	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
	SE(m)±	0.11	0.15	0.12	0.13	0.10	0.14	0.14	0.10	0.10	0.11	0.10	0.11
	CD at 5%	0.35	0.49	0.38	0.42	0.31	0.46	0.46	0.32	0.32	0.36	0.32	0.37
	CV(%)	7.92	11.28	8.35	9.49	7.37	10.22	10.3	7.53	7.10	8.08	7.68	8.13

Figures in parenthesis are corresponding square root transformation values. DAT = Days after transplanting.

Efficacy of treatment modules on per cent fruit damage by brinjal shoot and fruit borer after 70 DAT at 3, 7 and 10 DAS

At the 3 DAS stage, the treatment module M2 exhibited the significantly lowest fruit infestation at 70 DAT, recording 6.66 percent fruit damage per plant. This result was on par with the performance of treatment module M3, which demonstrated a fruit damage of 7.96 percent. Both of these treatment modules proved significantly more effective in mitigating fruit damage compared to the treatment module of M1. Treatment modules M4 and M1 recorded the highest fruit damage at 10.27 and 12.30 percent per plant, respectively and were statistically similar to each other (Table 5).

Moving to the 7 DAS point, the treatment module M2 once again showcased the significantly lowest fruit infestation at 70 DAT, noting 6.12 percent fruit damage per plant. This result was on par with the performance of treatment module M3, which displayed fruit damage of 7.45 percent. Both treatment modules exhibited significantly greater effectiveness in controlling fruit damage compared to the treatment module of M1. Meanwhile, treatment modules M4 and M1 recorded the highest fruit damage at 9.22 and 11.34 percent per plant, respectively and were statistically similar to each other.

At the 10 DAS mark, the treatment module M2 continued to demonstrate the significantly lowest fruit infestation at 70 DAT (Table 5), registering 6.82 percent fruit damage per plant. This result was on par with the performance of treatment module M3, which presented fruit damage of 8.84 percent. Both treatment modules proved significantly more effective in mitigating fruit damage compared to treatment module M1. Following closely, treatment modules M4 and M1 recorded the highest fruit damage at 10.61 and 13.09 percent per plant, respectively, and were statistically similar to each other.

Efficacy of treatment modules on per cent fruit damage by brinjal shoot and fruit borer after 80 DAT at 3, 7 and 10 DAS

At 3 DAS, the treatment module M2 exhibited the significantly lowest fruit infestation at 80 days after treatment (DAT), registering 6.50 percent fruit damage per plant. This outcome aligned with the performance of treatment module M3, which documented a fruit damage of 8.12 percent. Both of these treatment modules demonstrated significant

Table 6 : Cumulative efficacy of treatment modules on per cent fruit infestation of brinjal shoot and fruit borer at 3,7 and 10 DAT.

