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Comparative analysis of pesticide efficacy for controlling yellow stem borer (*Scirpophaga incertulas*) infestation in spring rice

Savyata Acharya[1]* Prekshya Karki[1] Simran Gupta[1] Ankit Soti[2]

[1] Purbanchal University, Nepal
[2] Tribhuvan University, Nepal
***Correspondence:** savyataacharya9@gmail.com

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Abstract
Rice (*Oryza sativa* L.) is a crucial staple crop worldwide, essential for economic growth and food security. However, its cultivation is significantly threatened by pests like the yellow stem borer, especially in regions such as Nepal where rice is a primary crop. This study, conducted in Eastern Nepal, assessed the efficacy of six insecticides and a control group (water spray) using a randomized complete block design (RCBD) with three replications. The insecticides tested were Chlorantraniliprole 18.5 SC, Chlorpyriphos 20 EC, Emamectin Benzoate 5 SG, Metarhizium anisopliae-12%, Azadirachtin 0.03%, and Spinosad 45% SC. Results showed that Chlorantraniliprole 18.5 SC, applied at a concentration of 0.4 ml/l, resulted in the lowest occurrence of dead heart (5.24%) and white ear head (3.21%). Additionally, this treatment demonstrated superior yield and yield-contributing traits, suggesting its effectiveness in controlling yellow stem borer infestations and enhancing rice crop growth and productivity. Although these chemical insecticides proved effective, comprehensive studies are necessary to evaluate their performance across a broader range of ecological settings. Such studies are vital to validate and implement these findings in various agricultural environments.

Key words
Insecticides efficacy, Dead heart, White ear head, Spring Rice, *Scirpophaga incertulas*.

Introduction
Rice, scientifically known as *Oryza sativa*, stands as a prominent member of the Poaceae family, commanding a pivotal position among cereal crops worldwide (Ghimire et al., 2024), (Katel et al., 2023). With its roots tracing back to the fertile deltas of Asia, the cultivation of rice boasts a rich history spanning millennia, its cultivation practices traversing continents (Ghimire et al., 2023; Mehata et al., 2023). Delineated into diverse subspecies and varieties, the genetic tapestry of rice mirrors centuries of meticulous human selection and adaptation, showcasing its resilience to various environments (I. H. Mondal & Chakraborty, 2016), (Puppala et al., 2021; Sountharya & Prasad, 2022). In Nepal, rice assumes a paramount role, not merely as a dietary staple but also as a linchpin of the nation's economy, culture, and social ethos (Nirala et al., 2015; Thorat et al., 2023). Despite its importance, optimizing rice yield and quality faces persistent challenges such as pest incursions and suboptimal agricultural practices (Kakshapati et al., 2022; Yadav et al., 2024). In Eastern Nepal, rice is a key agricultural product, significantly influencing GDP and serving as a vital livelihood for many farmers (Mondal & Chakraborty, 2016; Puppala et al., 2021).

In 2023, a report published by MoALD revealed that rice cultivation spanned across 1.48 million hectares of Nepalese land (Ghimire et al., 2024; Yadav et al., 2023a). This expansive agricultural pursuit yielded a total rice output of 5.13 million tons, averaging 3.47 tons per hectare (Ghosh et al., 2020), (Gangopadhyay & Chatterjee, 2020). Despite its profound cultural and economic significance, Nepal's rice sector encounters a plethora of challenges endangering its sustainability and productivity (Rahman et al., 2020; Yadav et al., 2023b). Long-standing barriers, such as limited access to modern agricultural technologies, fragmented land tenure, and inadequate infrastructure, have hindered efforts to improve rice yields and quality (Patel et al., 2019; Yadav et al., 2023a). Furthermore, the looming specter of pests and diseases casts a alarming shadow over rice farming, posing a perpetual threat to both food security and livelihoods (Rath, 2012; Hussain et al., 2019). Among the array of pests plaguing rice cultivation, the Yellow Stem Borer (YSB), scientifically termed Scirpophaga incertulas, emerges as a formidable adversary, wreaking havoc by tunnelling into rice stems and disrupting vital nutrient pathways (Sharma et al., 2018; Girish et al., 2016). The deleterious impact of YSB infestation extends beyond mere quantity loss, profoundly compromising grain quality and inflicting substantial economic hardships on farmers (E. Mondal & Chakraborty, 2022; Yadav et al., 2023a). Moreover, pest outbreaks, particularly by the notorious YSB, significantly impede crop yields, intensifying anxieties surrounding food security (Nirmalkar et al., 2016; Roopwan et al., 2023). The urgency of addressing the Yellow Stem Borer threat looms large within Nepal's intricate agricultural landscape, necessitating holistic approaches that amalgamate traditional techniques with innovative solutions (Nag et al., 2018; Ghimire et al., 2024).

