

Assessing the impact of foliar insecticides on yellow stem borer *Scirpophaga incertulas* and rice yield enhancement

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ABSTRACT: The field efficacy of various foliar insecticides with different modes of action was carried out against yellow stem borer during summer 2023 at CoA, V.C. Farm, Mandya. Among the treatments, flubendiamide 39.35 SC emerged as the most effective treatment, followed by chlorantraniliprole 18.5 SC and fipronil 5 SC with the least dead heart and white ears. Flubendiamide also recorded the highest grain and biomass yield followed by chlorantraniliprole 18.5 SC and fipronil 5 SC. Additionally, the economic analysis revealed that among the evaluated insecticide treatments, flubendiamide 39.35 SC demonstrated the highest net returns (Rs. 150819 per hectare) and benefit-cost ratio (4.44).

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KEY WORDS: Paddy, diamides, bio-efficacy, dead hearts, white ears, yield, cost-economics

INTRODUCTION

Rice, frequently referred to as the cornerstone of sustenance, holds immense significance worldwide, acting as the main source of nourishment for more than half of the global population (Rai, 2006; Pathak *et al.*, 2018). The crop is predominantly cultivated in India, followed by China and Indonesia; however, China leads in overall production, while Australia boasts the highest productivity rates. In India, rice is grown over an area of 46.38 million hectares, producing 130.29 million tonnes and productivity of 2809 kg per hectare (Indiastat, 2022). In a country where rice is vital for food security, its cultivation covers extensive regions, with significant contributions from states such as West Bengal, Uttar Pradesh, Punjab, Telangana, Odisha, and Karnataka (Indiastat, 2022). Within Karnataka, rice cultivation

occurs across 27 districts, with an area of 1.39 million hectares, production of 4.31 million tonnes and productivity of 3089 kg per hectare (MoA&FW, 2022). Nonetheless, several biotic and abiotic factors have been recognized as significant limitations that hinder the potential yield of rice, resulting in considerable decreases in quality and quantity.

The intensification of rice cultivation practices, marked by the widespread adoption of high-yielding varieties and monocropping, exacerbates pest incidences, exacerbating losses (Neeta *et al.*, 2013). Among different groups of insect pests, stem borer (40%), planthopper (25%), gall midge (10%) and other pests (25%) are ranked in order of the indicated per cent share of the total losses caused by insect pests together (Reddy *et al.*, 2010).

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Furthermore, pest outbreaks can lead to complete crop failure or severe yield loss. Amongst the stem borers that feed on rice, yellow stem borer (YSB) *Scirpophaga incertulas* (Walker) is the most destructive pest causing about a 25-30 per cent reduction in yield. This results in an annual yield loss of 27-34 per cent of the production (Pasalu *et al.*, 2002; Chatterjee and Mondal, 2014). Attack by stem borers at the vegetative stage of plant growth produces symptoms called 'dead hearts' (DHs). In contrast, attack at the reproductive stage produces 'whit ears' (WEs). Rice plants can compensate for low incidences of DHs, but a 1-3 per cent loss of yield is expected for every per cent of WEs (Pathak *et al.*, 1971; Balaji, 2024).

Insecticides provide an effective approach to controlling pests. Their application positively influences rice yields (Abro *et al.*, 2013) and is characterized by being highly effective, fast-acting, convenient, and cost-effective, making them essential tools in pest management. It is crucial to utilize selective insecticides that target the YSB while being less harmful to beneficial species. However, excessive reliance on conventional insecticides has led to the development of resistance, highlighting the need to investigate new insecticide molecules (Pasalu *et al.*, 2002; Singh and Rajshree, 2017). Developing and implementing novel insecticide molecules for managing the paddy yellow stem borer is vital for tackling resistance, enhancing efficacy, reducing environmental impact, promoting sustainability, and protecting rice production. In this regard, evaluating insecticide molecules is of utmost importance. By assessing their effectiveness against YSB infestation, their effects on yield attributes, and their cost-benefit ratios, this study aims to enhance the range of pest management strategies crucial for ensuring rice production and global food security.

MATERIALS AND METHODS

The field experiment was conducted during *Summer* 2023 at "A" block, College of Agriculture, V.C. Farm Mandya (12.5690° N, 76.8107° E) to evaluate new and conventional foliar insecticides. The trial consisted of nine treatments, including control (Table 1) with three replications and the treatments

were imposed following Randomized Complete Block Design. The susceptible and popular rice variety Jaya was sown and 25 days old seedlings were transplanted in replicated blocks of 4 x 3 m with the spacing of 20 x 15 cm between rows and plants respectively. The crop was raised as per packages of practices except for the management schedule for YSB (POP, 2017). In each treatment, the recommended insecticides were applied based on ETL *i.e.*, 5 per cent DH during the booting stage or 1 egg mass m⁻² (Asghar *et al.*, 2009) and the second spray was initiated at 90 DAT. In each spray, per cent DH and WEs were observed a day before application (to compare pre- and post-spray differences and calculate per cent infestation reduction) and 5, 10, 15 and 20 days after application on ten hills using the Standard Evaluation System for Rice (SES) formula (IRRI, 2013).

