**Efficacy of novel insecticides against major insect pests of Okra (*Abelmoschus esculentus* L.): impact on pest populations, natural enemies, yield, and economics**

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ABSTRACT

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| **Aims:** To evaluate the efficacy of eight novel insecticides against major okra pests (jassids, whiteflies, shoot and fruit borer), their safety to beneficial coccinellid beetles, and their economic viability in terms of yield and cost-benefit ratio.**Study design:** Randomized block design with three replications.**Place and Duration of Study:** Central Research Station, Odisha University of Agriculture and Technology, Bhubaneswar, during 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 in okra plots. 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 yielded 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 coccinellids (3.89–4.25/5 leaves, P > 0.05 vs. control).**Conclusion:** Flupyradifurone, diafenthiuron, and emamectin benzoate offer effective, ecologically safe, and economically viable pest management for okra, 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 cornerstone of vegetable production 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.

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 and 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% (Singh and Brak, 1994), 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, 2007).

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 (Wale et al., 2017), and emamectin benzoate reduces lepidopteran damage in okra (Kuttalam et al., 2008). 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.

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. material 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.

Seeds of okra (*Abelmoschus esculentus* L. Moench), of a locally adapted cultivar (variety unspecified in the provided document), were sown in early March each year. 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 murate of potash, respectively. Manual weeding was performed to minimize interference with pest and treatment observations.

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 based on Central Insecticide board recommendations, Government of India, tailored to address the pest complex under investigation.

**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 | *Flupyradifurone* 17.09% SL | 250 g a.i./ha | Seed treatment + foliar spray | Nicotinic acetylcholine receptor agonist |
| T2 | *Clothianidin*  | 20 g a.i./ha | Seed treatment + foliar spray | Neonicotinoid (systemic) |
| 50% WDG |
| T3 | *Spinosad*  | 75 g a.i./ha | Seed treatment + foliar spray | Nicotinic acetylcholine receptor allosteric activator |
| 45% SC |
| T4 | *Emamectin benzoate* 5% SG | 7 g a.i./ha | Seed treatment + foliar spray | Chloride channel activator |
| T5 | *Diafenthiuron*  | 300 g a.i./ha | Seed treatment + foliar spray | Inhibitor of mitochondrial ATP synthase |
| 50% WP |
| T6 | *Abamectin*  | 5 g a.i./ha | Seed treatment + foliar spray | Chloride channel modulator |
| 1.9% EC |
| T7 | *Spinetoram*  | 50 g a.i./ha | Seed treatment + foliar spray | Nicotinic acetylcholine receptor allosteric activator |
| 11.7% SC |
| T8 | *Fipronil* 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.

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 = (Incremental benefit (Rs/ha)) / (Total cost of treatment (Rs/ha))
where incremental benefit = (yield value of treated plot – yield value of control). Treatment costs here encompasses cost of insecticides, labour (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 × (1 - ((Treatment population after treatment × Control population before treatment) / (Control population after treatment × 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 Wale et al. (2017), who reported similar efficacy in brinjal, and Garg et al. (2018), 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/plant, P = 0.05) compared to the control (10.62/plant), 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 (Razaq et al., 2005), curbs whitefly damage and viral spread, addressing losses up to 54.04% (Anitha and Nandihalli, 2008).

**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 Kuttalam et al. (2008), explains its efficacy, reducing losses reported at 32.06–40.48% (Singh and Brak, 1994). 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 Mohanasundaram and Sharma (2011), who found spinosyns safe for coccinellids, and Visnupriya and Muthukrishnan (2017), 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 Patra et al. (2007) and Harinkhere (2014), 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.

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

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | ***A. biguttula biguttula* (No./plant)** | **PROC (%)** | ***B. tabaci* (No./plant)** | **PROC (%)** | **Coccinellids (No./5 leaves)** | **S.E(m)±** | **CD (P=0.05)** |
| T1 (*Flupyradifurone*) | 2.47 | 79.84 | 1.97 | 68.36 | 3.89 | 0.12 | 0.35 |
| T2 (*Clothianidin*) | 3.68 | 73.36 | 2.02 | 68.84 | 4.01 | 0.11 | 0.33 |
| T3 (*Spinosad*) | 5.12 | 65.43 | 3.45 | 62.15 | 3.72 | 0.14 | 0.4 |
| T4 (*Emamectin benzoate*) | 6.89 | 58.72 | 4.12 | 56.23 | 4.25 | 0.1 | 0.3 |
| T5 (*Diafenthiuron*) | 3.68 | 71.91 | 1.2 | 79.39 | 3.65 | 0.13 | 0.38 |
| T6 (*Abamectin*) | 7.45 | 55.62 | 4.89 | 51.32 | 3.54 | 0.15 | 0.42 |
| T7 (*Spinetoram*) | 5.89 | 62.34 | 3.78 | 60.15 | 3.96 | 0.12 | 0.36 |
| T8 (*Fipronil*) | 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 (*Flupyradifurone*) | 7.89 | 67.23 | 6.45 | 69.12 | 6.23 | 56.93 | 01:04.1 | 35,450 |
| T2 (*Clothianidin*) | 8.45 | 65.12 | 7.12 | 66.34 | 6.45 | 62.47 | 01:04.9 | 39,780 |
| T3 (*Spinosad*) | 5.67 | 75.71 | 4.63 | 78.09 | 7.08 | 78.34 | 01:05.7 | 52,956 |
| T4 (*Emamectin benzoate*) | 4.12 | 82.35 | 3.4 | 83.92 | 7.54 | 89.92 | 01:12.4 | 66,090 |
| T5 (*Diafenthiuron*) | 9.12 | 62.34 | 8.01 | 63.45 | 6.12 | 54.16 | 01:04.0 | 33,120 |
| T6 (*Abamectin*) | 10.34 | 58.12 | 9.23 | 59.78 | 5.67 | 42.82 | 01:03.5 | 28,340 |
| T7 (*Spinetoram*) | 5.15 | 77.94 | 4.42 | 79.09 | 7.11 | 79.09 | 01:06.1 | 54,230 |
| T8 (*Fipronil*) | 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.

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 for integrated pest management in okra cultivation.

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