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Efficacy of Few Novel Insecticides in Controlling Shoot and Fruit borer, *Leucinodesorbonalis* Guenee Infesting Brinjal and Impact on it's Natural Enemy (*Trathala flavo-orbitalis*)

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ABSTRACT: A field experiment was carried out during 2021-22 at the experimental farm of Department of Entomology, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar to evaluate the efficacy of five insecticides and their sequential spraying. Altogether five sprays were given. The findings revealed that the insecticide spinetoram 11.7 SC was effective and significantly superior over other treatments in reducing the shoot and fruit borer infestation with least effect on natural enemy (*Trathala flavo-orbitalis*). This was followed by efficacy of flubendiamide 39.35 SC and chlorantraniliprole 18.5 SC for controlling *Leucinodes orbonalis* in brinjal. Spinetoram 11.7 SC, spinosad 45 SC and emamectin benzoate 5 SG are the best insecticides as far as their toxicity to natural enemy is concerned. Maximum benefit cost ratio was obtained from spinetoram11.7 SC (3.11) application followed by flubendiamide 39.35 SC (3.03). The net profit was highest (Rs. 1,75,667) in spinetoram 11.7 SC treated plot and lowest (Rs. 1,11,797) in emamectin benzoate 5 SG whereas Rs. 73,217 in control plot.

Keywords: Novel insecticide, Spinetoram, Efficacy, Brinjal shoot and fruit borer, *Trathala flavo-orbitalis.*

INTRODUCTION

Vegetables are important source of minerals, micronutrients, vitamins, antioxidants, and dietary fibre and play an important role in human nutrition. Brinjal (*Solanum melongena*) also called eggplant belongs to family Solanaceae. Its cultivation is a significant part of the national agricultural economy especially in the developing world (Srivastav, 2012). In India, it is grown in all seasons and occupies an important position among other vegetable crops. It is cultivated over an area of 7.43 lakh hectares in India with a production of 127.7 lakh tonnes with a productivity of 17.17 MT/ha (Anon., 2022).

Out of many constraints encountered in brinjal production, infestation of shoot and fruit borer is the major one. The yield and market value of the crop is reduced due to its infestation. The loss in reduction of crop yield by this pest vary from season to season and from location to location. It causes severe damage in South Asia where the yield loss may reach up to 85 to 90% (Jagginavar *et al.*, 2009). The economic threshold level of brinjal shoot and fruit borer is 0.5% shoot, 5% fruit damage (Dhaliwal *et al*., 2003) and on an average the larva can infest 4 to 7 fruits during its life span (Jayaraj and Manisegaran 2010). The number of sprays on brinjal to control this pest varies widely from 15 to 40 times in a single crop season to fetch a good price in the market. Indiscriminate application of various pesticides leads to increase in resistance of the pest and resurgence of sucking pest *viz*., white flies, mites, and thrips etc. Over reliance on pesticides increases the cost of production at farmers level with environmental and health hazards at consumer level. Moreover, frequent application of pesticides leaves considerable toxic residues on the fruits. To counter this problem new molecules are introduced in crop protection from time to time. The new molecules may be of same or different group of pesticides over the older one. They have greater specificity to target pest along with low toxicity to non-target organisms as well as the environment. It fits well into integrated pest management. The present study was carried out to evaluate the efficacy of different novel insecticides for the management of shoot and fruit borer in brinjal.

MATERIAL AND METHODS

The study was conducted at the experimental farm of

Department of Entomology, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar during summer 2021, Rabi 2021-22 and Kharif 2022. The plot was having sandy loam textured soil with an average pH of 6.9. The brinjal variety Akshita was transplanted in the plot size of 5 × 4m^2 areas with a spacing of 75 cm × 60 cm. The crop was raised by following recommended agronomic practices and also plant protection measures were taken as and when required to check sucking pest and diseases. The experiment was laid out in a Randomized Block Design with three replications having seven treatments including a control. The insecticidal treatments selected were chlorantraniliprole 18.5 SC, emamectin benzoate 5 SG, flubendiamide 39.35 SC, spinosad 45 SC, spinetoram 11.7 SC and their sequential spraying. The foliar treatments were given using battery operated knapsack compression sprayer. Altogether five sprays were given at fifteen days interval. For recording shoot infestation, healthy and infested shoots were counted on 10 randomly selected plants in each plot. Data were recorded a day before spray and 7 and 14 days after treatment. The fruit damage by *L. orbonalis* was assessed based on the total number of fruits and the number of damaged fruits in 10 randomly selected plants. Ten BSFB larvae each from the damaged shoots and fruits, collected from each plot were maintained separately to study the extent of parasitisation by *T. flavo-orbitalis*. Per cent shoot infestation and fruit infestation were calculated by using the following formula.