$$\% \text{ Dead heart} = \frac{\text{Total No. of dead heart per 10 hill}}{\text{Total No. of tillers}} \times 100$$

$$\% \text{ White ears} = \frac{\text{Total No. of white ears per 10 hills}}{\text{Total No. of panicles}} \times 100$$

Data on percent DH and WEs were analyzed in Microsoft Excel 2021, arc sin-transformed, and subjected to ANOVA (Gomez and Gomez, 1984; Hoshmand, 1988), with means separated by Tukey's HSD (Tukey, 1965). Results are graphically represented using GraphPad Prism 8.0.2 for better interpretation.

Grain yield and cost economics: Grain yield was recorded at physiological maturity and converted to quintals per hectare. Grain and biomass yields were analyzed using ANOVA (Gomez and Gomez, 1984; Hoshmand, 1988), with means separated by Tukey's HSD (Tukey, 1965). The percent additional yield gain over the untreated control was calculated for each treatment.

$$\text{Per cent additional grain yield} = \frac{(\text{Yield in treatment} - \text{Yield in control})}{\text{Yield in control}} \times 100$$

The cost economics of insecticidal treatments was analyzed using prevailing market prices of insecticides, labor wages, and additional costs, with the benefit-cost ratio calculated accordingly.

$$\text{Benefit Cost ratio} = \frac{\text{Net profit (Rs)}}{\text{Total cost (Rs)}}$$

RESULTS AND DISCUSSION

All the insecticides significantly reduced the dead heart infestation compared to the control at 5, 10, 15 and 20 days after treatment in the first application. The first application was done 35 days after transplanting and one day before treatment the mean dead heart ranged from 15.88 to 17.16 per cent during summer 2023 and there were no statistical differences among the treatments. In all the treatments at 20 DAS, the per cent dead heart was reduced (Table 1). Among all the treatments the minimum per cent dead heart was observed in flubendiamide 39.35 SC (4.18%), followed by chlorantraniliprole 18.5 SC (5.83%) which was on par with fipronil 5 SC (6.48%). The next best treatments were thiamethoxam 25 WG (7.22%), carbosulfan 25 EC (7.83%), quinalphos 25 EC (8.16%), cartap hydrochloride 50 SP (9.92%) and lambda cyhalothrin 2.5 EC (11.15%). Significantly

higher per cent dead hearts was observed in the control (23.32%) (Table 2). At 90 DAT, the second spray was taken and per cent white ears were recorded. One day before spraying the mean white ears ranged from 12.56 to 15.43 per cent. There were significant statistical differences between the treatments and the control (Table 2). At 20 DAS, a substantial and lower per cent white ear was observed in flubendiamide 39.35 SC which recorded 4.88 per cent white ears followed by chlorantraniliprole 18.5 SC (5.41%) and fipronil 5 SC (5.81%). Significantly higher per cent white ears was observed in the control which recorded 20.12 per cent. Similar results were reported by Devi and Singh (2016), where they found flubendiamide 39.35 SC @ 24g a.i. ha⁻¹ as the most effective molecule against *S. incertulas* in both 2013 and 2014, with the lowest percentages of dead heart (3.48 and 3.49) and white ear (1.32 and 1.33). Likewise, previous workers reported that lowest

Table 1. Bio-efficacy of foliar insecticides against *S. incertulas*, summer (I Spray)

