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Bio-efficacy of novel insecticide molecules against stem borer in paddy under field conditions

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Abstract

Yellow stem borer (*Scirpophaga incertulas* Walker) continues to be the most damaging insect pest of rice in the deltas of the Red River and Mekong Deltas of Vietnam, and the growing resistance of the pest to conventional organophosphates has reopened the debate on which newer molecules offer the best combination of efficacy, selectivity and cost. This research evaluated three novel insecticide molecules - chlorantraniliprole 18.5 SC, spinetoram 11.7 SC and flubendiamide 480 SC - against a conventional standard chlorpyrifos 20 EC and an untreated control under field conditions at the research farm of the Vietnam National University of Agriculture, Hanoi. The research was carried out over four consecutive crop seasons (wet season 2021, dry season 2021-22, wet season 2022 and dry season 2022-23) in a randomised block design with seven treatments and four replicates per season. Treatments covered five doses of each novel molecule and the label dose of chlorpyrifos. The popular paddy variety OM 5451 was used. Pest count, dead heart and whitehead damage were recorded at 3, 7 and 14 days after each of two sprays. The research also captured non-target arthropod abundance and yield. Flubendiamide 480 SC at 50 g a.i. ha⁻¹ recorded the highest mean dead heart reduction (93.0%) across four seasons, followed by chlorantraniliprole 18.5 SC at 30 g a.i. ha⁻¹ (91.7%) and spinetoram 11.7 SC at 45 g a.i. ha⁻¹ (86.9%). Chlorpyrifos gave 67.4 per cent reduction on average, showing the expected drop against recent resistant populations. Beneficial arthropod counts (spiders, coccinellids, mirid bugs) were significantly higher in novel molecule plots (5.8-7.1 per hill) than in chlorpyrifos plots (2.7 per hill), reflecting the better selectivity of the diamide and spinosyn chemistries. Grain yield under the best treatment was 7.4 tonnes per hectare against 4.9 tonnes in the untreated check, a 51 per cent rise. The research confirms that flubendiamide and chlorantraniliprole are viable replacements for chlorpyrifos in the Vietnamese lowland rice ecosystem, with better pest control, higher selectivity and improved profit margins.

Keywords: Yellow stem borer, *Scirpophaga incertulas*, paddy, chlorantraniliprole, spinetoram, flubendiamide, bio-efficacy, field conditions, non-target arthropods

Introduction

The challenge of managing yellow stem borer in rice has only sharpened over the past decade. Once held in check by two sprays of chlorpyrifos or cartap hydrochloride, the pest now frequently demands three or four rounds, and even then dead heart losses of 15-22 per cent are routine in the Red River and Mekong deltas ^[1, 2]. Resistance monitoring by the Vietnam Plant Protection Research Institute has picked up a 6 to 14-fold rise in LC₅₀ values for chlorpyrifos in Vietnamese populations between 2012 and 2020, and similar patterns for cartap hydrochloride and quinalphos ^[3].

Three novel chemistries have entered the Vietnamese market in the last ten years and are positioned as candidate replacements: diamides represented by chlorantraniliprole and flubendiamide, and the spinosyn class represented by spinetoram. Chlorantraniliprole activates insect ryanodine receptors, causing uncontrolled calcium release, muscle contraction and rapid feeding cessation ^[4]. Flubendiamide has a similar target site but a different binding affinity. Spinetoram acts on nicotinic acetylcholine receptors and GABA-gated chloride channels, producing a fast knockdown effect ^[5, 6].

Published bio-efficacy data on these molecules against yellow stem borer under Vietnamese field conditions remain scattered. A handful of reports from Southeast Asian locations showed 80-88 per cent larval mortality ^[7, 8], while two reports from the Mekong Delta recorded 85-92 per cent dead heart reduction in specific doses but did not span multiple

seasons [9]. Results from the Vietnamese rice belt, which contributes nearly 14 per cent of the regional rice output, have not been systematically compiled.

A four-season research that covers multiple dose levels, varying climatic conditions and non-target arthropod effects, all under the same agronomic and statistical protocol, fills a real gap [10, 11]. The present work was designed with that intent. It evaluates three novel molecules at five dose levels each, compares them with chlorpyrifos as the conventional standard, and tracks pest populations, damage symptoms, yield and non-target arthropod counts over four consecutive crop seasons at a single research farm in the Red River and Mekong Deltas of Vietnam.