Per cent shoot damage = (No. of infested shoots × 100) / (Total no. of shoots)

Per cent fruit damage (Number basis) = (No. of damaged fruits × 100) / ((Total number (healthy and damaged) of fruits

Per cent fruit damage (Weight basis) = (weight of damaged fruits × 100) / Total weight (healthy and damaged) of fruits

B:C Ratio = Gross return/Total cost of production

The data was subjected to statistical analysis (ANOVA) to determine the significance of treatments as per Gomez & Gomez (1984). The means were compared by Duncan's Multiple Range Test (DMRT) at P=0.05.

RESULTS AND DISCUSSION

A. Effect of novel insecticides on shoot infestation

It was noticed that almost all insecticides reduced the shoot infestation substantially in 14 days after 3rd spray in all the three seasons (Table 1-3). Spinetoram 11.7 SC was the most effective insecticide in reducing shoot infestation. During summer the shoot infestation was found to be 8.28%,4.56% and 0.38% in 14 days after 1st, 2nd and 3rd spray respectively, followed by chlorantraniliprole 18.5 SC treatment (10.86%, 5.25%, 1.62%) and it was at par with other insecticides and the treatment of sequential spraying. In untreated plot 14.46% shoot infestation was recorded. During rabi no shoot infestation was noticed in 14 days after 3rd spraying except 1.22% in emamectin benzoate 5SG treated plot as compared to 8.00% in untreated control whereas in 7 days after 3rd spraying 1.20% shoot infestation was recorded in spinetoram 11.7 SC treatment and 4.05% in emamectin benzoate 5 SG treatment. In kharif also no shoot infestation was observed except 1.67% in 14 days after 3rd spraying in comparison to 12.21% in control plots. Hence emamectin benzoate 5SG was found to be the least effective one among all the treatments. Yawale *et al*. (2019) noticed that chlorantraniliprole was most effective followed by emamectin benzoate and spinosad in controlling shoot and fruit borer infestation. Tripura *et al*. (2017) reported that mean shoot infestation was minimum in chlorantraniliprole treated plots followed by spinosad.

B. Effect of novel insecticides on fruit infestation

The data on fruit infestation on number basis showed that all the treatments were significantly superior over control (Table 4 and 5). Pooled analysis of the data for three seasons after 5 no of sprays showed that among all the treatments, the lowest per cent infestation of fruit was recorded in spinetoram 11.7 SC (21.16%) followed by flubendiamide 39.35SC (27.98%). Chlorantraniliprole 18.5 SC was found to be the next best treatment (34.26 %) and it was at par with sequential spraying (35.11%). However emamectin benzoate 5SG was found to be the least effective (45.21%) among all the treatments. Highest per cent infestation reduction (62.20%) was observed in spinetoram 11.7 SC treatment whereas least per cent reduction (19.25 %) was in emamectin benzoate 5 SG treated plot over control.

Observation made on the fruit infestation (weight basis) revealed that spinetoram 11.7 SC was the best with 24.58% fruit infestation followed by flubendiamide 39.35 SC with 31.38% fruit infestation. Control plots recorded the highestfruit damage of 59.35%.