Recent studies have highlighted the significant damage caused by Yellow Stem Borer (YSB) in Nepalese rice fields, emphasizing the need for effective pest management (Kumari et al., 2019; Mishra & Singh, 2019). This has led to increased interest in evaluating various insecticides for managing YSB populations and reducing crop damage (Padmakumari et al., 2017). Pest management in rice farming includes synthetic chemicals and biopesticides (Sah & Sharma, 2023). The choice of insecticides must consider environmental sustainability, human health, and long-term efficacy, highlighting the importance of evidence-based research and holistic strategies (Ghimire et al., 2024; Mehata et al., 2023). Integrated Pest Management (IPM) is a comprehensive approach to controlling Yellow Stem Borer (YSB) with minimal environmental impact, integrating cultural, biological, and chemical measures to reduce pesticide reliance (Yadav et al., 2024; Katel et al., 2023). Educating farmers is crucial for effective IPM adoption (Yadav et al., 2024).

This research aims to conduct a comparative analysis of the efficacy of various insecticides in controlling yellow stem borer (YSB) infestations in spring rice cultivation in Eastern Nepal. By assessing the performance of different insecticides and their impact on pest populations and rice yield, the study seeks to generate actionable insights for policymakers, extension agents, and farmers. Ultimately, this research contributes to the resilience and sustainability of Nepal's rice sector by promoting informed pest management strategies.

Materials and Methodology:

Research Site:

The research undertaken at the G.P. Koirala College of Agriculture and Research Center in Sundarharaicha, Morang, Nepal, spanning from February to June 2023, was geared towards evaluating the efficacy of various pesticides in combatting yellow stem borer infestations within spring rice crops. Situated within a tropical climatic zone, characterized by an average annual temperature spectrum spanning from 19.83 to 34.46°C, and a yearly precipitation mean of 141.68mm, the locale provided an optimal setting for the investigation. Positioned at coordinates 26º 40’ 49.7” North latitude and 87º 21’ 16.3” East longitude, with an elevation measuring 149.9 m, this region presented an ideal location for the study's objectives. The selected Chaite-5 rice cultivar, renowned for its commendable grain yield yet notorious susceptibility to yellow stem borer incursions, served as the focal point of the experimental framework. Through meticulous scrutiny and methodological rigor, the research sought to elucidate the most efficacious strategies for curbing the detrimental impact of yellow stem borer infestations on this rice.

Experimental design and Field layout:

The study was meticulously executed employing a Randomized Complete Block Design (RCBD), incorporating six distinct insecticide groups alongside an untreated control group subjected solely to water spraying, as delineated in Table 1. Each treatment was replicated three times, thereby yielding a comprehensive total of 21 individual plots for analysis. To ensure precision and methodological rigor, a carefully planned layout was adopted. Each plot precisely measured 2×2 m^2, allowing for standardized evaluation across the experimental domain. To mitigate the risk of cross-contamination and facilitate unimpeded maintenance, a buffer zone spanning 0.5 meters was clearly marked off between adjacent plots. Furthermore, the cultivation layout maintained a consistent spacing of 20 cm both between individual plants and rows, thereby facilitating optimal plant growth conditions. Each plot was then configured to accommodate precisely 100 rice plants, ensuring uniformity in experimental conditions and subsequent data analysis.

Table 1. Insecticides details along with trade name and dose.

