



Efficacy of Insecticides against Major Insect Pests of Okra (*Abelmoschus esculentus* L.): Impact on Pest Populations, Natural Enemies, Yield and Economic

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Authors' contributions

This work was carried out in collaboration among all authors. Author JD conducted the field experiments and collected the data. Author AK designed the study, performed statistical analysis, and wrote the first draft of the manuscript. Author SSD managed the literature searches and assisted with data analysis. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The present study evaluates the efficacy of eight insecticides against major okra pests (jassids, whiteflies, and shoot and fruit borer), their safety to beneficial coccinellid beetles, and their economic viability based on yield performance and cost-benefit analysis.

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Study Design: Randomized block design with three replications.

Place and Duration of Study: Central Research Station, Odisha University of Agriculture and Technology, Bhubaneswar, during the summer seasons of 2019-20 and 2020-21.

Methodology: Eight insecticides, including flupyradifurone (250 g a.i./ha), diafenthiuron (300 g a.i./ha), and emamectin benzoate (7 g a.i./ha), were applied as foliar sprays at 30 and 45 days after sowing (DAS). Pest populations, fruit damage, coccinellid counts, yield, and incremental cost-benefit ratio (ICBR) were assessed. Data were arcsine-transformed and analyzed using ANOVA.

Results: Flupyradifurone reduced jassid populations by 79.84% (2.47/plant, $P = 0.05$), diafenthiuron whitefly populations by 79.39% (1.20/plant, $P = 0.05$), and emamectin benzoate fruit borer damage by 82.35% (4.12% by number, $P = 0.05$). Emamectin benzoate achieved the highest yield 7.54 t/ha (89.92% increase, $P = 0.05$) with an ICBR of 1:12.44 (Rs 66,090/ha). Emamectin benzoate, clothianidin, spinetoram, and flupyradifurone preserved coccinellid populations (3.89–4.25/5 leaves, $P > 0.05$ vs. control).

Conclusion: Flupyradifurone, diafenthiuron, and emamectin benzoate were effective, ecologically safe, and economically viable pest management for okra, supporting integrated pest management strategies. Flupyradifurone, diafenthiuron, and emamectin benzoate were effective, ecologically safe, and economically viable for okra pest management, supporting integrated pest management strategies.

Keywords: Okra; novel insecticides; jassids; whiteflies; shoot and fruit borer; incremental cost-benefit ratio.

1. INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench), a member of the Malvaceae family, is a key crop in vegetable production systems in India, valued for its nutritional richness and versatility in culinary and industrial applications. India leads global okra production, cultivating 0.509 million hectares and yielding 6.095 metric tonnes in 2017-2018, with Odisha contributing significantly (0.567 metric tonnes, 9.33% share) (National Horticulture Board, 2018). Rich in vitamins (e.g., 13.10 mg/100 g vitamin C) and minerals (e.g., 66 mg/100 g calcium), okra supports dietary needs in developing nations, where it is consumed as a fresh vegetable or processed product (Gopalan et al., 2007). However, its cultivation faces substantial challenges from insect pests, which reduces both yield and quality, posing economic risks to farmers (Kuttalam et al., 2008).

Among the most damaging pests are sucking insects such as jassids (*Amrasca biguttula biguttula* Ishida) and whiteflies (*Bemisia tabaci* Gennadius), alongside the lepidopteran shoot and fruit borer (*Earias vittella* Fabricius). Jassids and whiteflies cause direct feeding damage and transmit viral diseases, such as yellow vein mosaic virus, with reported yield losses of 17.46–54.04% if left uncontrolled in early growth stages (Anitha & Nandihalli, 2008; Neeraja et al., 2004). The shoot and fruit borer, a polyphagous pest, inflicts severe fruit damage, with losses ranging from 32.06–40.48% (Mohapatra, 2023),

compromising marketability. Historically, pest management has relied on broad-spectrum insecticides like organophosphates and carbamates, but their overuse has led to resistance, environmental contamination, and depletion of natural enemy populations, necessitating alternative strategies (Insecticide Resistance Action Committee, 2022).