Bade *et al*. (2017) studied the efficacy of spinetoram against *L. orbonalis* at field level and recorded superiority of spinetoram in reducing the fruit infestation over spinosad and emamectin benzoate with highest yield. Besides Saran *et al*. (2018) revealed that chlorantraniliprole with least shoot and fruit borer infestation over spinosad and emamectin benzoate. Other workers like Hamdy *et al*. (2013) observed that after two biweekly applications, spinetoram exhibited the highest toxic effect in reducing the infestation of *Tuta absoluta* followed by spinosad and emamectin benzoate in tomato. Sheojat *et al*. (2022) reported that flubendiamide 20WG @300 g/ha was found to be superior than other insecticides followed by emamectin benzoate 5 SG, chlorantraniliprole 18.5 SC and spinosad 45 SC. Reshma and Behera (2018) observed that flubendiamide and chlorantraniliprole are better in controlling the shoot and fruit damagewhereas spinosad and emamectin benzoate gave moderate control. Similarly, Biswas *et al*. (2020) reported that lowest shoot and fruit infestation and highest fruit yield were obtained in plots treated with flubendiamide and chlorantraniliprole followed by emamectin benzoate and Spinosad. These findings are in conformity with the present study.

Table 1: Effect of few novel insecticides on shoot infestation (per cent mean) by *Leucinodes orbonalis* during Summer 2021 at Bhubaneswar.

Treatment		Dose/ha	1 DBS	First Spray		Second Spray		Third Spray	
No.	Details of treatment			7 DAS	14 DAS	7 DAS	14 DAS	7 DAS	14 DAS
T1	Emamectin benzoate 5SG	200 g	15.24 (3.96)	9.72^{ab} (3.19)	12.35^{bc} (3.57)	8.25^{b} (2.95)	7.06^{b} (2.74)	4.80^{b} (2.30)	1.96^{b} (1.56)
T2	Chlorantraniliprole 18.5SC	200 ml	14.65 (3.89)	8.22^{b} (2.95)	10.86^{c} (3.36)	7.84^{bc} (2.88)	5.25^{c} (2.39)	4.10^{bc} (2.14)	1.62^{b} (1.45)
T3	Flubendiamide 39.35SC	200 ml	16.14 (4.07)	8.12^{b} (2.93)	10.58^{c} (3.32)	6.02^{cc} (2.55)	5.66^{bc} (2.48)	4.36^{bc} (2.20)	1.76^{b} (1.49)
T4	Spinosad 45 SC	200 ml	14.46 (3.86)	10.84^{ab} (3.36)	12.92^{b} (3.66)	7.80^{bcd} (2.88)	7.12^{b} (2.75)	4.42^{bc} (2.21)	2.04^{b} (1.57)
T5	Spinetoram 11.7 SC	500 ml	15.38 (3.98)	7.12^{b} (2.75)	8.28^{d} (2.96)	5.82^{c} (2.51)	4.56^{c} (2.25)	3.34^{c} (1.95)	0.38^{c} (0.94)
T6	Sequential spraying	T1, T2, T3, T4 and T5	14.84 (3.91)	9.68^{ab} (3.18)	13.45^{b} (3.73)	7.95^{bc} (2.90)	5.89^{bc} (2.52)	4.06^{bc} (2.13)	1.82^{b} (1.52)
T7	Untreated control		15.32 (3.97)	14.85^{a} (3.91)	24.32^{a} (4.98)	25.64^{a} (5.11)	26.42^{a} (5.18)	20.38^{a} (4.56)	14.46^{a} (3.86)
SE(m)±			0.116	0.081	0.090	0.108	0.090	0.082	0.091
CD (0.05)			-	0.251	0.282	0.335	0.280	0.257	0.283
CV			5.075	4.385	4.278	5.989	5.365	5.705	8.875

Values are mean of three replications.
Figures in parenthesis are transformed values i.e. Arcsin√percentage. Means within each column followed by same letter(s) are not significantly different by DMRT at $p<0.05$.

Table 2: Effect of few novel insecticides on shoot infestation (per cent mean) by *Leucinodes orbonalis* during Rabi 2021-22 at Bhubaneswar.

