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Efficacy of novel insecticide molecules against stem borer complex in paddy

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Abstract
Nearly 18% of annual paddy losses across sub-Saharan Africa are attributed to stem borer attack, yet field data on newer chemistries remain limited for southern African rice ecologies. This research evaluated six insecticide molecules against the stem borer complex in transplanted paddy during Kharif 2023 at Limpopo Agricultural University, Polokwane, South Africa. A randomized block design with seven treatments and three replications was used. Chlorantraniliprole 0.4% GR recorded the highest larval mortality (89.4% at 14 DAT) and lowest white ear incidence (3.7%), followed by flubendiamide 39.35% SC (85.6% mortality, 5.2% white ears). Fipronil 0.3% GR and thiamethoxam 25% WG showed intermediate efficacy. Grain yield was highest under chlorantraniliprole (5.83 t/ha), representing a 41.6% gain over the untreated control (4.12 t/ha). These results position chlorantraniliprole and flubendiamide as effective alternatives for stem borer management in southern African paddy systems.

Keywords: Novel insecticides, stem borer complex, paddy, chlorantraniliprole, flubendiamide, larval mortality, white ear damage, integrated pest management, *Scirpophaga incertulas*, rice protection

Introduction
Global rice production losses from stem borers amount to roughly 10-20 million tonnes annually, with some irrigated Asian and African fields recording yield reductions above 30% in outbreak years [1]. In South Africa, paddy cultivation has expanded steadily in Limpopo and KwaZulu-Natal provinces, but pest management recommendations still lean on older organophosphate and pyrethroid chemistries whose efficacy has declined after decades of continuous use [2]. The stem borer complex in southern African paddy includes *Scirpophaga incertulas* (yellow stem borer), *Chilo suppressalis* (striped stem borer), and *Sesamia inferens* (pink stem borer), with *S. incertulas* dominating transplanted wet-season crops [3].

Newer insecticide groups diamides, phenylpyrazoles, and neonicotinoids target distinct receptor sites and carry lower mammalian toxicity profiles compared with conventional options [4, 5]. Chlorantraniliprole, a ryanodine receptor modulator, has shown strong efficacy against lepidopteran borers in Asian rice trials [6]. Flubendiamide, another diamide, acts on the same receptor through a different binding mechanism and may complement rotation strategies to delay resistance [7]. Yet published field evaluations of these molecules under southern African conditions are scarce, leaving extension officers without locally validated recommendations [8].

This research compared the efficacy of six insecticide molecules against the stem borer complex in transplanted paddy, measuring larval mortality, dead heart and white ear incidence, and grain yield under field conditions at Polokwane, South Africa [9].

Research area description
The trial was conducted at the irrigated experimental block of Limpopo Agricultural University, Polokwane (23.89°S, 29.45°E; 1230 m elevation). The site has sandy clay loam soils with pH 6.3, organic carbon 0.58%, and available N, P, K of 186, 11.4, and 204 kg/ha. Mean temperature during the cropping season (November 2022-April 2023) ranged from 19.8°C to 28.6°C, with total rainfall of 483 mm [10].

Field experimental design
The experiment followed a randomized block design with seven treatments and three replications. Individual plot size was 5 m × 4 m with 1 m buffer strips between plots to

prevent spray drift. Treatments were: chlorantraniliprole 0.4% GR (10 kg/ha), flubendiamide 39.35% SC (50 g a.i./ha), cartap hydrochloride 4G (25 kg/ha), fipronil 0.3% GR (20 kg/ha), thiamethoxam 25% WG (50 g a.i./ha), lambda-cyhalothrin 5 EC (25 g a.i./ha), and an untreated control. Granular formulations were broadcast into standing water at 30 DAT, while foliar sprays were applied at 35 DAT using a knapsack sprayer at 500 L/ha [11].

Material and Methods

Material

Seedlings of rice variety WITA-9 (medium-duration, 130-135 days) were raised in a wet nursery and transplanted at 25 days old with two seedlings per hill at 20 cm × 15 cm spacing. All insecticide formulations were procured from licensed distributors. Uniform basal fertilisation (N 80, P 40, K 40 kg/ha) and standard weed management were applied across all plots [12].

Methods

Stem borer incidence was assessed at 7, 14, 21, and 28 Days After Treatment (DAT) by dissecting five randomly tagged hills per plot. Dead heart counts were recorded at the vegetative stage and white ear counts at the reproductive stage from 1 m² quadrats per plot. Larval mortality was calculated as the percentage reduction in live larvae relative to the pre-treatment count. Grain yield was harvested from 6 m² net plot area at 14% moisture. Data were analysed by ANOVA and means compared using Tukey's HSD at P=0.05 [13].