Mo. No.	Treatment modules	Percent shoot infestation of *L. orbonalis* / plant			Mean
		3 DAS	7 DAS	10 DAS	
M1	a. Dipping of seedlings in Dimethoate 30 EC @ 10 ml/L of water before transplanting. b. Removal of infested terminal shoot at 20, 30 and 40 DAT. c. Release of *T.chilonis* 1.5 lakh/ha at 50 and 60 DAT. d. Application of Azadirachtin 1500 ppm (3 ml/L) at 70 and 80 DAT. e. Application of *Metarhizium anisopliae* 1x10^9 cfu @ 4 g/L 90 and 100 DAT	12.38 (3.63)	11.68 (3.51)	12.88 (3.70)	12.31 (3.61)
M2	a. Dipping of seedlings in Imidacloprid 17.8% SL @ 0.5 ml/l of water before transplanting. b. Removal of infested terminal shoots at 20, 30 and 40 DAT. c. Application *of B. bassiana* 1×10^9 cfu @ 4 g/L at 50 and 60 DAT. d. Application of *Metarhizium anisopliae* 1x10^9 cfu @ 4 g/L at 70 and 80 DAT. e. Spraying of Chlorantroniliprole 18.5% SC @ 0.3 ml/L at 90 and 100 DAT.	6.63 (2.75)	6.14 (2.71)	7.03 (2.83)	6.60 (2.76)
M3	a. Soil application of neem cake @ 250 kg/ha. b. Removal of infested terminal Shoots at 20, 30 and 40 DAT. c. Release of *T.chiloni*s @ 1.5 lakh/ha at 50 60 and 70 DAT. d. Application of NSE 5% at 80 and 90 DAT. e. Application *B.bassiana*1x10^9 cfu @ 4 gm/L at 100 DAT.	8.07 (3.00)	7.35 (2.86)	8.32 (3.04)	7.91 (2.96)
M4	a. Chloropyriphos 20 EC @ 2 ml/L at 20 DAT. b. Diafenthiuron 50% WP @ 0.80 ml/L at 30 and 40 DAT. c. Cypermethrin 25% EC @ 0.5 ml at 50 and 60 DAT. d. Fenpropathrin 30% EC @ 0.5 ml/L at 70 DAT. e. Emamectin benzoate 5% SG @ 0.5 gm/L at 80 and 90 DAT. f. Chlorantraniliprole 18.5% SC @ 0.3 ml/L at 100 DAT	10.50 (3.37)	9.57 (3.20)	11.05 (3.45)	10.37 (3.34)
	F 'test'	Sig	Sig	Sig	Sig
	SE (m) ±	0.12	0.12	0.11	0.11
	CD at 5%	0.40	0.38	.0.37	0.38
	CV(%)	9.21	9.02	8.33	8.85

Figures in parenthesis are corresponding square root transformation values. DAT = Days after transplanting.

effectiveness in mitigating fruit damage compared to the treatment module of M1. Meanwhile, treatment modules M4 and M1 recorded the significantly highest fruit damage at 10.77 and 12.58 percent per plant, respectively and were statistically similar to each other (Table 5).

Shifting to the 7 DAS juncture, the treatment module M2 once again showcased the significantly lowest fruit damage at 80 DAT (Table 5) recording 5.88 percent fruit damage per plant. This finding was on par with the performance of treatment module M3, which presented fruit damage of 7.32 percent. Both of these treatment modules were significantly more effective in controlling fruit damage compared to the treatment modules of M1 and M4. Meanwhile, treatment modules M4 and M1 recorded the significantly highest fruit damage at 10.14 and 11.16 percent per plant, respectively and were statistically similar to each other.

At the 10 DAS, the treatment module M2 once again demonstrated the significantly lowest fruit infestation at 80 DAT, recording 7.12 percent fruit damage per plant. This result was on par with the performance of treatment module M3, which reported fruit damage of 8.30 percent. Both of these treatment modules were significantly more effective in mitigating fruit damage compared to the treatment modules of M1 and M4. The treatment modules of M4 and M1 recorded the significantly highest fruit damage at 11.22 and 13.02 percent per plant, respectively and were statistically similar to each other (Table 5).

Table 7 : Incremental cost benefit ratio (ICBR) various treatment modules in brinjal.