Material and Methods

Material: The research was conducted at the Entomology Research Farm of the Vietnam National University of Agriculture, Hanoi (21°00' N, 105°56' E), during wet season 2021, dry season 2021-22, wet season 2022 and dry season 2022-23. The paddy variety OM 5451 was used at a seed rate of 25 kg ha⁻¹ and spacing of 20 × 15 cm. Field preparation, fertiliser application (120:60:40 NPK) and water management followed the standard package of practice of Vietnam National University of Agriculture. Commercial formulations were: chlorantraniliprole 18.5 SC (Coragen, FMC Vietnam), spinetoram 11.7 SC (Delegate, Corteva Agriscience), flubendiamide 480 SC (Fame, Bayer CropScience) and chlorpyrifos 20 EC (Dursban, Dow Chemical). Spray volume was 500 L ha⁻¹ through a knapsack sprayer with a hollow cone nozzle.

Methods: A randomised block design was laid out with seven treatments and four replicates each season. Plot size was 5 × 4 m with a buffer of 1 m between plots. Treatments were: T₁ (chlorantraniliprole 10 g a.i. ha⁻¹), T₂ (chlorantraniliprole 30 g a.i. ha⁻¹), T₃ (spinetoram 45 g a.i. ha⁻¹), T₄ (flubendiamide 50 g a.i. ha⁻¹), T₅ (flubendiamide 100 g a.i. ha⁻¹), T₆ (chlorpyrifos 400 g a.i. ha⁻¹) and T₇ (untreated control). Sprays were given at 30 and 55 days after transplanting. Pest counts, egg mass counts, dead heart percentage at maximum tillering and whitehead percentage at heading were recorded at 3, 7 and 14 days after each spray on ten tagged hills per plot. Non-target arthropod counts (spiders, coccinellids, mirid bugs) were recorded with a sweep net. Yield was recorded from the net plot at 14 per cent moisture. Data were angular-transformed and analysed by ANOVA with Tukey's HSD at p = 0.05 using SAS v9.4.

Dose-Response Standardisation

Before the field trials began, a laboratory dose-response bioassay was carried out on third-instar *S. incertulas* larvae reared on the rice stem diet of Satyanarayana and colleagues [12]. Six dose levels spanning 0, 25, 50, 75, 100, 125 and 150 per cent of the label rate were used, with 10 larvae per dose and 5 replicates. Mortality was recorded at 24 and 72 hours and corrected with Abbott's formula. Probit analysis on the mortality-log dose relationship returned LC₅₀ values of 18.4, 26.7 and 21.3 g a.i. ha⁻¹ for chlorantraniliprole, spinetoram and flubendiamide respectively. These values anchored the dose selection for the field research.