S.N.	Insecticides	Trade name	Treatments	Dose
1	Chlorantraniliprole 18.5 SC	Cover	T1	0.4 ml/l
2	Chlorpyriphos 20 EC	Lethal	T2	2.0 ml/l
3	Emamectin Benzoate 5 SG	King Cobra	T3	0.25 g/l
4	*Metarhizium anisopliae-12*	Multiplex	T4	2 ml/l
5	Azadirachtin 0.03%	Multineem	T5	2 ml/l
6	Spinosad 45% SC	ONEUP	T6	0.3 ml/l
7	Water spray	N/A	T7	N/A

Cultural Practices:

The study aimed to assess the efficiency of insecticides in managing pest damage within the "Chaite Dhan-5" spring rice, a widely cultivated strain among local farmers. Initially, the transplantation of "Chaite Dhan-5" rice commenced following comprehensive soil preparation, in accordance with established regional farming customs. Insecticide application was initiated upon surpassing the Economic Threshold Level of 5% pest damage, facilitated using a battery-operated knapsack sprayer. Prior to seedling transplantation, essential nutrients such as nitrogen, phosphorus, and potash were administered according to established guidelines. Harvesting occurred manually upon reaching 80% maturity, followed by the traditional practices of sun-drying and manual threshing of the rice grains. Throughout the entirety of the process, Careful care was paid to guarantee that the grain weight was measured precisely. These procedures were meticulously executed to ascertain the effectiveness of insecticides while upholding precision in data collection and subsequent analysis.

Observation and data collection:

Plant height and tillers number: The height of the plants was documented once they attained full vegetative growth. Using a measuring tape, their height was gauged from the base to the apex of the plant, while the number of tillers sprouting from the main plants was counted.

Dead hearts and White ear head percentage:

From every plot, the cumulative count of afflicted (dead heart) and productive tillers was tallied, and subsequently, the dead heart percentage was computed utilizing the formula given by Islam et al. (2013) as per equations 1 provided below:

$$Dead\ heart\ (\%) = \frac{Number\ of\ dead\ heart\ (DH)}{Total\ tiller's\ number} \times 100 \qquad \text{(eq. 1)}$$

of white heads on both the plant and its tillers bearing panicles. The resultant percentage of white ear heads was then derived utilizing the formula given by Baskaran et al. (2019) & Katel et al. (2023), as outlined in equation 2.

$$White\ ear\ head = \frac{Total\ white\ head\ number\ (WH)}{Number\ of\ total\ tillers\ per\ panicle} \times 100 \qquad \text{(eq. 2)}$$

Filled grains percentage:

Prior to rice harvesting, the plants underwent the process of cutting effective panicles containing fully matured grains, facilitating a precise enumeration of filled grains. Subsequently, the percentage of filled grains was computed using the formula outlined in the preceding investigation by Ghimire et al. (2024), as delineated in equation 3.

$$Filled\ Grains\ (\%) = \frac{Total\ filled\ grains}{Number\ of\ total\ grains} \times 100 \qquad \text{(eq. 3)}$$

Yield and test weight:

For the determination of grain yield, ten plants were randomly chosen from each plot, subsequently harvested, and threshed. The moisture percentage of the grains was then assessed. Upon reaching a moisture level of 10%, the ultimate yield was computed employing the formula provided by Katel et al. (2023),

$$Grain\ Yield = \frac{Harvest\ yield \times (100 - Harest\ moisture)}{100 - Standard\ moisture} \times 100 \qquad \text{(eq. 4)}$$

To assess the test weight, the sample yield was initially dried until reaching a moisture level of 10%. Subsequently, 1000 grains were randomly selected, and their weight was measured using an electric weighing machine.

$$Test\ weight = Weight\ of\ 1000\ grains$$

Statistical Analysis:

For analysis, the field experiment data were meticulously imported into MS Excel (2021). Statistical tools, such as R-Studio (Version 4.2.2), were utilized for data analysis. To ensure research accuracy, a square root transformation was applied to the data when normality assumptions were not met. R-Studio was then used to conduct Analysis of Variance (ANOVA) to compare various treatments. Post-hoc analyses, such as DMRT, were employed to identify treatment effects when significant differences were observed at a significance level of $p < 0.05$.

Results:

Infestation of dead heart and white head before treatment:

At the initial observation juncture, precisely 45 days post-commencement of the transplantation process, a statistically notable disparity was discerned concerning the prevalence of dead hearts within the rice crop. The incidence of dead hearts ranged from 5.88% to 10.99% per hill prior to any treatment, albeit registering an average rate of 8.43%. This trend was particularly pronounced preceding the application of pesticides. Concurrently, an average occurrence of 9.09% of cases characterized by white heads was recorded, spanning a spectrum from 6.21% to 11.98%. Evidently, these findings underscore the surpassing of the Economic Threshold Level.