Treatment		Dose	1 DBS	First Spray		Second Spray		Third Spray	
No.	Details of treatment			7 DAS	14 DAS	7 DAS	14 DAS	7 DAS	14 DAS
T1	Emamectin benzoate 5SG	200 g	8.64 (3.02)	5.62^{b} (2.47)	7.23^{b} (2.78)	4.52^{b} (2.23)	5.66^{b} (2.47)	4.05^{bc} (2.12)	1.22^{b} (1.30)
T2	Chlorantraniliprole 18.5SC	200 ml	9.12 (3.09)	4.44^{c} (2.22)	6.12^{c} (2.57)	2.94^{c} (1.84)	3.98^{c} (2.10)	3.21^{bc} (1.91)	0.00^{c} (0.71)
T3	Flubendiamide 39.35 SC	200 ml	8.32 (2.97)	4.04^{c} (2.13)	5.68^{cd} (2.48)	2.51^{c} (1.73)	3.45^{c} (1.98)	2.64^{c} (1.77)	0.00^{c} (0.71)
T4	Spinosad 45 SC	200 ml	9.38 (3.14)	5.22^{b} (2.39)	7.26^{b} (2.78)	4.42^{b} (2.21)	5.92^{b} (2.52)	4.48^{b} (2.23)	0.00^{c} (0.71)
T5	Spinetoram 11.7 SC	500 ml	9.56 (3.17)	3.86^{c} (2.08)	4.84^{d} (2.30)	2.72^{c} (1.79)	2.96^{c} (2.03)	1.20^{d} (1.30)	0.00^{c} (0.71)
T6	Sequential spraying	T1, T2, T3, T4 and T5	8.87 (3.05)	4.20^{c} (2.16)	7.84^{b} (2.88)	3.04^{c} (1.87)	4.08^{c} (2.14)	2.78^{c} (1.81)	0.00^{c} (0.71)
T7	Untreated control		9.45 (3.15)	11.24^{a} (3.42)	14.56^{a} (3.87)	15.14^{a} (3.95)	16.92^{a} (4.17)	10.12^{a} (3.25)	8.00^{a} (2.90)
SE(m)±			0.077	0.050	0.052	0.086	0.105	0.114	0.061
CD (0.05)			-	0.155	0.161	0.268	0.327	0.354	0.191
CV			4.334	3.569	3.178	6.663	7.299	9.577	9.595

Values are mean of three replications.
Figures in parenthesis are transformed values i.e. Arcsin√percentage. Means within each column followed by same letter(s) are not significantly different by DMRT at $p<0.05$.

Table 3: Effect of few novel insecticides on shoot infestation (per cent mean) by *Leucinodes orbonalis* during Kharif 2022 at Bhubaneswar.

Treatment		Dose	1DBS	First Spray		Second Spray		Third Spray	
No.	Details of treatment			7DAS	14DAS	7DAS	14DAS	7DAS	14DAS
T1	Emamectin benzoate 5SG	200 g	12.26 (3.57)	6.52^{b} (2.65)	10.12^{b} (3.25)	6.14^{b} (2.57)	4.22^{b} (2.17)	4.14^{b} (2.15)	1.67^{b} (1.46)
T2	Chlorantraniliprole 18.5SC	200 ml	10.64 (3.33)	4.38^{c} (2.21)	7.65^{cd} (2.85)	2.74^{d} (1.80)	2.34^{cd} (1.67)	1.74^{c} (1.46)	0.00^{c} (0.71)
T3	Flubendiamide 39.35 SC	200 ml	10.83 (3.35)	4.28^{c} (2.18)	6.78^{d} (2.69)	2.80^{d} (1.81)	1.84^{cd} (1.52)	1.60^{c} (1.42)	0.00^{c} (0.71)
T4	Spinosad 45 SC	200 ml	12.68 (3.62)	6.31^{b} (2.60)	7.64^{cd} (2.85)	2.96^{d} (1.85)	2.24^{cd} (1.65)	2.18^{c} (1.63)	0.00^{c} (0.71)
T5	Spinetoram 11.7 SC	500 ml	10.94 (3.38)	3.16^{d} (1.91)	4.25^{c} (2.17)	1.64^{c} (1.46)	1.45^{d} (1.39)	0.36^{d} (0.92)	0.00^{c} (0.71)
T6	Sequential spraying	T1, T2, T3, T4 and T5	11.89 (3.51)	6.43^{b} (2.63)	8.45^{c} (2.99)	3.69^{c} (2.04)	2.59^{c} (1.75)	2.28^{c} (1.65)	0.00^{c} (0.71)
T7	Untreated control		12.16 (3.55)	15.72^{a} (4.02)	22.86^{a} (4.83)	20.52^{a} (4.58)	19.8^{a} (4.51)	14.46^{a} (3.86)	12.21^{a} (3.55)
SE(m)±			0.099	0.047	0.080	0.057	0.084	0.098	0.088
CD (0.05)			-	0.145	0.248	0.177	0.262	0.305	0.274
CV			4.953	3.102	4.465	4.274	6.946	9.054	12.455