Mo. no.	Treatment module	No. of spray	Qty. per ha.	Rate per kg or lit	Cost of treatment			Yield (q/ha)	Value of increase yield (Rs.) B	Incremental benefit (Rs.) B-A	ICBR (B-A)/A	Rank
					Cost of insectcide (Rs./ha)	Labour and machinery charges (Rs./ha)	Total cost (Rs./ha) A					
M1	Dimethoate 30 EC.	1	250 ml	520	130	4400	6870	128.18	2,56,360	249490	1:36.31	IV
	Removal of infested shoot.	-	-	-	-							
	T. chilonis	2	3 lakh	375/1.5 lakh egg	750							
	Azadi. 1500 ppm	2	1 lit	860	860							
	M. anisopliae 1x10^9 cfu	2	1 kg	730	730							
M2	Imidacloprid 17.8% SL	1	50 ml	1900	120	4400	6540	202.70	4,05,400	398860	1:60.98	I
	Removal of infested shoots	-	-	-	-							
	B. bassiana 1×10^9 cfu	2	2 kg	440	880							
	M. anisopilae 1×10^9 cfu	2	2 kg	730	730							
	Chlorantroniliprole 18.5% SC	2	50ml	9000	850							
M3	Neem cake	1	10 kg	25	250	4400	6615	173.79	3,47,580	340965	1:51.54	II
	Removal of infested Shoot.	-	-	-	-							
	T. chilonis	3	4.5 lakh	375/1.5 lakh eggs	1125							
	NSE 5%.	2	10 kg	40	400							
	B. bassiana 1×10^9 cfu			440	880							
M4	Chloropyriphos 20 EC	1	250 ml	500	130	4400	6770	154.38	3,08,780	302010	1:45.29	III
	Diafenthiuron 50% WP	2	50 ml	2500	90							
	Cypermethrin 25% EC	2	500 ml	650	300							
	Fenpropathrin 30% EC	1	100 ml	1000	100							
	Emamectin benzoate 5% SG	2	250 gm	3500	900							
	Chlorantraniliprole 18.5% SC	1	50 ml	9000	850							

Efficacy of treatment modules on per cent fruit damage by brinjal shoot and fruit borer after 90 DAT at 3, 7 and 10 DAS

At 3 DAS, the treatment module M2 displayed the significantly lowest fruit infestation at 90 DAT, registered 6.66 percent fruit damage per plant. This result was on par with the performance of treatment module M3, which recorded a fruit damage of 8.02 percent. Both of these treatment modules proved significantly more effective in mitigating fruit damage compared to the treatment module of M1. However, treatment modules M4 and M1 recorded the significantly highest fruit damage at 11.14 and 12.40 percent per plant, respectively and were statistically similar to each other (Table 5).

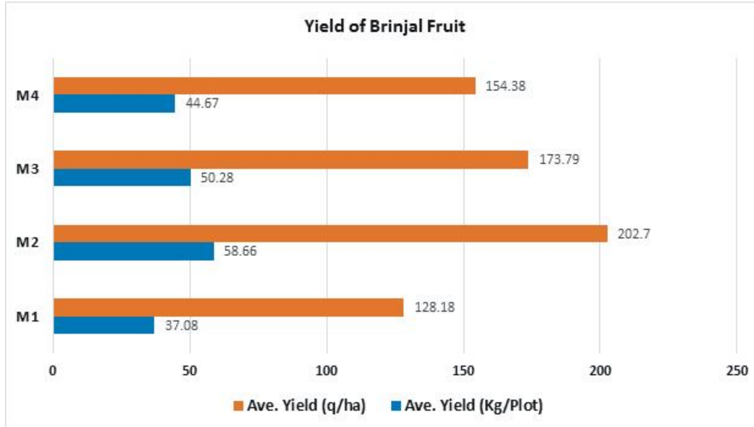

Fig. 1 : Effects of treatment modules on the yield of brinjal fruit.

Moving to the 7 DAS point, the treatment module M2 once again showcased the significantly lowest fruit infestation at 90 DAT, noting 6.12 percent fruit damage per plant. This result was on par with the performance of treatment module M3, which exhibited fruit damage of 7.08 percent. Both treatment modules were significantly more effective in controlling fruit damage compared to the treatment modules of M1 and M4. However, treatment modules M4 and M1 recorded the significantly highest fruit damage at 9.72 and 11.00 percent per plant, respectively and were statistically similar to each other.

At the 10 DAS, the treatment module M2 continued to demonstrate the significantly lowest fruit infestation at 90 DAT, registering 7.20 percent fruit damage per plant. This result was on par with the performance of treatment module M3, which recorded fruit damage of 8.24 percent. Both of these treatment modules were significantly more effective in mitigating fruit damage compared to treatment module M1 and M4. However, treatment modules M4 and M1 recorded the significantly highest fruit damage at 11.60 and 12.82 percent per plant, respectively and were statistically similar to each other.