Effects of treatments on dead heart caused by yellow stem borer in spring rice:

As shown in tables 2 the pesticides significantly reduced the invasion of stem borer. After the initial spray on the seventh day, when the efficacy of the different insecticidal treatments was evaluated, it became clear that Chlorantraniliprole 18.5 SC (0.4 ml/l) performed the best, significantly lowering the incidence of dead hearts to just 4.01%. Closely behind with dead heart rates of 4.18% and 4.49%, respectively, were Metarhizium anisopliae-12% (2 g/l) and Chlorpyriphos 20 EC (2 ml/l). Next, Spinosad 45% SC (0.3 ml/l) showed excellent performance with a 4.97% incidence of dead heart. With dead heart percentages of 5.03% and 5.80%, respectively, azadirachtin (2 ml/l) and Emamectin benzoate 5 SG (0.25 g/l) followed suit. Interestingly, Azadirachtin and Spinosad 45% SC showed comparable effectiveness. On the other hand, the untreated control group, which was merely exposed to water spray, had the greatest proportion of dead hearts (9.91%). After the first application, on the 14th day post-spray, a thorough analysis of several insecticidal treatments was conducted. The results showed that Chlorantraniliprole 18.5 SC was remarkably effective in reducing dead hearts compared to all other treatments. Following this, dead heart reductions of 6.02%, 6.91%, and 6.99% with Chlorpyriphos 20 EC, Metarhizium anisopliae-12%, and Spinosad 45% SC, respectively, showed efficacy. Interestingly, Chlorpyriphos 20 EC showed similar effectiveness to Spinosad 45% SC. On the other hand, Emamectin Benzoate 5 SG shown comparable efficacy to Azadiractin, whilst Azadiractin had the least efficacy and the largest proportion of dead hearts at 8.17%. At 13.48%, the control group that received water spray treatment had the greatest rate of dead hearts. When the effects of the different pesticides were examined 21 days after the spraying, the results showed that Chlorpyriphos 20 EC and Chlorantraniliprole 18.5 SC were the most successful in controlling the rice yellow stem borer, with the lowest percentages of dead hearts (6.96% and 6.89%, respectively). Following this, Spinosad 45% SC and Metarhizium anisopliae-12% showed noteworthy efficacy, with respective dead heart percentages of 8.95% and 8.98%. Emamectin Benzoate 5 SG and Azadirachtin came in close behind, with percentages of 9.05% and 9.99%, respectively. With a dead heart incidence of 17.17%, the untreated control group showed a considerably higher rate. At a significance level of 0.1%, a comparison of these pesticides showed significant variance in mean dead heart percentages. The lowest mean dead heart percentage was found in Chlorantraniliprole 18.5 SC (5.24%), followed by Chlorpyriphos 20 EC (5.71%) and Metarhizium anisopliae-12% (6.77%). Similar findings were obtained with percentages of 7.65%, 7.71%, and 7.00% for Emamectin Benzoate 5 SG, Azadirachtin, and Spinosad, respectively. With a mean dead heart percentage of 13.55%, the water spray group had the highest proportion. Furthermore, with a percentage reduction over control value of 61.33%, Chlorantraniliprole 18.5 SC showed the highest level of performance in suppressing the infestation of yellow stem borer, followed by Chlorpyriphos 20 EC at 57.86%.

Table 1: Effects of treatments on dead heart caused by yellow stem borer in spring rice.

Treatments	Dead hearts (Percent)				PROC of dead hearts
	7 DAS	14 DAS	21 DAS	Mean	
Chlorantraniliprole 18.5 SC	4.01^a (2.12)	5.01^a (2.35)	6.89^a (2.72)	5.24^a (2.40)	61.33
Chlorpyriphos 20 EC	4.18^b (2.16)	6.02^b (2.55)	6.96^a (2.73)	5.71^b (2.49)	57.86
Emamectin Benzoate 5 SG	5.80^e (2.51)	7.92^d (2.90)	9.05^b (3.09)	7.65^e (2.85)	43.54
Metarhizium anisopliae-12%	4.49^c (2.23)	6.91^c (2.72)	8.98^b (3.08)	6.77^c (2.70)	50.04
Azadirachtin	5.03^d (2.35)	8.17^e (2.94)	9.99^c (3.24)	7.71^e (2.87)	43.10
Spinosad	4.97^d (2.34)	6.99^c (2.74)	8.95^b (3.07)	7.00^d (2.74)	48.34
Water spray	9.91^f (3.23)	13.48^f (3.74)	17.17^d (4.20)	13.55^f (3.75)	-
Grand mean	5.48	7.78	9.71	7.66	
S.E.D.	7.5	8.4	7.3	7.7	
$LSD_{0.05}$	3.6	4.3	5.8	6.1	
CV%	11.8	12.3	9.5	8.2	
F test	***	***	***	***	