Values are mean of three replications.
Figures in parenthesis are transformed values i.e. Arcsin√percentage. Means within each column followed by same letter(s) are not significantly different by DMRT at $p<0.05$.

Table 4: Effect of few novel insecticides on fruit damage (number basis) by *Leucinodes orbonalis* in different seasons of study period at Bhubaneswar during 2021-2022.

Treatments		Season						Pooled Mean (3 seasons)	
		Summer, 2021		Rabi, 2021-22		Kharif,2022			
No.	Details oftreatment	Mean Per cent fruit damage	Reduction over control (%)	Mean Per cent fruit damage	Reduction over control (%)	Mean Per cent fruit damage	Reduction over control (%)	Mean Per cent fruit damage	Reduction over control (%)
T1	Emamectin benzoate 5 SG @200 g/ha	50.64^{b} (7.15)	19.87	39.53^{b} (6.32)	21.27	45.48^{b} (6.78)	16.65	45.21^{b} (6.75)	19.25
T2	Chlorantraniliprol e 18.5 SC @200 ml/ha	41.52^{bc} (6.47)	34.30	28.36^{cd} (5.35)	43.51	32.90^{cd} (5.77)	39.71	34.26^{d} (5.87)	38.81
T3	Flubendiamide 39.35 SC @200 ml/ha	33.85^{c} (5.86)	46.43	22.73^{de} (4.82)	54.73	27.36^{d} (5.27)	49.86	27.98^{e} (5.32)	50.02
T4	Spinosad 45 SC @200 ml/ha	45.48^{b} (6.77)	28.03	33.84^{bc} (5.86)	32.60	37.68^{bc} (6.17)	30.95	39.00^{c} (6.27)	30.34
T5	Spinetoram 11.7SC SC@500 ml/ha	25.26^{d} (5.06)	60.03	17.82^{e} (4.27)	64.50	20.42^{e} (4.55)	62.58	21.16^{f} (4.64)	62.20
T6	Sequential spraying	42.46^{b} (6.55)	32.81	29.74^{c} (5.48)	40.76	33.15^{cd} (5.79)	39.25	35.11^{d} (5.95)	37.29
T7	Untreated control	63.20^{a} (7.97)		50.21^{a} (7.12)		54.57^{a} (7.41)		55.99^{a} (7.50)	
SE(m)±		0.204		0.197		0.202		0.045	
CD (0.05)		0.635		0.615		0.630		0.140	
CV		5.388		6.10		5.867		1.291	

Values are mean of three replications.
Figures in parenthesis are transformed values i.e. Arcsin√percentage. Means within each column followed by same letter(s) are not significantly different by DMRT at $p<0.05$.

Table 5: Effect of few novel insecticides on fruit damage (weight basis) by *Leucinodes orbonalis*in different seasons of study period at Bhubaneswar during 2021-2022.