Cumulative efficacy of treatment modules on per cent fruit infestation of brinjal shoot and fruit borer at 3, 7 and 10 DAS

At 3 DAS, the cumulative data, as presented in Table 6, exhibit statistical significance. The treatment module M2 displayed the least cumulative fruit damage due to brinjal shoot and fruit borer, at 6.63 percent. Following closely, treatment modules M3 and M4 recorded 8.07 and 10.50 percent fruit damage, respectively, with both treatments showing statistical parity. In contrast, treatment module M1 recorded the highest fruit damage, reaching 12.38 percent.

Shifting to the 7 DAS timeframe, the cumulative data demonstrate statistical significance. Treatment module M2 exhibited the least cumulative fruit damage at 6.14 percent, attributed to brinjal shoot and fruit borer. Subsequently, treatment modules M3 and M4 recorded 7.35 and 9.57 percent fruit damage, respectively, with both treatments showing statistical parity. Conversely, treatment module M1 recorded the highest fruit damage, reaching 11.68 percent.

At the 10 DAS, the cumulative data in Table 6 reveal statistical significance. Treatment module M2 displayed the least cumulative fruit damage, noting 7.03 percent due to brinjal shoot and fruit borer. Following closely, treatment modules M3 and M4 recorded 8.32 and 11.05 percent fruit damage, respectively, with both treatments showing statistical parity. However, treatment module M1 recorded the highest fruit damage, reaching 12.88 percent.

Effects of treatment modules on the yield of brinjal fruit

The data, as depicted in Fig. 1, indicate statistical significance in the results. The highest yield of tomato fruit was observed in treatment module M2, reaching 202.70 q/ha. Following closely, treatment module M3 recorded a yield of 173.79 q/ha and both of these treatment modules exhibited statistical parity. Treatment module M4 yielded 154.38 q/ha. However, the lowest yield of 128.18 q/ha was observed in treatment module M1 and both of these treatment modules showed statistical equality in their effectiveness.

Incremental cost benefit ratio (ICBR) of various treatment modules

The data regarding the details of Incremental Cost Benefit Ratio (ICBR) are presented in Table 7. The maximum ICBR of 1:60.98 was observed in the treatment modules of M2. Following in order of incremental cost benefit ratio, the next best treatment modules were M3 (1:51.54) and M4 (1:45.49). Treatment module M1 was found lowest, recording an ICBR of 1:36.31.

Discussion

The study delves into a crucial area of agricultural concern, focusing on the persistent issue of pest infestation in brinjal cultivation. n. Brinjal, being a widely consumed and economically significant vegetable crop, faces substantial threats from pests, particularly the brinjal shoot and fruit borer, caused by the insect *Leucinodes orbonalis*. This pest poses a significant economic threat to brinjal farmers globally, leading to considerable yield losses if not effectively managed.

The economic impact of pest infestations on brinjal crops cannot be overstated. Yield losses due to brinjal shoot and fruit borer infestations can result in reduced income for farmers, affecting their livelihoods. Moreover, the increased use of chemical pesticides to combat these pests can lead to environmental concerns, posing risks to human health and the broader ecosystem. Therefore, finding effective, sustainable, and eco-friendly pest management strategies for brinjal cultivation is of principal importance.

The study focuses on the effectiveness of treatment module M2, which involves the removal of infested shoots, application of bio-pesticides, and chemical measures, in controlling brinjal shoot and fruit borer infestations. This is a critical area of investigation due to the significant economic impact of these pests on brinjal crops, leading to substantial yield losses. Brinjal shoot and fruit borer, caused by the insect *Leucinodes orbonalis*, pose a major threat to brinjal cultivation worldwide, making effective pest management strategies essential for sustainable crop production. Several previous studies by researchers such as Neupane (2000), Chakraborti (2001), Talekar (2002), Arida *et al*. (2003) and Satpathy *et al*. (2005) have similarly highlighted the efficacy of such practices in minimizing infestation by *L. orbonalis*, aligning with the current findings.

