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Research Article

Evaluation of novel insecticides against fruit borers in okra in the coastal belt of Odisha

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ABSTRACT

Investigations were carried out during Kharif, 2016, 2017 and 2018 at RRTTS, Coastal Zone, OUAT, Bhubaneswar to evaluate the efficacy of some novel insecticides against fruit borer, Earias vittella (Fabricius) and Earius insulana (Boisduval) on okra. Six novel insecticides along with one standard chemical check and an untreated control were imposed in RBD replicated thrice on okra variety 'Utkal Gaurav'. Results revealed that Chlorantraniliprole 18.5%SC @50ml ha^{-1} recorded the least fruit damage (3.5%) with 85.1% reduction in fruit damage over untreated control and 72% reduction over the standard chemical (Triazophos 40%EC). Chlorantraniliprole 18.5%SC resulted in highest fruit yield (93.34qha^{1}). Spinosad 45%SC, indoxacarb 15.8%EC and flubendiamide 39.35%SC. recorded 86.16q, 85.42q and 85.30q per hectare yield and were at par with each other. Highest economic returns were obtained in chlorantraniliprole ((Rs.56,842ha^{-1}) with highest incremental B:C ratio (11.06:1.0). Among different insecticides, chlorantraniliprole 18.5%SC and emamectin benzoate 5%SC were found safer to natural enemies (coccinellid predators and spiders) whereas indoxacarb 15.8%EC was found relatively more toxic.

Keywords**:** Bioefficacy, B:C, fruit borer, novel insecticides, natural enemy and okra

Okra (*Abelmoschus esculentus*) is a significant vegetable crop in tropical and warm temperate regions worldwide. It is known for its exceptional heat and drought tolerance, making it suitable for cultivation in areas with poor soil conditions. The fruits of okra are highly nutritious, containing dietary fiber, protein, and Vitamin C (Candlish *et al*., 1987).In India, the states of Uttar Pradesh (U.P.), Bihar, and Odisha are the major producers of okra. However, the crop is susceptible to various insect pests that can cause significant damage. According to Mandal *et al*. (2006), the cotton jassid, *Amrasca biguttula biguttula* (Ishida)) and fruit borers, *Earias vittella* Fabr. and *E. insulana* (Boisduval) are considered major and serious pests of okra. These insect pests, along with the *Helicoverpa armigera* (Hub), are reported to inflict serious damage, leading to fruit damage ranging from 88% to 100% (Bheemanna *et al*., 2005).The presence of insect pests poses a significant challenge to achieve high productivity in okra cultivation. Additionally, according to Dhandapani *et al*. (2003) leaf hoppers and fruit borers accounted for losses of approximately 50-52% and 49-74%, respectively, in India. Pareek *et al*. (2003) also highlighted that the fruit borer complex alone caused economic damage ranging from 52.33% to 70.75%.

The indiscriminate use of insecticides by farmers to manage fruit borers has resulted in insecticide resistance, pest resurgence and residual toxicity issues. Therefore, there is a need to identify safer molecules with better insecticidal properties, lower mammalian toxicity and safety to natural enemies that can be integrated into an Integrated Pest Management (IPM) approach. To address this need, field trials were conducted to assess the effectiveness of new insecticidal molecules in suppressing fruit borer populations while also assessing their impact on natural enemies. The information generated from these experiments will be valuable in identifying effective and safer insecticide molecules against fruit borer while minimizing the impact on natural enemies, which are critical in maintaining the ecological balance of agroecosystems.

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MATERIALS AND METHODS

The field trail was carried out at the RRTTS, Coastal Zone, OUAT located at coordinates 20°27'43"N and 85°78'88"E, with an elevation of 25.9 meters above mean sea level. The experiment aimed to evaluate the efficacy of insecticides against fruit borers in okra over three consecutive rainy seasons: 2016, 2017, and 2018. The experimental design employed was a randomized block design with eight treatments and three replications. The treatments were having six chemical insecticides along with a standard chemical check using triazophos 40% EC and an untreated control (Table 1).