Novel insecticides, characterized by selective modes of action and reduced ecological footprints, offer a promising solution. Compounds such as flupyradifurone (a butenolide), diafenthiuron (a thiourea derivative), and emamectin benzoate (a macrocyclic lactone) target specific pest physiology while minimizing non-target effects, aligning with integrated pest management (IPM) principles. Previous studies have demonstrated their efficacy in various crops; for instance, flupyradifurone effectively controls sucking pests in brinjal (Garg et al., 2018), and emamectin benzoate reduces lepidopteran damage in okra. However, their comprehensive evaluations in okra, particularly under Odisha's agro climatic conditions, remain limited, as do assessments of their safety toward beneficial insects like coccinellid beetles, key predators of sucking pests (Sharma et al., 2025).

This study addresses these gaps by evaluating eight novel insecticides against okra's major pests over two seasons (Summer 2019-20 and 2020-21) at the Central Research Station, Odisha University of Agriculture and Technology,

Bhubaneswar. The objectives were threefold: (1) to quantify the field efficacy of these insecticides against jassids, whiteflies, and shoot and fruit borer; (2) to assess their impact on coccinellid populations as an indicator of ecological safety; and (3) to analyze their economic viability through yield and incremental cost-benefit metrics. By integrating pest control efficacy, ecological compatibility, and profitability, this research aims to inform sustainable pest management practices for okra cultivation, enhancing productivity while mitigating environmental risks.

2. MATERIALS AND METHODS

Field experiments were conducted during the summer seasons of 2019-20 and 2020-21 at the Central Research Station, Department of Entomology, Odisha University of Agriculture and Technology (O.U.A.T.), Bhubaneswar, Odisha, India (20.26°N, 85.81°E, elevation 25.9 m above sea level). The site features a hot and humid climate, with average temperatures ranging from

25°C to 38°C and relative humidity of 70–85% during the experimental period. The soil, characterized as sandy loam with a pH of 6.2–6.5, supports optimal okra growth. The experimental design employed a randomized block design (RBD) with nine treatments, encompassing eight insecticide applications and an untreated control, each replicated three times. Plots were established at 5 m × 4 m, with optimum spacing maintained at 50 cm between rows and 30 cm within rows to ensure uniform pest exposure and treatment consistency.

Okra seeds were sown in early March each year, following standard agronomic practices. Standard agronomic practices included pre-sowing soil enrichment with farmyard manure (10 t/ha), irrigation via drip systems at 5–7-day intervals, and fertilization with N: P:K (120:60:60 kg/ha) applied as urea, single superphosphate, and muriate of potash, respectively. Manual weeding was performed to minimize interference with pest and treatment observations.

Table 1. Details of insecticide treatments evaluated against major insect pests of okra

Treatment	Insecticide (Formulation)	Active Ingredient (a.i.) Dose	Application Method	Mode of Action
T1	<i>Flupyradifurone</i> 17.09% SL	250 g a.i./ha	Seed treatment + foliar spray	Nicotinic acetylcholine receptor agonist
T2	<i>Clothianidin</i> 50% WDG	20 g a.i./ha	Seed treatment + foliar spray	Neonicotinoid (systemic)
T3	<i>Spinosad</i> 45% SC	75 g a.i./ha	Seed treatment + foliar spray	Nicotinic acetylcholine receptor allosteric activator
T4	<i>Emamectin benzoate</i> 5% SG	7 g a.i./ha	Seed treatment + foliar spray	Chloride channel activator
T5	<i>Diafenthiuron</i> 50% WP	300 g a.i./ha	Seed treatment + foliar spray	Inhibitor of mitochondrial ATP synthase
T6	<i>Abamectin</i> 1.9% EC	5 g a.i./ha	Seed treatment + foliar spray	Chloride channel modulator
T7	<i>Spinetoram</i> 11.7% SC	50 g a.i./ha	Seed treatment + foliar spray	Nicotinic acetylcholine receptor allosteric activator
T8	<i>Fipronil</i> 5% SC	75 g a.i./ha	Seed treatment + foliar spray	GABA-gated chloride channel blocker
T9	Untreated control	-	foliar spray of water	-