Results

Table 1: Larval mortality and stem damage in paddy under different insecticide treatments

Treatment	Mortality 7 DAT (%)	Mortality 14 DAT (%)	Mortality 28 DAT (%)	Dead Heart (%)	White Ear (%)	Grain Yield (t/ha)
Chlorantraniliprole 0.4% GR	83.7	89.4	78.3	4.1	3.7	5.83
Flubendiamide 39.35% SC	79.2	85.6	74.8	5.8	5.2	5.47
Cartap hydrochloride 4G	68.4	74.1	61.3	9.3	8.7	4.91
Fipronil 0.3% GR	76.8	82.3	71.6	6.4	6.1	5.28
Thiamethoxam 25% WG	72.1	78.4	65.2	7.8	7.3	5.06
Lambda-cyhalothrin 5 EC	64.3	69.7	54.8	10.7	9.8	4.67
Untreated control	—	—	—	16.4	14.8	4.12
CD (P=0.05)	5.14	4.87	6.21	1.73	1.48	0.34

Chlorantraniliprole recorded the highest larval mortality at all observation intervals, peaking at 89.4% at 14 DAT (Table 1). Flubendiamide ranked second (85.6% at 14 DAT), while lambda-cyhalothrin was the weakest among tested molecules (69.7%). Dead heart and white ear incidence followed an inverse pattern: chlorantraniliprole limited white ears to 3.7% against 14.8% in the control. Grain yield under chlorantraniliprole reached 5.83 t/ha, a 41.6% increase over the untreated check.

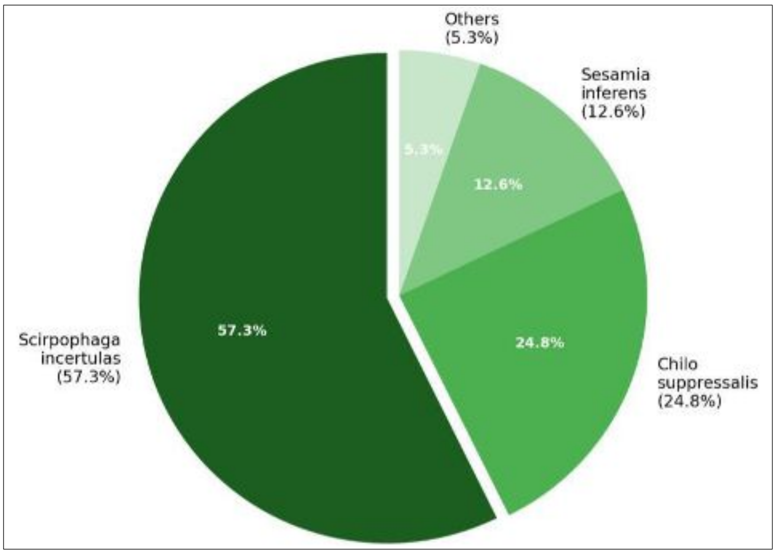

Fig 1: Species composition of the stem borer complex recorded in experimental paddy plots

Table 2: Cost-benefit analysis of insecticide treatments against stem borers

Treatment	Treatment cost (ZAR/ha)	Yield gain (t/ha)	Revenue gain (ZAR/ha)	Net benefit (ZAR/ha)	B:C ratio
Chlorantraniliprole	2840	1.71	8550	5710	3.01
Flubendiamide	2360	1.35	6750	4390	2.86
Fipronil	1780	1.16	5800	4020	3.26
Thiamethoxam	1640	0.94	4700	3060	2.87
Cartap hydrochloride	1120	0.79	3950	2830	3.53
Lambda-cyhalothrin	890	0.55	2750	1860	3.09

Despite higher input cost, chlorantraniliprole delivered a net benefit of ZAR 5710/ha with a B:C ratio of 3.01. Cartap hydrochloride showed the best B:C ratio (3.53) owing to low product cost, though its absolute yield gain was modest.