No.	Treatments (dose @ ml or g l ⁻¹)	Dead hearts (%)				
		1 DBS	5 DAS	10 DAS	15 DAS	20 DAS
1	Cartap hydrochloride 50 SP (2)	16.65	12.21	12.00	10.30	9.92
		(24.09) ^a	(20.46) ^{bc}	(20.28) ^{bc}	(18.73) ^{bc}	(18.37) ^{bc}
2	Carbosulfan 25 EC (1.5)	17.14	11.24	10.44	8.98	7.83
		(24.47) ^a	(19.6) ^{bcd}	(18.86) ^{cde}	(17.45) ^{bc}	(16.26) ^{de}
3	Chlorantraniliprole 18.5 SC (0.3)	16.88	9.13	8.82	6.52	5.83
		(24.27) ^a	(17.6) ^{de}	(17.29) ^{ef}	(14.8) ^{de}	(13.98) ^f
4	Fipronil 5 SC (2)	16.05	10.00	9.34	7.72	6.48
		(23.63) ^a	(18.44) ^{cd}	(17.81) ^{def}	(16.14) ^{cd}	(14.75) ^{ef}
5	Lambda cyhalothrin 2.5 EC (1)	16.06	13.65	12.67	11.53	11.15
		(23.63) ^a	(21.69) ^b	(20.87) ^b	(19.86) ^b	(19.52) ^b
6	Thiamethoxam 25 WG (0.3)	16.40	10.10	10.09	8.66	7.22
		(23.9) ^a	(18.54) ^{cd}	(18.53) ^{cde}	(17.13) ^{cd}	(15.59) ^{def}
7	Quinalphos 25 EC (3)	16.01	11.60	11.08	9.95	8.16
		(23.6) ^a	(19.92) ^{bc}	(19.46) ^{bcd}	(18.39) ^{bc}	(16.61) ^{cd}
8	Flubendiamide 39.35 SC (0.15)	15.88	7.85	7.87	5.29	4.18
		23.49) ^a	(16.28) ^c	(16.3) ^f	(13.31) ^c	(11.81) ^g
9	Untreated control	17.16	19.28	20.23	21.76	23.32
		(24.49) ^a	(26.06) ^a	(26.74) ^a	(27.82) ^a	(28.89) ^a
SE m ±			0.42	0.37	0.52	0.36
CD (p = 0.05)		NS	1.26	1.10	1.57	1.07

DBS-Day before spray; DAS- Days after spray; Figures in the parenthesis indicate arc sin transformed values; Values in the column followed by common letters are non-significant at p=0.05 as per Tukey's HSD (Tukey, 1965)

Table 2. Bio-efficacy of foliar insecticides against *S. incertulas*, summer (II Spray)

No.	Treatments	White ears (%)				
		1 DBS	5 DAS	10 DAS	15 DAS	20 DAS
1	Cartap hydrochloride 50 SP	12.56	10.35	9.37	10.30	8.47
		(20.77) ^b	(18.78) ^{bc}	(17.83) ^{bc}	(16.97) ^{bc}	(16.93) ^b
2	Carbosulfan 25 EC	13.28	8.95	8.57	8.98	6.96
		(21.38) ^b	(17.42) ^{cde}	(17.03) ^{bcd}	(15.86) ^{cde}	(15.31) ^c
3	Chlorantraniliprole 18.5 SC	13.61	7.39	6.66	6.52	5.41
		(21.66) ^b	(15.78) ^{ef}	(14.97) ^c	(14.1) ^{ef}	(13.45) ^{ef}
4	Fipronil 5 SC	13.27	7.81	7.24	7.72	5.81
		(21.37) ^b	(16.24) ^{ef}	(15.62) ^{dc}	(14.88) ^{def}	(13.96) ^{dc}
5	Lambda cyhalothrin 2.5 EC	13.01	11.26	10.59	11.53	9.26
		(21.15) ^b	(19.61) ^b	(19) ^b	(18.13) ^b	(17.73) ^b
6	Thiamethoxam 25 WG	13.52	8.47	7.86	8.66	6.68
		(21.59) ^b	(16.93) ^{def}	(16.28) ^{cde}	(15.37) ^{cde}	(14.99) ^{cd}
7	Quinalphos 25 EC	12.91	9.90	8.82	9.95	7.12
		(21.07) ^b	(18.35) ^{bcd}	(17.28) ^{bcd}	(16.15) ^{cd}	(15.49) ^c
8	Flubendiamide 39.35 SC	13.08	6.97	6.14	5.29	4.88
		(21.21) ^b	(15.32) ^f	(14.35) ^c	(13.33) ^f	(12.77) ^f
9	Untreated control	15.43	17.57	18.32	21.76	20.12
		(23.14) ^a	(24.79) ^a	(25.36) ^a	(25.53) ^a	(26.67) ^a
	SE m ±	0.28	0.33	0.41	0.39	0.23
	CD (p = 0.05)	0.85	0.98	1.21	1.16	0.69

DBS-Day before spray; DAS- Days after spray; Figures in the parenthesis indicate arc sin transformed values; Values in the column followed by common letters are non-significant at $p=0.05$ as per Tukey's HSD (Tukey, 1965)

incidence of YSB was seen in the chlorantraniliprole 18.5 SC (1.75%) treated plot, followed by fipronil 5 SC (2.59%) (Kinjale *et al.*, 2021). Fipronil 5 SC reduced both dead heart and white ears after the application, at 3, 10 and 15 days, respectively (Abhinandan and Gupta, 2020). Similarly, Singh and Rajshree (2017) found flubendiamide 39.35 SC @ 24 g a.i./ha as effective, followed by chlorantraniliprole 18.35SC @ 30 g a.i./ha and thiamethoxam 25 WG @ 25 g a.i./ha. The per cent reduction ranged from 71.36 to 45.40 per cent. A Similar trend was found in the case of white ear infestation (Fig. 1).