Furthermore, the use of bio-pesticides like *M. anisopliae* and *B. bassiana* in treatment modules has shown commendable performance in reducing shoot infestation due to *L. orbonalis*. This aligns with findings reported by Nayak *et al*. (2013) and Phukon *et al*. (2014) and showcasing the effectiveness of *M. anisopliae* and *B. bassiana* against brinjal shoot and fruit borer.

Similarly, the inclusion of chlorantraniliprole 20 EC in treatment module M1, as observed in studies by Mishra (2011), Rajvel *et al*. (2011) and Munje *et al*. (2015), resulted in the minimum shoot and fruit infestation. These outcomes support the current findings, indicating the efficacy of chlorantraniliprole 20 EC in minimizing infestation.

In the case of fruit infestation, treatment module M2, which involves the removal of infested shoots, bio-pesticides and chemicals has demonstrated effectiveness, supported by the work of Duca *et al*. (2004) and Srinivasan (2008) in minimizing fruit infestation by *L. orbonalis*. Consistent with these findings, Mishra (2011), Rajvel *et al*. (2011) and Munje *et al*. (2015) recorded the minimum shoot and fruit infestation in chlorantraniliprole 20 EC, aligning with the present study.

Furthermore, studies by researchers like Tiwari *et al*. (2011) have shown that Imidacloprid 17.8 SL provides maximum protection and minimum shoot damage, corresponding to the present finding where treatment module M2, inclusive of bio-pesticides and chemical measures, resulted in effective control.

The economic aspect, measured by Incremental Cost Benefit Ratio (ICBR), also reflects the effectiveness of treatment module M2. Previous studies by Duca *et al*. (2004) and Srinivasan (2008) have demonstrated the economic benefits of such practices in reducing damage and increasing yield. Correspondingly, Singh *et al*. (2005) and Rath and Maity (2005) reported that the mechanical clipping of infested shoots significantly reduced pest infestation and increased yield.

Regarding the use of bio-pesticides, treatment modules with *M. anisopliae* and *B. bassiana* have shown promising results in maximizing brinjal fruit yield. This aligns with findings by Chaudhary **et al**. (2014), Phukon *et al*. (2014), Chaudhary *et al*. (2017) and Patil *et al*. (2018), emphasizing the higher efficacy of *M. anisopliae* and *B. bassiana* in increasing brinjal fruit yield.

The importance of this study lies in its contribution to addressing the challenges faced by brinjal farmers in mitigating the impact of shoot and fruit borer infestations. The selected treatment module, M2, incorporates various control measures that have been suggested by previous researchers, including the removal of infested shoots, the use of bio-pesticides and application of chemical solutions. The study aims to evaluate the efficacy of these measures in reducing pest infestation and enhancing brinjal yield.

Conclusion

In conclusion, this study sheds light on critical strategies to address the persistent challenge of pest infestation in brinjal cultivation, with a particular focus on the effectiveness of treatment module M2. The significance of this research lies in its potential to offer practical solutions for farmers facing economic losses due to brinjal shoot and fruit borer infestations.

The findings underscore the importance of adopting integrated pest management practices, such as the removal of infested shoots and the application of bio-pesticides and chemicals, as demonstrated in treatment module M2. These measures not only prove effective in minimizing pest infestation but also align with sustainable and environmentally friendly agricultural practices.

Furthermore, the study contributes valuable insights to the ongoing efforts to enhance crop yield and ensure food security. By providing evidence-based recommendations for controlling pest infestations, the research offers a promising avenue for farmers to protect their livelihoods and contribute to a more reliable and sustainable food supply.

In essence, the outcomes of this study emphasize the significance of adopting holistic approaches to pest management in brinjal cultivation. The implementation of such practices not only mitigates economic losses for farmers, but also aligns with broader goals of environmental sustainability and food security. As we navigate the challenges of agricultural productivity, the lessons learned from this study serve as a beacon for promoting resilient and effective practices in brinjal cultivation.

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