Table 1: Treatment details

Treatment	Chemical	Dose (mlha^{-1})
T_1	Chlorantraniliprole 18.5% SC	50
T_2	Indoxacarb 15.8% EC	500
T_3	Flubendiamide 39.35% SC	125
T_4	Emamectin benzoate 5% SC	200
T_5	Novaluron 10% EC	625
T_6	Spinosad 45% SC	125
T_7	Triazophos 40% EC (Standard check)	1000
T_8	Untreated control	-

Okra variety Utkal Gaurav with a spacing of 90 cm × 30 cm in a 4.0 m x 5.0 m sized plot. The recommended package of practices for okra cultivation was followed. Two sprays were applied at 30 and 45 days after sowing to assess the efficacy of the different insecticides. To evaluate the impact of the treatments on fruit damage, observations were made at each harvesting by distinguishing between undamaged and damaged fruits. The percentage of fruit damage was calculated based on these observations. Additionally, the predator population was recorded seven days after the insecticide sprays to understand the effect of the new molecules on beneficiary faunas. The benefit: cost ratio for each treatment was determined, considering the cost of the treatment of each chemical. This ratio provides an economic perspective on the effectiveness of the treatments by comparing the costs incurred with the potential benefits obtained. OPSTAT software was used to analyse the data obtained (Sheoran *et al*., 1998; Sheoran *et al*., 2020). The extent of damage and B: C was computed through the following formula:

$$\textbf{Percent fruit damage} = \frac{\text{Number of damaged fruit}}{\text{Total number of fruits}} \times 100$$

$$\textbf{Incremental benefit Cost ratio (IBCR)} = \frac{\text{Net profit (Value of saved yield – Treatment cost)}}{\text{Treatment cost}}$$

RESULTS AND DISCUSSION

During *Kharif*, 2016, chlorantraniliprole18.5%SC @ 50 ml ha^{-1} recorded the least fruit borer damage (3.1%) and was found at par with spinosad 45%SC (3.3%) @125 ml ha^{-1} (Table 1). The next best treatment was flubendiamide 39.35%SC @125 ml ha^{-1}(3.8%). Indoxacarb 15.8%SC @ 500 ml ha^{-1}recorded 4.7% fruit damage followed by emamectin benzoate 5%SC @200 g ha^{-1} (8.3% fruit infestation) and novaluron 10%EC 625 ml ha^{-1} (9.2% fruit infestation). In comparison, the untreated plots exhibited significantly higher fruit damage at 31.1%. The standard check i.e. triazophos 40% EC 1000 ml ha^{-1}showed a fruit damage percentage of 12.6%. During *Kharif*, 2017 minimum borer infestation (3.7%) was registered in chlorantraniliprole 18.5%SC which was statistically superior to all other chemicals. Spinosad 45%SC was the second-best chemical recorded 4.4% fruit damage followed by indoxacarb 15.8%SC (5.4%). The extent of damage in standard chemical was 11.5% and the untreated plot had 18.3% damaged fruits. Similar trend of effectiveness was also observed during *Kharif*, 2018 when significantly lower population of fruit borer damage (2.8%) was observed in chlorantraniliprole18.5%SC treatment. Spinosad 45%SC was the second-best treatment followed by flubendiamide 39.35%SC and indoxacarb 15.8%SC. The mean of three season data on fruit borer damage reveals that, the efficacy of chlorantraniliprole 18.5%SC, accounting for 3.5% fruit borer infestation, was statistically superior to other treatments. Spinosad 45%SC was the second most effective treatment against fruit borer with 4.2% fruit damage. Flubendiamide 39.35%SC and indoxacarb 15.8%SC had equal effectiveness.

Table 1: Influence of insecticides on fruit borers in okra

Treatments	Percent fruit Borer damage (%)				% reduction over control	% reduction over standard check
	***Kharif*, 2016**	***Kharif*, 2017**	***Kharif*, 2018**	**Mean**		
T_1: Chlorantraniliprole 18.5%SC @ 150ml ha^{-1}	3.1 (10.10)*	3.7 (11.08)	2.8 (9.62)	3.5 (10.77)	85.1	72.0
T_2: Indoxacarb15.8%EC @ 500 ml ha^{-1}	4.7 (12.37)	5.4 (13.42)	6.5 (14.76)	5.5 (13.56)	76.6	56.0
T_3: Flubendiamide 39.35%SC @ 125 ml ha^{-1}	3.8 (11.17)	6.1 (14.29)	5.7 (13.81)	5.2 (13.17)	77.9	58.4
T_4: Emamectin benzoate 5%SC @ 200 g ha^{-1}	8.3 (16.77)	7.4 (15.77)	10.4 (18.80)	8.7 (17.15)	63.1	30.4
T_5: Novaluron 10%EC @ 625ml ha^{-1}	9.2 (17.66)	8.1 (16.52)	11.6 (19.90)	9.6 (18.04)	59.3	23.2
T_6: Spinosad 45%SC @ 125 ml ha^{-1}	3.3 (10.48)	4.4 (12.09)	4.9 (12.78)	4.2 (11.82)	82.2	66.4
T_7: Triazophos 40%EC @ 1000ml ha^{-1}(Standard check)	12.6 (20.78)	11.5 (19.81)	13.4 (21.46)	12.5 (20.69)	47.0	-
T_8: Untreated control	31.1 (33.90)	18.3 (25.31)	21.5 (27.61)	23.6 29.05	-	-
SEm (±)	**0.20**	**0.29**	**0.25**	**0.24**	-	-
LSD (0.05)	**0.60**	**0.90**	**0.76**	**0.75**	-	-