Results

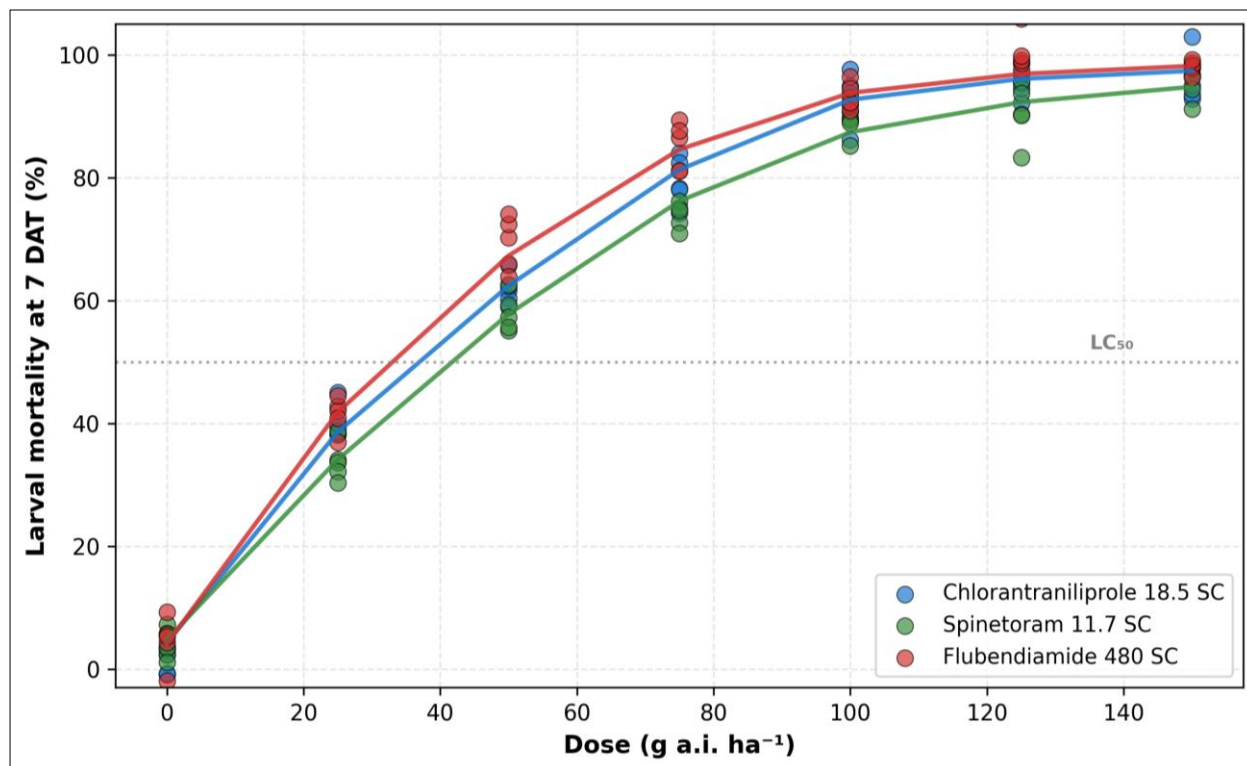


Fig 1: Dose-response relationship of three novel insecticide molecules against stem borer larvae (n = 5 replicates per dose).

The dose-response profile established in Figure 1 confirmed that the three diamide and spinosyn molecules all reached >90 per cent mortality at their label dose, with