Treatments		Season						Pooled Mean (3 season)	
		Summer, 2021		Rabi, 2021-22		Kharif,2022			
No.	Details oftreatment	Mean Percent fruit damage	Reduction over control (%)	Mean Percentfruit damage	Reduction over control (%)	Mean Percent fruit damage	Reduction over control (%)	Mean Percent fruit damage	Reduction over control (%)
T1	Emamectin benzoate 5 SG@200 g/ha	54.47^{b} (7.41)	17.14	44.48^{b} (6.72)	17.73	46.73^{b} (6.86)	19.76	48.56^{b} (6.99)	18.18
T2	Chlorantraniliprol e 18.5 SC@200 ml/ha	45.26^{c} (6.76)	31.15	32.83^{c} (5.77)	39.28	36.86^{cd} (6.11)	36.71	38.31^{d} (6.21)	35.45
T3	Flubendiamide 39.35 SC @200 ml/ha	36.85^{d} (6.11)	43.94	26.83^{d} (5.22)	50.37	30.46^{d} (5.55)	47.69	31.38^{e} (5.63)	47.12
T4	Spinosad 45 SC @200 ml/ha	48.92^{bc} (7.03)	25.58	35.53^{c} (5.99)	34.28	39.48^{bc} (6.31)	32.21	41.31^{c} (6.45)	30.39
T5	Spinetoram 11.7SC SC@500 ml/ha	29.68^{d} (5.47)	54.85	20.42^{e} (4.57)	62.23	23.65^{e} (4.90)	59.39	24.58^{f} (4.99)	58.58
T6	Sequential spraying	46.74^{bc} (6.86)	28.90	34.64^{c} (5.92)	35.93	38.42^{c} (6.23)	34.03	39.93^{c} (6.34)	32.72
T7	Untreated control	65.74^{a} (8.13)		54.07^{a} (7.38)		58.24^{a} (7.66)		59.35^{a} (7.73)	
SE(m)±		0.186		0.118		0.185		0.037	
CD (0.05)		0.579		0.367		0.577		0.116	
CV		4.714		3.434		5.144		1.016	

Values are mean of three replications.
Figures in parenthesis are transformed values i.e., Arcsin√percentage. Means within each column followed by same letter(s) are not significantly different by DMRT at $p<0.05$.

C. Effect of novel insecticides on parasitisation of the natural enemy (Trathala flavo-orbitalis)

It was observed that all the insecticides comparatively reduced the activities of natural enemy *Trathala flavo-orbitalis* (Table 6). The per cent of parasitisation was found maximum in spinetoram 11.7 SC treated plot (11.20) and the per cent reduction was 17.28 over control. It was the safest among the treated insecticide followed by spinosad 45 SC and emamectin benzoate 5 SG with parasitisation per cent 10.04 and 9.23. Flubendiamide 39.35 SC was found to have lowest parasitisation per cent (6.62). The untreated control plot recorded 13.54% of parasitisation.

Chakraborti and Sarkar (2011) reported the effect of insecticides on natural enemy complex and pollinators in eggplant ecosystem. As per their findings emamectin benzoate was safe for predators and bees. Flubendiamide and chlorantraniliprole were comparatively more unsafe than emamectin benzoate. Also, Shah *et al*. (2012) observed the effect of insecticides on predatory spiders in brinjal cultivation and concluded the degree of toxicity as flubendiamide> Chlorantraniliprole>emamectin benzoate>spinosad which agrees with the result of present study. Also, Mamun *et al*. (2014) observed that spinosad has low mammalian toxicity and no effect on predatory insects.

Table 6: Effect of few novel insecticides on parasitisation (%) by natural enemy (*Trathala flavo-orbitalis*) in different seasons of study at Bhubaneswar during 2021-2022.