*Note: *Figure in the parenthesis are angular transformed values*

Highest percent reduction over untreated control was achieved in chlorantraniliprole 18.5%SC (85.1%). Spinosad 45%SC, flubendiamide 39.35%SC and indoxacarb 15.8%SC had a good control over fruit borer infestation where 82.2%, 77.9% and 76.6% reduction over untreated control were recorded. Moderate effectiveness was seen in emamectin benzoate 5%SC and novaluron 10%EC treated plots with 63.1% and 59.3% reduction.

When the relative efficacy of the insecticides tested in the experiment over the commonly used chemical by the farmers against fruit borer in okra was observed, the clearcut superiority of chlorantraniliprole18.5%SC was noticed with 72% reduction over the standard check (Triazophos 40%EC). Spinosad 45%SC proved its effectiveness with 66.4% reduction followed by flubendiamide39.35%SC and indoxacarb 15.8%SC with 58.4% and 56% reduction respectively.

The efficacy of chlorantraniliprole 18.5%SC against okra fruit borer observed in the present investigation is similar to the opinion of Anuradha (2013) who reported its efficacy against maize stem borer. Kumar *et al*. (2013) reported lowest mean fruit damage in okra with application of chlorantraniliprole (coragen @ 30g *a.i.*/ha) corroborates the present finding of superiority of chlorantraniliprole 18.5%SC. Sanjana and Ashwani (2022) also revealed that chlorantraniliprole 18.5% SC had the lowest percent of shoot and fruit infestation with 11.71% and 11.96% followed by emamectin benzoate 5% SG with 12.96% and 14.11% after two round of spray which is similar with the results obtained in this experiment. The efficacy of spinosad 45% SC and indoxacarb 15.8% SC, as observed in the current investigation, aligns with the findings of previous studies conducted by Udikeri *et al.* (2004) and Dhanalakshmi *et al.* (2010), who found emamectin benzoate 5% SG as the best, safe and promising treatment against cotton bollworm and okra fruit borer, respectively. Furthermore, the effectiveness of indoxacarb found in the current investigation confirms the results reported by Dhawan and Simwat (2000), who reported indoxacarb 15.8% SC was best to control bollworm complex and sucking pests in control while having a minimal effect on the beneficial arthropods. The agreement between the current investigation and the mentioned studies reinforces the effectiveness of spinosad and indoxacarb as viable options for fruit borer management in okra cultivation.

Among different treatments, chlorantraniliprole 18.5%SC and emamectin benzoate 5% SC spared good number of predators (0.8 coccinellids plant^{-1}) proving their safety to natural enemies which was at par with the predatory population in untreated control (0.9 coccinellids plant^{-1}) plot (Table 2). However, spinosad 45%SC, novaluron 10%EC and flubendiamide 39.35%SC were at par with each other and moderately safe towards natural enemies where 0.7and 0.6 coccinellids plant^{-1} were noted.

Indoxacarb 15.8%EC recorded significantly lower predatory population (0.5 coccinellidplant^{-1}) and the standard check triazophos 40%EC was found to be toxic to predatory fauna with lowest population (0.1 coccinellids plant^{-1}).

The mean population of predatory spider was highest (1.1spiders plant^{-1}) in chlorantraniliprole18.5%SC treated plots which was at par with other treatments *viz*. emamectin benzoate 5%SC, novaluron 10%EC and spinosad 45%SC (1 spider plant^{-1} in each treatment). All these chemicals except indoxacarb 15.8% EC and flubendiamide 39.35% SC were at par with untreated control plot (1.4 spiders plant^{-1}) which shows their safety towards predators. The safety profile of indoxacarb 15.8%EC towards predatory spiders is low where a mean population of 0.5spiders plant^{-1}was viewed. However, triazophos 40%EC was highly toxic towards predatory spiders with very sparce predatory population (0.1 spiders plant^{-1}) was seen.