Notes: Seed treatment involved imidacloprid 600 FS at 5 ml/kg seed for all treated plots. Foliar sprays were applied at 30 and 45 DAS. SL = Soluble Liquid, WDG = Water Dispersible Granules, SC = Soluble Concentrate, SG = Soluble Granules, WP = Wettable Powder, EC = Emulsifiable Concentrate

Eight novel insecticides were evaluated, each preceded by seed treatment with *imidacloprid* 600 FS at 5 ml/kg seed to provide initial protection against sucking pests. Foliar applications were administered at 30 and 45 days after sowing (DAS) using a knapsack sprayer calibrated to deliver 500 L/ha of spray solution. The treatments, outlined in Table 1, represented diverse chemical classes and modes of action, targeting the primary okra pests: jassids (*Amrasca biguttula biguttula* Ishida), whiteflies (*Bemisia tabaci* Gennadius), and shoot and fruit borer (*Earias vittella* Fabricius). An untreated control sprayed with water was maintained for comparison of treatment efficacy. Dosages were determined in accordance with the Central Insecticides Board and Registration Committee (CIBRC), Government of India.

Populations of *A. biguttula biguttula* and *B. tabaci* were assessed by counting individuals on three randomly selected leaves per plant from five plants per plot, recorded 1 day before treatment (DBT) and at 3, 7, and 14 days after treatment (DAT) for each spray application. Damage by *E. vittella* was evaluated by inspecting 50 fruits per plot at harvest, with percentage damage calculated by number (infested fruits/total fruits × 100) and weight (weight of infested fruits/total fruit weight × 100). Coccinellid beetles were enumerated on five leaves per plant from five plants per plot, synchronized with pest monitoring intervals. Observations were conducted between 06:00 and 08:00 to standardize insect activity levels.

Marketable fruit yield was determined by harvesting all mature, undamaged fruits from each plot at weekly intervals, weighed fresh, and expressed as tons per hectare (t/ha). Economic viability was assessed using the incremental cost-benefit ratio (ICBR), calculated as: $ICBR = (\text{Incremental benefit (Rs/ha)}) / (\text{Total cost of treatment (Rs/ha)})$ where incremental benefit = (yield value of treated plot – yield value of control). Treatment costs here encompass cost of insecticides, labor (application expenses) and the yield value is based on local market rates (assumed Rs 20,000/t, adjusted annually).

Data were pooled across both the years and analyzed using analysis of variance (ANOVA) appropriate for RBD, as described by Panse and Sukhatme (1967) using Microsoft Excel version 2016. Pest population and damage percentage

data were arcsine-transformed to ensure normality, and treatment means were separated using the critical difference (CD) at a 5% significance level. Standard error of the mean (S.E(m)±) was computed to evaluate variability. Percentage reduction over control (PROC) was determined (Henderson and Tilton (1955): $PROC (\%) = 100 \times (1 - ((\text{Treatment population after treatment} \times \text{Control population before treatment}) / (\text{Control population after treatment} \times \text{Treatment population before treatment})))$

3. RESULTS AND DISCUSSION

Field trials conducted over two summer seasons (2019-20 and 2020-21) at the Central Research Station, Bhubaneswar, evaluated eight novel insecticides against okra pests (*Amrasca biguttula biguttula*, *Bemisia tabaci*, *Earias vittella*), their impact on beneficial coccinellid beetles, and economic outcomes. Data, pooled across seasons and analyzed using ANOVA (Panse and Sukhatme, 1967), reveal significant pest control, ecological safety, and profitability, supporting integrated pest management (IPM). Findings and interpretations are presented below, organized by pest, beneficial insects, yield, and economics, with statistical significance reported as exact *P*-values.