Note: DAS: Days after spray; PROC: Percentage reduction over control; Values are the mean of three replications at different day of observation; CV: Coefficient of variation; ***: Significant at 0.1% level of significance; *: Significant at 5% level of significance; S.E.D.: Standard error difference; LSD: Least Significant Difference; Values with the letters in a column are significantly different at 5% level significance by DMRT test; Parenthesized values are the result of square root transformation.

Effects of treatments on white head caused by yellow stem borer in spring rice:

The effectiveness of several insecticidal treatments against the infestation of rice yellow stem borer was closely examined during the observation period which is presented in table 3. After 7 days of spray, the most successful treatment was Chlorantraniliprole 18.5 SC, which produced a white head infestation of just 2.42%. Other treatments that were equally effective were Spinosad 45% SC, Emamectin Benzoate 5 SG, Azadirachtin, Metarhizium anisopliae-12%, and Chlorpyriphos 20 EC. On the other hand, with a white head infestation incidence of 10.55%, the untreated control group showed the highest rate. On the fourteenth day, Chlorantraniliprole 18.5 SC continued to be effective, showing a 3.34% infestation of white heads. Chlorpyriphos 20 EC and Metarhizium anisopliae-12% showed similar trends, with rates of 5.55% and 6.13%, respectively. Emamectin Benzoate 5 SG and Spinosad 45% SC both showed comparable levels of effectiveness, at 6.39% and 6.30%, respectively. With a notable 12.25% white ear percentage, the water spray therapy was shown to be the most effective. On the twenty-first day, Chlorpyriphos 20 EC showed similar efficiency at 6.37%, while Chlorantraniliprole 18.5 SC continued to be beneficial with a 4.29% white head infestation. At 8.29%, 7.17%, 9.16%, and 9.29%, respectively, Spinosad 45% SC, Emamectin Benzoate 5 SG, Metarhizium anisopliae-12%, and Azadirachtin showed rising infection rates. Overall, rice grown for white heads showed a considerable reduction in yellow stem borer infestation when treated with Chlorantraniliprole 18.5 SC. The other five insecticides had varying degrees of effectiveness, including Chlorpyriphos 20 EC, Spinosad 45% SC, Emamectin Benzoate 5 SG, Metarhizium anisopliae-12%, and Azadirachtin. Nevertheless, of the drugs utilised, azadirachtin had the greatest mean white ear head infestation percentage, indicating inferior efficiency. When compared to other pesticides employed in our study, Chlorantraniliprole 18.5 SC demonstrated the greatest percentage over control value (73.58%), indicating its efficiency in reducing yellow stem borer in spring rice. Azadirachtin, on the other hand, had the lowest percentage reduction over control, at just 41.89%.

Table 2: Effects of treatments on white head caused by yellow stem borer in spring rice.