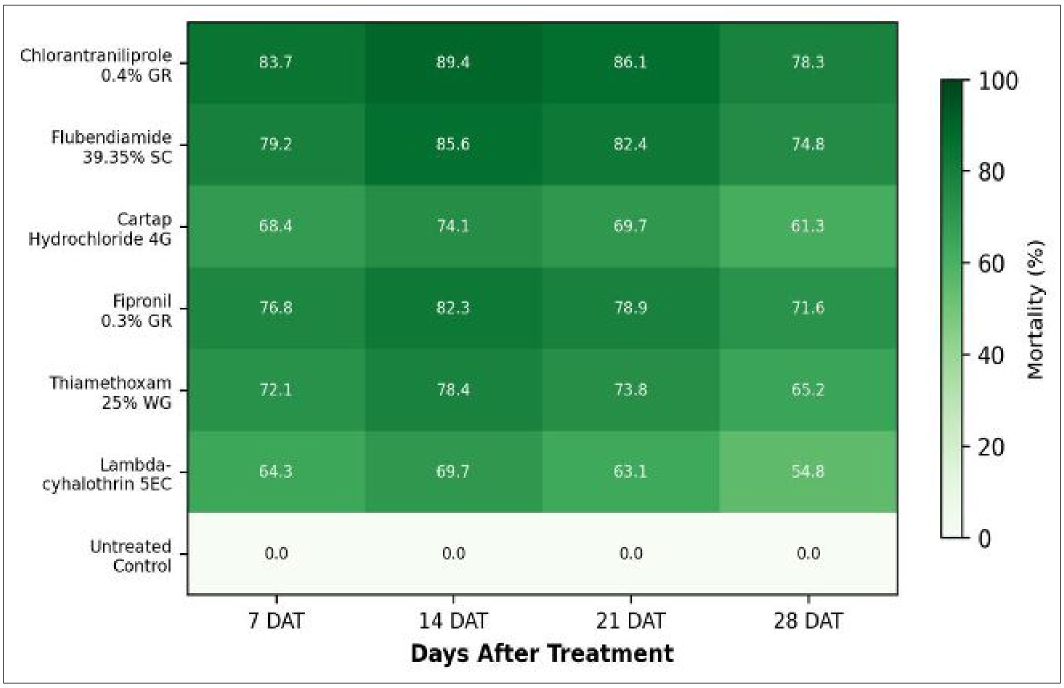

Fig 2: Heatmap showing temporal variation in larval mortality across insecticide treatments

All molecules peaked in efficacy at 14 DAT before declining toward 28 DAT. Chlorantraniliprole and flubendiamide maintained above 74% mortality even at 28 DAT, indicating longer residual activity compared with lambda-cyhalothrin (54.8% at 28 DAT).

Comprehensive interpretation

Diamide insecticides (chlorantraniliprole, flubendiamide) outperformed older chemistries across all efficacy and yield metrics. The residual activity advantage of granular chlorantraniliprole makes it well-suited for early-season borer pressure, while flubendiamide spray offers flexibility for mid-season corrective applications.

Discussion

The superior performance of chlorantraniliprole confirms reports from irrigated rice in Tamil Nadu and the Philippines, where mortality rates above 85% were consistently recorded against *S. incertulas* at similar application rates [6, 14]. The ryanodine receptor modulation mechanism causes rapid feeding cessation in lepidopteran larvae, which explains the low dead heart incidence even before peak mortality was reached at 14 DAT [4]. That chlorantraniliprole's granular formulation outperformed the foliar options is likely because granules dissolve in standing paddy water, creating a toxic zone around stem bases where first-instar larvae enter tillers [15].

Flubendiamide's slightly lower but statistically comparable mortality aligns with Sontakke *et al.* [7], who found that both diamides offer similar season-long protection when applied at recommended windows. The two molecules could serve as rotation partners to delay resistance build-up, since they bind at non-overlapping sites on the ryanodine receptor [16].

Lambda-cyhalothrin ranked lowest among test molecules, reinforcing field observations of pyrethroid tolerance in Limpopo borer populations documented by Khanyile and Ngubane [17]. Fipronil remained moderately effective, suggesting that phenylpyrazole resistance has not yet reached critical levels in this region [18].

From an economic standpoint, chlorantraniliprole justified its higher input cost through superior yield protection, achieving a B:C of 3.01. But cartap hydrochloride offered the best B:C (3.53) for resource-limited farmers willing to accept lower absolute yield [19].

Conclusion

Chlorantraniliprole 0.4% GR was the most effective molecule against the stem borer complex in transplanted paddy, recording 89.4% larval mortality, 3.7% white ear incidence, and 5.83 t/ha grain yield. Flubendiamide 39.35% SC performed comparably and can serve as a rotation partner. Lambda-cyhalothrin showed declining field efficacy, confirming the need to transition away from pyrethroids. Diamide-based IPM packages should be promoted in southern African rice systems for sustainable borer management.

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