3.1 Sucking Pests

Flupyradifurone reduced *A. biguttula biguttula* populations to 2.47 per plant (79.84% reduction over control's 27.57/plant, $P = 0.05$), outperforming clothianidin (3.68/plant, 73.36% reduction, $P = 0.05$) and diafenthiuron (3.68/plant, 71.91% reduction, $P = 0.05$) (Table 1). Its systemic nicotinic acetylcholine receptor agonism aligns with Garg et al. (2018), who reported similar efficacy in brinjal, and noting its precision against jassids. This control is critical, as jassids cause 17.46–54.04% yield losses via feeding and viral transmission (Anitha and Nandihalli, 2008). For *B. tabaci*, diafenthiuron achieved a 79.39% reduction (1.20 individuals per plant, $P = 0.05$), in contrast to 10.62 individuals per plant in the untreated control, followed by clothianidin (2.02/plant, 68.84%, $P = 0.05$) and flupyradifurone (1.97/plant, 68.36%, $P = 0.05$) (Table 1). Diafenthiuron's mitochondrial ATP synthase inhibition, effective in cotton (Madesh et al., 2024), curbs whitefly damage and viral spread, addressing losses up to 54.04% (Anitha & Nandihalli, 2008).

Table 2. Efficacy of novel insecticides against major pests of okra and impact on Coccinellids

Treatment	<i>A. biguttula</i> <i>biguttula</i> (No./plant)	PROC (%)	<i>B. tabaci</i> (No./plant)	PROC (%)	Coccinellids (No./5 leaves)	S.E(m)±	CD (P=0.05)
T1 (<i>Flupyradifurone</i>)	2.47	79.84	1.97	68.36	3.89	0.12	0.35
T2 (<i>Clothianidin</i>)	3.68	73.36	2.02	68.84	4.01	0.11	0.33
T3 (<i>Spinosad</i>)	5.12	65.43	3.45	62.15	3.72	0.14	0.4
T4 (<i>Emamectin benzoate</i>)	6.89	58.72	4.12	56.23	4.25	0.10	0.3
T5 (<i>Diafenthiuron</i>)	3.68	71.91	1.2	79.39	3.65	0.13	0.38
T6 (<i>Abamectin</i>)	7.45	55.62	4.89	51.32	3.54	0.15	0.42
T7 (<i>Spinetoram</i>)	5.89	62.34	3.78	60.15	3.96	0.12	0.36
T8 (<i>Fipronil</i>)	6.23	60.12	3.12	64.78	3.68	0.13	0.39
T9 (Control)	27.57	-	10.62	-	4.35	0.09	0.27

a Data pooled over two seasons and three replicates. b PROC calculated using Henderson and Tilton (1955). c P-values reported as exact values per journal guidelines

Table 3. Impact of insecticide treatments on fruit damage, yield, and economic returns

Treatment	Fruit Damage (% Number)	PROC (% Number)	Fruit Damage (% Weight)	PROC (% Weight)	Yield (t/ha)	% Increase Over Control	ICBR	Incremental Benefit (Rs/ha)
T1 (<i>Flupyradifurone</i>)	7.89	67.23	6.45	69.12	6.23	56.93	01:04.1	35,450
T2 (<i>Clothianidin</i>)	8.45	65.12	7.12	66.34	6.45	62.47	01:04.9	39,780
T3 (<i>Spinosad</i>)	5.67	75.71	4.63	78.09	7.08	78.34	01:05.7	52,956
T4 (<i>Emamectin benzoate</i>)	4.12	82.35	3.4	83.92	7.54	89.92	01:12.4	66,090
T5 (<i>Diafenthiuron</i>)	9.12	62.34	8.01	63.45	6.12	54.16	01:04.0	33,120
T6 (<i>Abamectin</i>)	10.34	58.12	9.23	59.78	5.67	42.82	01:03.5	28,340
T7 (<i>Spinetoram</i>)	5.15	77.94	4.42	79.09	7.11	79.09	01:06.1	54,230
T8 (<i>Fipronil</i>)	6.78	70.23	5.89	71.34	6.61	66.5	01:08.5	47,230
T9 (Control)	39.67	-	32.67	-	3.97	-	-	-

Notes: Fruit damage assessed on 50 fruits/plot; PROC = Reduction over control (%); ICBR = Incremental cost-benefit ratio; yield and economic data pooled over two seasons. Market price assumed at Rs 20,000/t.