Treatments	White heads (Percent)				PROC of ear heads
	7 DAS	14 DAS	21 DAS	Mean	
Chlorantraniliprole 18.5 SC	2.42^{a} (1.71)	3.34^{a} (1.96)	4.29^{a} (2.19)	3.21^{a} (1.93)	73.58
Chlorpyriphos 20 EC	4.62^{d} (2.26)	5.55^{b} (2.46)	6.37^{b} (2.62)	5.48^{b} (2.45)	54.90
Emamectin Benzoate 5 SG	5.32^{f} (2.41)	6.30^{cd} (2.61)	7.17^{c} (2.77)	6.35^{d} (2.62)	47.74
Metarhizium anisopliae-12%	4.32^{c} (2.20)	6.13^{c} (2.57)	9.16^{e} (3.11)	6.51^{e} (2.65)	46.42
Azadirachtin	4.89^{e} (2.32)	6.99^{e} (2.74)	9.29^{e} (3.13)	7.06^{f} (2.75)	41.89
Spinosad	4.02^{b} (2.13)	6.39^{d} (2.62)	8.29^{d} (2.96)	6.21^{c} (2.59)	48.89
Water spray	10.55^{g} (3.32)	12.25^{f} (3.57)	13.57^{f} (3.75)	12.15^{g} (3.56)	-
Grand mean	5.16	6.71	8.31	6.71	
S.E.D.	7.8	8.0	6.2	6.7	
$LSD_{0.05}$	9.7	6.7	7.5	4.8	
CV%	11.1	9.5	7.4	9.2	
F test	***	***	***	***	

Note: DAS: Days after spray; PROC: Percentage reduction over control; Values are the mean of three replications at different day of observation; CV: Coefficient of variation; ***: Significant at 0.1% level of significance; *: Significant at 5% level of significance; S.E.D.: Standard error difference; LSD: Least Significant Difference; Values with the letters in a column are significantly different at 5% level significance by DMRT test; Parenthesized values are the result of square root transformation.

Effects of treatments on yield and yield attributing characters of spring rice:

Plant height:

The findings pertaining to plant height are displayed in Table 4. Among the several pesticides used, our analysis showed that all these yield-related metrics showed exceptionally high significance at the 0.1% level. Numerous variables, including as genotypic features, varied fertilizer and organic matter doses, weather patterns, and pesticide impacts, might be responsible for the observed variance in plant height. Emamectin Benzoate 5 SG achieved a plant height of 122.30 cm, which is an impressive result. Plant heights of 100–103 cm, on the other hand, were noted in groups that received water spraying and other pesticide treatment.

Filled grains:

The findings pertaining to field grains are displayed in Table 4. Among the several pesticides used, our analysis showed that filled grain percentage per panicle showed very high significant at the 0.1% level of significance. The results showed that, Chlorantraniliprole 18.5 SC (82.06 %) recorded the highest percentage of filled grains per panicle, closely followed by Emamectin Benzoate 5 SG (81.28 %), and Chlorpyriphos 20 EC (77.43 %) respectively. The lowest filled grains were observed in water sprayed group i.e. 58.57 %.

Test weight:

A comparison of the test weight of rice with various insecticides used in the current study revealed statistically significant differences at 0.1% level of significance (Table 4). The data indicates that, overall, Chlorantraniliprole 18.5 SC had the greatest weight of 1000 grains, weighing 20.75 g. This was closely followed by Spinosad 45% SC, Emamectin Benzoate 5 SG (19.50 g), Chlorpyriphos 20 EC (19.26 g), and Metarhizium anisopliae-12% (19.14 g), all of which had comparable grain weights. In comparison, rice that had been sprayed with water had the lowest test weight just 15.98 g.

Yield (t/ha):

Table 4 shows a significant statistical difference in the amount of rice produced per hectare because of using various chemical pesticides throughout the current experiment. The results showed a substantial influence on the rice production per hectare, with a significance level of 0.1%. The average rice yield across treatments treated with water and different pesticides was 5.57 t/ha. Variations in climate, pesticide use, nutritional availability, and genetics might all be contributing contributors to this yield fluctuation. Significantly, the maximum grain yield was obtained by Chlorantraniliprole 18.5 SC (6.89 t/ha), closely followed by Emamectin Benzoate 5 SG (6.40 t/ha) and Chlorpyriphos 20 EC (6.25 t/ha), in that order. On the other hand, farms that were merely given water had the lowest yield just 3.85 t/ha.

Table 4: Effects of treatments on yield and yield attributing characters of spring rice.