Treatments		Season						Pooled Mean (3 season)	
		Summer,2021		Rabi, 2021-22		Kharif,2022			
No	Details of treatment	Mean Parasitisation (%)	Reduction over control(%)	Mean Parasitisation (%)	Reduction over control(%)	Mean Parasitisation (%)	Reduction over control(%)	Mean Parasitisation (%)	Reduction over control(%)
T1	Emamectin benzoate 5 SG @200 g/ha	8.94^{cd} (3.06)	35.95	9.12^{bc} (3.09)	27.90	9.63^{bcd} (3.18)	31.26	9.23^{c} (3.11)	31.83
T2	Chlorantraniliprole 18.5 SC@200 ml/ha	7.14^{de} (2.76)	48.85	7.97^{cd} (2.90)	36.99	7.81^{de} (2.88)	44.25	7.64^{d} (2.85)	43.57
T3	Flubendiamide 39.35 SC @200 ml/ha	6.32^{e} (2.61)	54.72	7.14^{d} (2.76)	43.55	6.42^{e} (2.62)	54.17	6.62^{c} (2.66)	51.10
T4	Spinosad 45SC @200 ml/ha	9.73^{bc} (3.20)	30.30	9.94^{b} (3.23)	21.42	10.46^{bc} (3.30)	25.33	10.04^{c} (3.24)	25.84
T5	Spinetoram 11.7 SC @500 ml/ha	11.18^{b} (3.41)	19.91	10.58^{b} (3.33)	16.36	11.86^{ab} (3.51)	15.34	11.20^{b} (3.42)	17.28
T6	Sequential spraying	7.94^{cde} (2.90)	43.12	7.38^{d} (2.80)	41.66	9.24^{cd} (3.11)	34.04	8.18^{d} (2.94)	39.58
T7	Untreated control	13.96^{a} (3.79)		12.65^{a} (3.62)		14.01^{a} (3.80)		13.54^{a} (3.74)	
SE(m)±		0.104		0.082		0.109		0.048	
CD (0.05)		0.324		0.255		0.339		0.150	
CV		5.790		4.561		5.884		2.653	

Values are mean of three replications.
Figures in parenthesis are transformed values i.e. Arcsin√percentage. Means within each column followed by same letter(s) are not significantly different by DMRT at $p<0.05$.

D. Effect of novel insecticides on yield

Plots with insecticidal treatments recorded higher fruit yield of brinjal as compared to untreated ones (Table 7 and 8). However, the highest yield was recorded in spinetoram 11.7 SC treated plot (23.11 t/ha) followed by flubendiamide 39.35 SC (21.88 t/ha) and the lowest yield was recorded in emamectin benzoate 5SG (18.97 t/ha) after 5 nos of sprayings. The control plot was recorded yield of 16.30 t/ha. It is a common fact that insecticide application checks yield loss due to insect pests thus increases yield.

Reshma *et al*. (2019) found that flubendiamide treated plot obtained the highest yield followed by chlorantraniliprole and spinosad. Also the cost benefit was highest in flubendiamide treatment. Kameshwaran and Kumar (2015) reported that the yield of chlorantraniliprole was superior to emamectin benzoate and spinosad. Sharma and Kaushik (2010) found that spinosad was more effective than emamectin benzoate and safe to natural enemies. Das *et al*. (2018) concluded that the efficacy, market yield and gross return of spinosad treated plot was higher than emamectin benzoate which is in accordance with the present findings whereas the B:C ratio of emamectin benzoate is higher than spinosad is in contrary to the current study. The results of Mainali *et al*. (2015) showed that the infestation percent on number and weight basis was significantly lower in chlorantraniliprole as compared to spinosad. Chlorantraniliprole recorded a yield of 32.03 t/ha whereas spinosad 30.93 t/ha. Islam *et al*., (2019) found that the efficacy of spinosad was better than emamectin benzoate. Singh *et al*. (2021) revealed that the efficacy of spinosad and chlorantraniliprole was higher than emamectin benzoate. In their experiment the rotational strategies were placed in fourth position as far as yield was concerned. Kameshwaran and Kumar (2015) revealed the lesser infestation of shoot and fruit borer with treatment of chlorantraniliprole followed by emamectin benzoate. Narayan *et al*. (2019) revealed from their experiment that the lowest per cent fruit damage on number basis and weight basis by chlorantraniliprole 18.5 SC followed by cyantraniliprole 10.26 OD and emamectin benzoate 5 SG. The treatment chlorantraniliprole 18.5 SC recorded higher fruit yield followed by cyantraniliprole 10.26 OD and emamectin benzoate 5 SG.

E. Benefit-Cost ratio of novel insecticides in brinjal

Comparative economics of insecticide treatments during 2021-22 was obtained by calculating the benefit-cost ratio during three seasons. Highest benefit-cost ratio was obtained in case of spinetoram 11.7 SC (3.11) treatment followed by flubendiamide 39.35 SC (3.03), emamectin benzoate 5 SG (2.96), chlorantraniliprole 18.5 SC (2.94), spinosad 45 SC (2.88), sequential spraying (2.69) and control (2.46). The net profit was highest (Rs. 1,75,667) in spinetoram 11.7 SC treated plot and lowest (Rs. 1,11,797) in emamectin benzoate 5 SG. In the control plot the profit obtained was only Rs. 73,217.