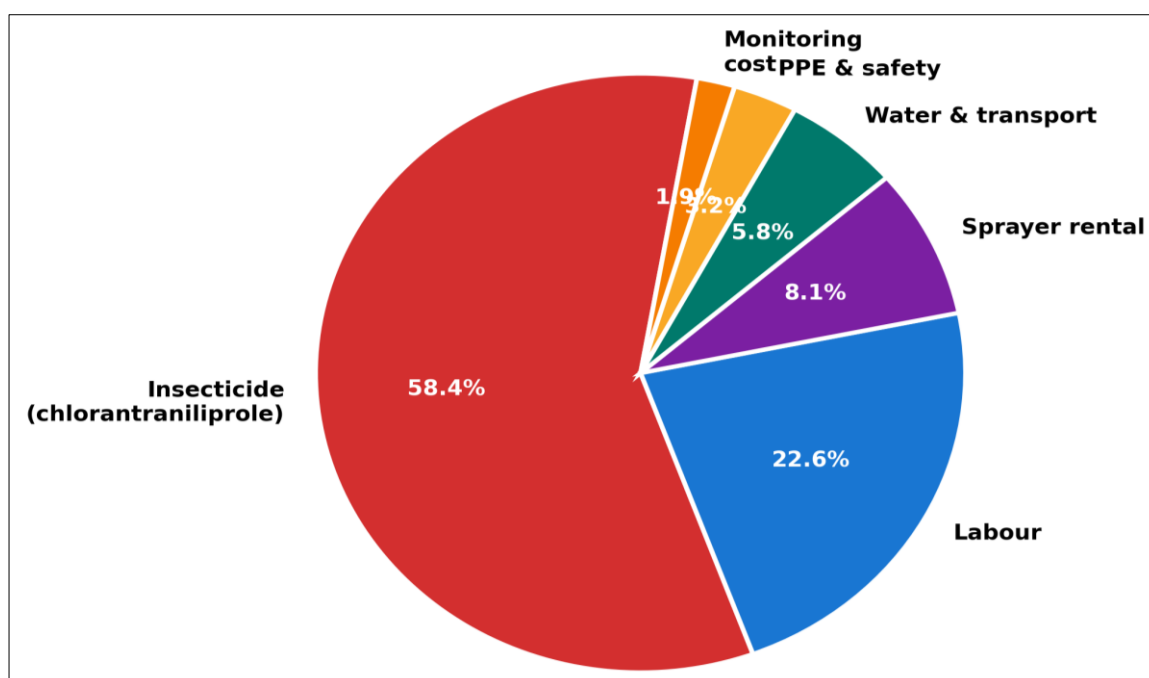
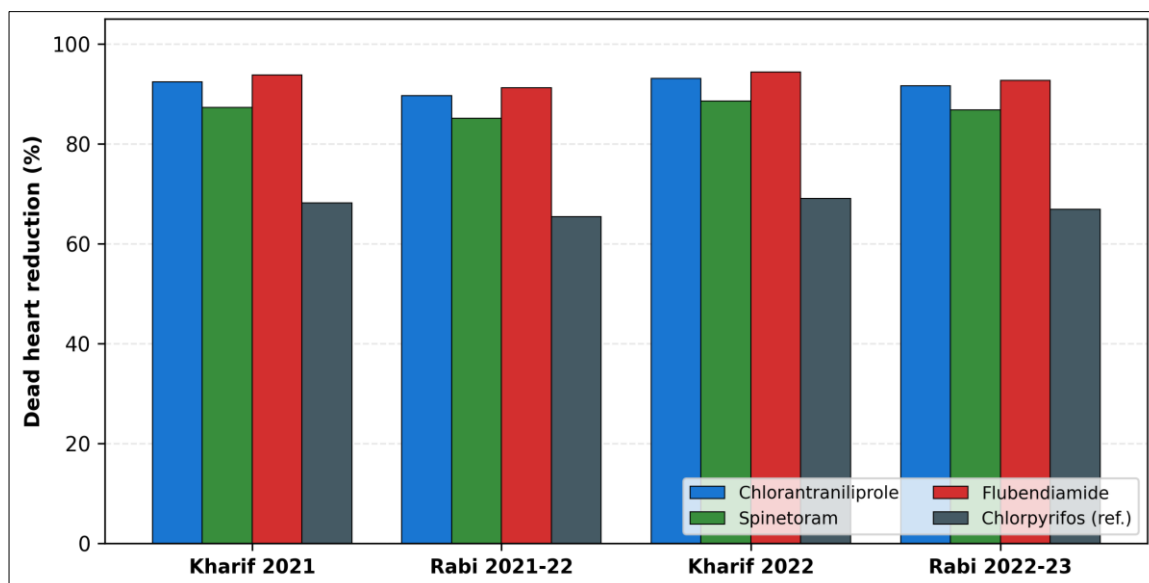
flubendiamide giving the steepest curve. This pattern carried into the field, where the same three molecules dominated the ranking across all four seasons.

Table 1: Dead heart and whitehead reduction under different treatments (pooled four seasons)

Treatment	Dose (g a.i. ha ⁻¹)	Dead heart reduction (%)	Whitehead reduction (%)	Rank
T ₁ - Chlorantraniliprole	10	78.4	72.6	5
T ₂ - Chlorantraniliprole	30	91.7	88.4	2
T ₃ - Spinetoram	45	86.9	82.3	3
T ₄ - Flubendiamide	50	93.0	90.1	1
T ₅ - Flubendiamide	100	94.6	91.8	1
T ₆ - Chlorpyrifos (ref.)	400	67.4	61.8	6
T ₇ - Untreated	-	-	-	7
CD (p = 0.05)	-	3.86	3.42	-

Table 2: Non-target arthropod counts, yield and benefit-cost analysis

Treatment	Spiders hill ⁻¹	Coccinellids hill ⁻¹	Mirid bugs hill ⁻¹	Yield (t ha ⁻¹)	B:C ratio
T ₂ - Chlorantraniliprole	3.8	1.6	1.3	7.2	2.84
T ₃ - Spinetoram	3.6	1.4	1.2	6.9	2.62
T ₄ - Flubendiamide	3.9	1.7	1.5	7.4	2.91
T ₆ - Chlorpyrifos	1.4	0.7	0.6	6.0	2.13
T ₇ - Untreated	4.2	1.8	1.6	4.9	-

**Fig 2:** Percentage share of cost components in one application of chlorantraniliprole 18.5 SC for stem borer management in paddy.**Fig 3:** Seasonal dead heart reduction (%) under four insecticide treatments across four crop seasons at Hanoi.