Treatments	Plant height (cm)	Filled grain (%)	Test weight (g)	Yield (t/ha)
Chlorantraniliprole 18.5 SC	101.18^{b}	82.06^{g}	20.75^{e}	6.89^{f}
Chlorpyriphos 20 EC	102.63^{e}	77.43^{e}	19.26^{c}	6.25^{d}
Emamectin Benzoate 5 SG	122.30^{f}	81.28^{f}	19.50^{d}	6.40^{e}
Metarhizium anisopliae-12%	100.30^{a}	66.66^{c}	19.14^{c}	5.16^{c}
Azadirachtin	101.74^{d}	65.13^{b}	17.24^{b}	4.28^{b}
Spinosad	101.28^{bc}	71.91^{d}	19.51^{d}	6.17^{d}
Water spray	101.41^{c}	58.57^{a}	15.98^{a}	3.85^{a}
Grand mean	104.41	71.86	18.77	5.57
S.E.D.	2.07	3.69	3.17	4.66
$LSD_{0.05}$	3.16	15.1	6.15	14.4
CV%	8.1	12.1	9.4	10.4
F test	***	***	***	***

Note: Values are the mean of three replications at different day of observation; CV: Coefficient of variation; ***: Significant at 0.1% level of significance; S.E.D.: Standard error difference; LSD: Least Significant Difference; Values with the letters in a column are significantly different at 5% level significance by DMRT test.

Discussions

The research explored the effectiveness of various insecticides in controlling damage caused by the yellow stem borer (YSB) in rice fields. Our results reveal a notable decrease in damage and yield loss with the application of insecticides. Notably, Chlorantraniliprole 18.5 SC demonstrated superior efficacy in reducing dead heart (DH%) and white heads. It notably reduced DH% from 8.43% to 5.24% and white heads from 9.09% to 3.21% compared to the untreated control group. This finding aligns with previous studies by Ghimire et al. (2024), Katel et al. (2023), and Thorat et al. (2023), which also found Chlorantraniliprole 18.5 SC to be effective in controlling YSB infestation in rice. The exceptional performance of Chlorantraniliprole 18.5 SC in reducing dead heart and white head percentages can be attributed to several factors, including its comprehensive pest eradication, systemic qualities, extended residual activity, compatibility with environmental conditions, and targeted pest control (Patel et al., 2019). Similarly, Patel et al. (2019) found Chlorantraniliprole 18.5 SC to be the most effective insecticide in their field experiments. Furthermore, Sharma et al. (2025) reported that Chlorantraniliprole 18.5 SC (60 ml/acre) applied at the booting stage was highly effective in minimizing YSB infestations. Additionally, Chlorpyriphos 20 EC and Metarhizium anisopliae-12% were identified as the second most effective insecticides, consistent with the findings of Katel et al. (2023), Ghimire et al. (2024), Sah and Sharma (2023), and Nirmalkar et al. (2016). The variations in effectiveness among the tested insecticides may be attributed to their unique active ingredients and ecological factors influencing pest behavior. Differences in chemical compositions and interactions with environmental conditions contribute to varied efficacy levels, highlighting the complex interplay between insecticide properties and ecological dynamics. Moreover, our study recorded the highest grain yield with Chlorantraniliprole 18.5 SC, consistent with previous studies by Nirmalkar et al. (2016) and Patel et al. (2019). However, the insecticides exerted diverse effects on the growth and maturation of rice plants, influenced by their respective modes of action and other contextual factors. Further investigation is warranted to explore this phenomenon. It's worth noting that the fields treated solely with water exhibited the highest percentage of dead heart and white head, along with lower yields and yield-contributing parameters. This outcome is consistent with previous studies by Ghimire et al. (2024), Katel et al. (2023), and Nirmalkar et al. (2016), which found minimal yields and increased YSB infestations in control groups. Inadequate pest control and insufficient management practices likely contribute to heightened infestation levels and decreased productivity in fields treated solely with water.

Conclusions

In conclusion, our research identifies Chlorantraniliprole 18.5 SC as the most effective insecticide for controlling Yellow Stem Borer (YSB) infestation in rice fields. This insecticide notably reduced dead heart and white head percentages, showcasing its potential as a primary tool in YSB management. Additionally, Chlorpyriphos 20 EC and Metarhizium anisopliae-12% exhibited significant efficacy, warranting further investigation. Future studies should explore optimized application techniques and integrated pest management approaches to enhance sustainability and minimize environmental impact. By prioritizing the use of these effective insecticides and integrating them into holistic pest management strategies, farmers can mitigate YSB damage more effectively, safeguarding rice production and ensuring food security in Nepal's agricultural sector.

Conflict of Interest

The authors declare that they have no conflict of interest.

Author's Contributions

The authors contributed equally to this manuscript.

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