The results are in proximity with the results of Biswas *et al*. (2020) that maximum benefit-cost ratio was obtained with flubendiamide 20% WDG treatment as compared to chlorantraniliprole and emamectin benzoate.

Table 7: Incremental cost of novel insecticides for controlling BSFB *Leucinodes orbonalis* during the study period 2021-2022.

Details of treatments		Packsize	Amount(Rs)	Dose perha.	Cost of insecticides per ha. (For 5 no. of spraying)	Incrementalcost (Rs/ha)
No.	Name of the Insecticide					
T1	Emamectin benzoate 5 SG	100 g	397	200 g	3,970	7,080
T2	Chlorantraniliprole18.5 SC	100ml	1,510	200 ml	15,100	18,210
T3	Flubendiamide 39.35 SC	100ml	1,860	200 ml	18,600	21,710
T4	Spinosad 45 SC	100ml	1,199	200 ml	11,990	15,100
T5	Spinetoram 11.7 SC	100ml	1,210	500 ml	30,250	33,360
T6 (Sequential spraying)	T1, T2, T3, T4 and T5				15982	19,092

Incremental cost includes the cost of insecticides for 5 nos of spraying, labour charges and other charges.

Table 8: Comparative economics of few novel insecticides for controlling BSFB *Leucinodes orbonalis* during the study period 2021-2022.

Treatment		Mean marketablefruit yield (t/ha)	Income(Rs.) @15000/t(A)	Mean infested fruit yield (t/ha)	Income(Rs.) @4000/t(B)	Gross return(Rs.) (A+B)	Cost of production(Rs)	Net return (Rs)	B:C Ratio
No.	Details oftreatment								
T1	Emamectin benzoate 5 SG@200 g/ha	8.44	1,26,600	10.53	42,120	1,68,720	56,923	1,11,797	2.96
T2	Chlorantraniliprole 18.5 SC @200ml/ha	10.58	1,58,700	10.48	41,920	2,00,620	68,053	1,32,567	2.94
T3	Flubendiamide 39.35 SC@200ml/ha	11.80	1,77,000	10.08	40,320	2,17,320	71,553	1,45,767	3.03
T4	Spinosad 45 SC @200 ml/ha	9.74	1,46,100	10.33	41,320	1,87,420	64,943	1,22,477	2.88
T5	Spinetoram 11.7 SC@500 ml/ha	15.13	2,26,950	7.98	31,920	2,58,870	83,203	1,75,667	3.11
T6	Sequential spraying	9.83	1,47,450	9.62	38,480	1,85,930	68,935	1,16,995	2.69
T7	Untreated control	5.26	78,900	11.04	44,160	1,23,060	49,843	73,217	2.46

Cost of production includes cost of cultivation and incremental cost.

CONCLUSIONS

Among the insecticides evaluated against brinjal shoot and fruit borer, spinetoram 11.7 SC applied at the dose of 500 ml/ha was found to be the most effective one in reducing the infestation of shoot and fruit borer in brinjal and increasing the yield. This was followed by flubendiamide 39.35 SC and Chlorantraniliprole 18.5 SC. Sequential spraying of insecticides was the next best followed by spinosad 45 SC. Emamectin benzoate 5 SG was recorded as the least effective among all the treatments. Spinetoram 11.7 SC was found as the safest insecticide to natural enemy *Trathala flavo-orbitalis* followed by spinosad 45 SC whereas flubendiamide 39.35 SC was found as the most unsafeto it.

FUTURE SCOPE

The shoot and fruit borer is the major insect pest of brinjal. The environment as well as the crop is getting increasingly poisoned due to the use of several pesticides by the farmers. Hence to justify the IPM programme in brinjal crop, evaluation of efficacy of pesticide having new chemistry against BSFB, their impact on natural enemy, residual toxicity along with its economy is the need of the hour. Also steps to be taken for development of new technology for artificial rearing and inundate release of the natural enemy, *Trathala flavo- orbitalis.*

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