Table 2: Influence of insecticides on predator populationin okra

Treatments	Number of lady bird beetles plant^{-1}				Number of spiders plant^{-1}			
	***Kharif*, 2016**	***Kharif*, 2017**	***Kharif*, 2018**	**Mean**	***Kharif*, 2016**	***Kharif*, 2017**	***Kharif*, 2018**	**Mean**
T_1: Chlorantraniliprole 18.5%SC@150ml ha^{-1}	1.0 (1.41)	0.7 (1.30)	0.8 (1.34)	0.8 (1.34)	1.1 (1.45)	1.3 (1.52)	0.9 (1.38)	1.1 (1.45)
T_2: Indoxacarb 15.8%EC@ 500 ml ha^{-1}	0.5 (1.22)	0.4 (1.18)	0.5 (1.22)	0.5 (1.22)	0.6 (1.26)	0.5 (1.22)	0.3 (1.14)	0.5 (1.22)
T_3: Flubendiamide 9.35%SC@ 125 ml ha^{-1}	0.7 (1.30)	0.6 (1.26)	0.5 (1.22)	0.6 (1.26)	0.9 (1.38)	0.8 (1.34)	0.6 (1.26)	0.8 (1.34)
T_4:Emamectin benzoate 5%SC@ 200 g ha^{-1}	0.9 (1.38)	0.7 (1.30)	0.8 (1.34)	0.8 (1.34)	1.1 (1.45)	1.2 (1.48)	0.8 (1.34)	1.0 (1.41)
T_5: Novaluron 10%EC@625ml ha^{-1}	0.8 (1.34)	0.5 (1.22)	0.7 (1.30)	0.7 (1.30)	1.1 (1.45)	1.1 (1.45)	0.9 (1.38)	1.0 (1.41)
T_6: Spinosad 45%SC@125 ml ha^{-1}	0.9 (1.38)	0.6 (1.26)	0.6 (1.26)	0.7 (1.30)	1.0 (1.41)	1.2 (1.48)	0.8 (1.34)	1.0 (1.41)
T_7: Triazophos 40%EC@1000 ml ha^{-1} (Standard check)	0.2 (1.10)	0 (1.00)	0.1 (1.05)	0.1 (1.05)	0.1 (1.05)	0.2 (1.10)	0.1 (1.05)	0.1 (1.05)
T_8: Untreated control	1.1 (1.45)	0.8 (1.34)	0.9 (1.38)	0.9 (1.38)	1.4 (1.55)	1.5 (1.58)	1.2 (1.48)	1.4 (1.55)
SEm (±)	**0.03**	**0.03**	**0.04**	**0.14**	**0.03**	**0.03**	**0.04**	**0.15**
LSD (0.05)	**0.10**	**0.10**	**0.11**	**0.05**	**0.10**	**0.10**	**0.12**	**0.44**

*Note: *Figure in the parenthesis are angular transformed values*

Anuradha (2013) reported that predatory coccinellid population remain unchanged in maize crop with foliar spray of chlorantraniliprole (Coragen 20 per cent w/v SC) corroborates with the findings of the present experiment where ample number of predators (Coccinellid predators and spiders) were observed in chlorantraniliprole treated plots. Patel *et al*. (2016) found that various doses (22, 26, 30 g. a.i.ha^{-1}) of chlorantraniliprole 35 wg was found comparatively harmless to spider population which supported the current study. The safety of emamectin benzoate 5% SC and spinosad 45%SC towards natural enemies observed in the current study is in confirmation with Udikeri *et al*. (2004). The toxic nature of indoxacarb 15.8%EC to predators has been documented by Udikeri *et al*. (2004).

The okra fruit yield presented in Table 3 reveals the consistent superiority of the treated chemical, chlorantraniliprole 18.5%SC over other chemicals in the consecutive three crop seasons where 90.54q, 95.25q and 94.23q per hectare okra have been harvested.

The pooled mean yield of three season data indicates that, among the various insecticides evaluated, chlorantraniliprole18.5%SC recorded significantly highest okra fruit yield (93.34q ha^{-1}) (Table 3). Spinosad 45%SC, indoxacarb 15.8%EC and flubendiamide 39.35%EC were at par in yield achievement where 86.16q, 85.42q and 85.30q per hectare yield were recorded respectively.The lowest yield (78.28qha^{-}1) obtained in untreated control plot where-as the triazophos40%EC treated plot had 78.28 q ha^{-1}yield.The yield saved in this treatment over untreated control was 20.66q ha^{-1}.