3.2 Shoot and Fruit Borer

Emamectin benzoate minimized *E. vittella* damage to 4.12% by number and 3.40% by weight (82.35% and 83.92% reductions, $P = 0.05$) compared to the control (39.67% and 32.67%) (Table 2). Spinetoram (5.15% number, 4.42% weight, $P = 0.05$) and spinosad (5.67% number, 4.63% weight, $P = 0.05$) followed closely. Emamectin benzoate's chloride channel activation, as noted by Govindan et al. (2012), explains its efficacy, reducing losses reported at 32.06–40.48% (Mohapatra, 2023). These treatments preserve fruit quality, enhancing marketability.

3.3 Coccinellid Populations

Emamectin benzoate (4.25 beetles/5 leaves), clothianidin (4.01), spinetoram (3.96), and flupyradifurone (3.89) maintained coccinellid counts similar to the control (4.35, $P = 0.12$) (Table 2), indicating ecological safety. This aligns with Mineva et al. (2024), who found spinosyns safe for coccinellids, praising spinetoram's selectivity. Such compatibility supports IPM by preserving natural enemies, countering the harm of broad-spectrum insecticides (Insecticide Resistance Action Committee, 2007).

3.4 Yield and Economic Outcomes

Emamectin benzoate yielded 7.54 t/ha (89.92% increase, $P = 0.05$), followed by spinetoram (7.11 t/ha, 79.09%, $P = 0.05$) and spinosad (7.08 t/ha, 78.34%, $P = 0.05$), compared to the control (3.97 t/ha) (Table 3). Emamectin benzoate achieved the highest incremental cost-benefit ratio (ICBR) of 1:12.44 (Rs 66,090/ha), followed by fipronil (1:8.48, Rs 47,230/ha). These gains, tied to reduced pest damage, echo Sarsaiya and Singh (2025) and Sharma and Neupane (2025), highlighting profitability for smallholder farmers. The results suggest scalability for IPM adoption across tropical okra-growing regions, though residue persistence and resistance risks require further study.

4. CONCLUSION

Flupyradifurone reduced *Amrasca biguttula biguttula* populations by 79.84% (2.47/plant, $P = 0.05$), diafenthiuron *Bemisia tabaci* by 79.39% (1.20/plant, $P = 0.05$), and emamectin benzoate *Earias vittella* damage by 82.35–83.92% (4.12%

number, 3.40% weight, $P = 0.05$). Emamectin benzoate achieved the highest yield (7.54 t/ha, 89.92% increase, $P = 0.05$) and incremental cost-benefit ratio (1:12.44, Rs 66,090/ha). These insecticides preserved coccinellid populations (3.89–4.25/5 leaves, $P = 0.12$ vs. control), supporting their efficacy and ecological safety.

The results of this study confirm that flupyradifurone, diafenthiuron, and emamectin benzoate provide effective, selective, and economically viable options for pest management in okra. Their compatibility with beneficial arthropods supports their integration into IPM strategies under tropical agroecosystems.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies have been used during the editing of this manuscript. Specifically, QuillBot (online platform, accessed via <https://quillbot.com/>, version not specified by the provider as of May 2025) was used to enhance the clarity and grammatical accuracy of selected sentences in the manuscript. The tool was applied minimally to polish language in the Abstract, Introduction, Materials and Methods, and Discussion sections, focusing on improving sentence flow and correcting minor grammatical errors. Input prompts were not explicitly provided, as QuillBot's paraphrasing and grammar-checking features were applied interactively by pasting text into the platform's editor and selecting suggested rephrasings or corrections. All AI-generated suggestions were manually reviewed and edited by the authors to ensure scientific accuracy, originality, and alignment with the manuscript's content. No AI tools were used for drafting content, generating data, or creating figures/tables.

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- Author Oversight:** All QuillBot suggestions were critically reviewed and edited by the authors to maintain the manuscript's scientific integrity and originality.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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