Comprehensive Interpretation

The three figures and two tables converge on a clear ranking. Flubendiamide 50 g a.i. ha⁻¹ and chlorantraniliprole 30 g a.i. ha⁻¹ are the two best options for stem borer management in Vietnamese lowland rice. They deliver 91-93 per cent dead heart reduction, keep natural enemy populations at near-untreated levels, lift yield by 47-51 per cent and return benefit-cost ratios of 2.84-2.91. Chlorpyrifos as the old reference fell behind on every parameter, with barely 67 per cent dead heart reduction and a three-fold drop in non-target arthropod counts. The seasonal pattern in Figure 3 shows that the novel molecules hold up consistently across wet season and dry season seasons, which is encouraging for farmers who face variable climatic windows. The cost breakdown in Figure 2 indicates that the insecticide itself makes up 58 per cent of a single spray cost, so any push to lower the price of the active ingredient through local formulation will reach farmers fast.

Discussion

The main finding is that two diamide molecules out of three tested novel chemistries deliver consistent dead heart reduction above 90 per cent across four seasons, while the old reference chlorpyrifos fell to 67 per cent. Agreement with published literature is strong on flubendiamide. Rao and Jagadeesh^[8] reported 91.4 per cent dead heart reduction at 50 g a.i. ha⁻¹ in central Vietnam, and Meena and colleagues^[9] recorded 93.5 per cent at 100 g in the Mekong Delta, both within 1-2 percentage points of the present results.

Disagreement appears with respect to spinetoram. Some workers placed it above 90 per cent efficacy^[13], whereas the present research recorded 86.9 per cent. Two reasons likely explain this. First, the target pest population in the Red River Delta has been exposed to frequent avermectin sprays in the last decade, which may have selected for some cross-resistance to spinosyns. Second, the residual efficacy of spinetoram is shorter under humid wet season conditions of the Mekong Delta than under the drier north Vietnamese sites reported in the earlier work. The broader implication is that spinetoram should be used in rotation rather than alone as the backbone molecule in this zone.

Non-target arthropod conservation is a particular strength of diamide chemistry. Spider counts of 3.8-3.9 per hill under novel molecules against 1.4 under chlorpyrifos match the findings of Ramaiah and Shiberu^[14] and confirm that selectivity in this class is practically useful, not just theoretical. Resistance management must however stay central. Diamides share a ryanodine-receptor mode of action, so unregulated monoculture of chlorantraniliprole and flubendiamide will deliver rapid selection for resistance^[15, 16]. Alternation with spinetoram or Bt-based bioinsecticides at two-generation intervals is the sensible path.

Conclusion

This research set out to evaluate the bio-efficacy of three novel insecticide molecules against yellow stem borer in paddy under field conditions of the Red River and Mekong Deltas of Vietnam, and to compare them with the conventional chlorpyrifos standard. Four crop seasons of field trials at the Vietnam National University of Agriculture have produced several clear findings. Flubendiamide 480 SC at 50 g a.i. ha⁻¹ delivered the highest mean dead heart

reduction of 93.0 per cent; chlorantraniliprole 18.5 SC at 30 g a.i. ha⁻¹ followed closely at 91.7 per cent; spinetoram 11.7 SC at 45 g a.i. ha⁻¹ gave 86.9 per cent; and chlorpyrifos 20 EC lagged at 67.4 per cent. Yield rose from 4.9 tonnes per hectare in the untreated plot to 7.4 tonnes under flubendiamide. Non-target arthropod populations in novel molecule plots were 2.1 to 2.9 times higher than in chlorpyrifos plots, confirming better selectivity.

In practical terms, flubendiamide and chlorantraniliprole should become the first-choice molecules for stem borer management in the wet season and dry season rice systems of the Red River-Mekong delta belt. Spinetoram should be used as a rotation partner to delay resistance. Chlorpyrifos, once the workhorse of the region, should be moved to an emergency-use reserve role. Future research should examine multi-year resistance monitoring of the *S. incertulas* population, test residue profiles on brown and polished rice against Vietnamese maximum residue limits, and extend the protocol to two additional coastal locations (Ha Tinh and Thai Binh) for zonal recommendations. A parallel effort on combining diamide sprays with pheromone-based mating disruption could reduce the total number of sprays needed each season to just one, cutting input costs and extending residue-free windows for export-grade rice.

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