Maximum return was obtained in chlorantraniliprole18.5%SC (Rs.56,842 ha^{-1}) followed by indoxacarb 15.8%EC (Rs. 34,820 ha^{-1}), spinosad45%SC (Rs.34,548 ha^{-1}) and flubendiamide 39.35%SC (Rs. 33,236 ha^{-1}). When the cost effectiveness of different new molecules was considered, chlorantraniliprole18.5% SC recorded highest incremental benefit cost ratio (11.06:1.00) followed by indoxacarb 15.8%EC (10.24:1.0), flubendiamide 39.35% SC (7.18:1.00), novaluron 10%EC (6.28:1.00) and spinosad45%SC (5.86:1.00) (Table 4).

Table 3: Influence of insecticides on yield of okra

Treatments	Fruit yield (q ha^{-1}) *Kharif*, 2016	*Kharif*, 2017	*Kharif*, 2018	Mean	Yield saved over control (q ha^{-1})
T_1: Chlorantraniliprole 18.5%SC@150ml ha^{-1}	90.54	95.25	94.23	93.34	20.66
T_2: Indoxacarb 15.8%EC@ 500 ml ha^{-1}	87.26	83.07	85.93	85.42	12.74
T_3: Flubendiamide 9.35%SC@ 125 ml ha^{-1}	87.45	82.69	85.76	85.30	12.62
T_4:Emamectin benzoate 5%SC@ 200 g ha^{-1}	76.18	80.42	82.74	79.78	7.10
T_5: Novaluron 10%EC@625ml ha^{-1}	80.37	85.14	82.11	82.54	9.86
T_6: Spinosad 45%SC@125 ml ha^{-1}	85.04	89.26	84.18	86.16	13.48
T_7: Triazophos 40%EC@1000 ml ha^{-1} (Standard check)	75.37	81.29	78.18	78.28	5.60
T_8: Untreated control	75.72	70.16	72.16	72.68	
SEm (±)	**1.18**	**1.70**	**1.49**	**0.85**	
LSD (0.05)	**3.61**	**5.20**	**4.57**	**2.43**	

Table 4: Influence of insecticides on incremental benefit cost ratio

Treatments	Value of produce (Rs ha^{-1})	Treatment Cost (Rs ha^{-1})	Net profit (Rs ha^{-1})	Incremental benefit cost ratio
T_1: Chlorantraniliprole 18.5%SC@150ml ha^{-1}	61980	5138	56842	11.06
T_2: Indoxacarb 15.8%EC@ 500 ml ha^{-1}	38220	3400	34820	10.24
T_3: Flubendiamide 9.35%SC@ 125 ml ha^{-1}	37860	4624	33236	7.18
T_4:Emamectin benzoate 5%SC@ 200 g ha^{-1}	21300	3800	17500	4.60
T_5: Novaluron 10%EC@625ml ha^{-1}	29580	4062	25518	6.28
T_6: Spinosad 45%SC@125 ml ha^{-1}	40440	5892	34548	5.86
T_7: Triazophos 40%EC@1000 ml ha^{-1} (Standard check)	16800	1500	15300	10.20

Note: Value of produce@Rs 30 kg^{-1}

Maximum fruit yield and economic benefit achieved by chlorantraniliprole 18.5%SC in the present experiment is similar with results of Kumar *et al*. 2017 who reported highest yield and cost benefit ratio (1:9.27) in okra with application of coragen @30g a.i.ha^{-1}.The cost effectiveness of chlorantraniliprole 18.5%SC on okra fruit borer in this study is similar with the study of Potai *et al*. (2019) who reported higher yield (155.10q ha^{-1}) in plots treated with chlorantraniliprole 18.5% SC @25g.a.i ha^{-1}. Sanjana and Ashwani (2022) while studying the efficacy of some selected insecticides against shoot and fruit borer in Okra, also found highest B:C (4.4:1) in chlorantraniliprole 18.5% SC treated plots in comparison to control followed by Imidacloprid (1: 4.2), Emamectin benzoate (1: 4.2), Spinetoram (1: 3.4), Diafenthiuron (1: 3.3), Flonicamid (1: 3.3), and Acephate (1: 3.1). The superiority of spinosad 45%SC and indoxacarb 15.8%EC are aligned with Udikeri *et al*. (2004).

Based on the current study conducted, it can be summarized that chlorantraniliprole (18.5% SC) demonstrated the highest effectiveness among all the tested chemicals against fruit borers in okra. It resulted in an 85.1% reduction in fruit borer infestation compared to the untreated control. Additionally, the use of chlorantraniliprole led to the attainment of the maximum yield, with a production of 93.34 quintals per hectare. In economic terms, chlorantraniliprole also proved to be financially advantageous. It yielded the highest net income of Rs. 56,842 per hectare and exhibited the highest incremental benefit cost ratio, which stood at 11.06:1.00.

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