Yield economics

The efficacy studies of insecticides against yellow stem borer showed significant variations in both grain and biomass yield. Flubendiamide 39.35 SC exhibited the highest grain yield (6.07 t ha⁻¹) and also the highest biomass yield (6.19 t ha⁻¹) followed

by chlorantraniliprole 18.5 SC which recorded the next highest grain (5.88 t ha⁻¹) and biomass (6.06 t ha⁻¹) yield. The economic analysis on the feasibility of various treatments indicated that higher net returns of Rs. 150819 per hectare were achieved in flubendiamide 39.35 SC with the highest BC ratio of 4.44 (Table 3). The control showed a reduction of 2.24 t ha⁻¹ when compared with the best insecticide treatment (flubendiamide 39.35 SC).

Recent advancements in the pesticide industry focussed on developing target-specific molecules like diamides, neonicotinoids, phenylpyrazoles and others. These new insecticides offer relatively low risk to non-target organisms and the environment and high target specificity, making them essential for environmentally safe integrated pest management and insect resistance management programs (Bhuvaneswari *et al.*, 2022). The diamides are the most recent addition to the limited number of insecticide classes with specific target

Table 4. Cost economics of insecticides influenced by yellow stem borer in rice, summer 2023

No	Treatments	Yield (t/ha)		Total cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net profit (Rs/ha)	Yield advantage over control (t/ha)	B: C ratio
		Grain	Biomass					
1	Cartap hydrochloride 50 SP	4.68	4.78	34250	142531	108281	0.85	3.16
2	Carbosulfan 25 EC	5.14	5.37	34758	157766	123008	1.32	3.54
3	Chlorantraniliprole 18.5 SC	5.88	6.06	35800	179704	143904	2.05	4.02
4	Fipronil 5 SC	5.70	5.81	35260	173598	138338	1.87	3.92
5	Lambda Cyhalothrin 2.5EC	4.39	4.41	32846	133165	100319	0.56	3.05
6	Thiamethoxam 25 WG	5.29	5.35	32959	160741	127782	1.46	3.88
7	Quinalphos 25 EC	4.78	5.00	33850	146687	112837	0.95	3.33
8	Flubendiamide 39.35 SC	6.07	6.19	34000	184819	150819	2.24	4.44
9	Untreated control	3.83	3.90	32500	116611	84111		-

The price of paddy per quintal = Rs. 2180, price of fodder per quintal = Rs. 850

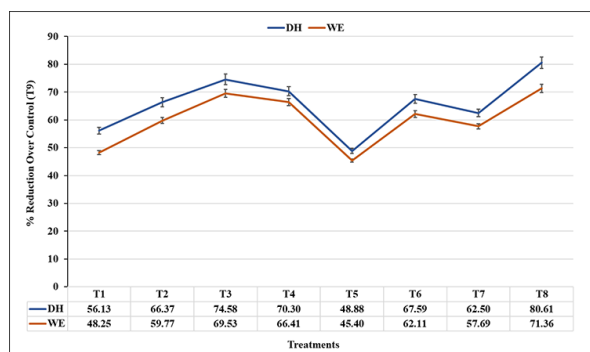


Fig. 1 Per cent reduction of *S. incertulas* incidence in different insecticidal treatments during summer. (DH – Dead heart; WE – White ears)

site activity that is highly efficacious, control a wide pest spectrum and have a favourable toxicological profile (Teixeira and Andaloro, 2013). Among diamides, flubendiamide and chlorantraniliprole have played a major role in preventing or delaying the evolution of insect resistance since the introduction of these novel insecticides. Flubendiamide is a phthalic acid diamide insecticide reported to target insects' ryanodine receptors (Richardson *et al.*, 2020). In contrast to other insecticide classes targeting the insect nervous system, it acts at receptors in insect muscles causing an immediate cessation of feeding and thus avoiding crop damage (Ebbinghaus-Kintscher, 2007). Chlorantraniliprole binds to a specific receptor in muscles called the ryanodine receptor, which causes muscle cells to leak calcium leads to stop working the muscles normally; hence the insect

would be paralyzed and die (NPIC, 2022).

The results of this study highlight the crucial role the novel insecticides, particularly flubendiamide 39.35 SC, chlorantraniliprole 18.5 SC and fipronil 5 SC, play in effectively managing the yellow stem borer in paddy cultivation. These insecticides not only significantly decreased the occurrence of dead hearts and white ears but also resulted in notable enhancements in grain and biomass yields. Flubendiamide demonstrated superior performance, yielding the highest grain output and net returns, indicating its potential as a leading solution for YSB management. Furthermore, the economic analysis underscores the effectiveness of these treatments in boosting both productivity and profitability for farmers.

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