RESEARCH ARTICLE

International Journal of Agriculture, Environment and Food Sciences 2024; 8(2): 251-260
DOI: https://doi.org/10.31015/jaefs.2024.2.2

Efficacy of different pesticides in suppressing yellow stem borer in spring rice (*Oryza sativa*) in Ratuwamai, Morang, Nepal

Netra Prasad GHIMIRE[1] • **Dipesh Kumar MEHATA**[1] • **Ravi ACHARYA**[2] • **Bishnu YADAV**[1]

[1] Faculty of Science and Technology, G. P. Koirala College of Agriculture and Research Centre, Purbanchal University, Gothgaun, Morang 56600, Nepal
[2] Department of soil science, G. P. Koirala College of Agriculture and Research Centre, Purbanchal University, Gothgaun, Morang 56600, Nepal

Type: Research Article
Subject: Entomology

Citation: Ghimire, N.P., Mehata, D.K., Acharya, R., Yadav, B. (2024). Efficacy of different pesticides in suppressing yellow stem borer in spring rice (*Oryza sativa*) in Ratuwamai, Morang, Nepal. International Journal of Agriculture, Environment and Food Sciences, 8(2), 251-260. https://doi.org/10.31015/jaefs.2024.2.2

Received: *January 30, 2024*
Accepted: *April 14, 2024*
Published Online: *May 2, 2024*

Corresponding Author:
Dipesh Kumar MEHATA
E-mail: mehatadipesh643@gmail.com

Available at:
https://dergipark.org.tr/jaefs/issue/84099/1428438

Abstract
Rice, a staple food for over half the global population, is crucial for food security, economic stability, and cultural significance. Its production, however, is threatened by pests like the Yellow Stem Borer (YSB), which causes substantial yield losses, especially in rice-dominant regions like Nepal. This study focuses on evaluating the effectiveness of biological, botanical, and chemical pesticides against YSB in spring rice crops of Ratuwamai, Morang, Nepal. For this, we apply biological methods/pathogens like *Bacillus thuringiensis*, to target YSB; botanical pesticides, derived from plants like Azadirachtin and Mugworth, act as repellents; while chemical pesticides such as Cypermethrin, Chlorpyriphos and Cartap Hydrochloride offer rapid control but come with environmental risks. Among those six pesticides used, the present findings revealed that chlorpyriphos 20% EC have minimum mean dead heart with 4.92% and cypermethrin 10% EC have minimum mean white ear head with 2.44% respectively after application of first and second dose of treatments respectively. Likewise, most plant yield attributes were superior where chlorpyriphos was used. Though bacillus and azadirachtin reduced the dead heart and white ear head symptoms, they couldn't give good yield than that of chemical pesticides. Thence, through our research we investigated the impacts of different biological, botanical and chemical pesticides in controlling YSB population densities, and influencing yield and yield attributing characters from the field experiment.
Keywords: Dead heart, Pesticides, Spring rice, White ear head, Yellow stem borer

INTRODUCTION

Rice is a crucial source of food for over half of the world's population for about 3.5 billion people, predominantly in Asia and Africa. Its global context is shaped by its significance to food security, economic livelihoods, and cultural importance (Roopwan et al., 2023; Rajput et al., 2020; Fukagawa & Ziska, 2019). Historically rooted in the fertile deltas of Asia, rice production has grown substantially to meet rising demands, making it the second most produced grain after maize. Nations like China and India dominate in rice cultivation, influencing international prices and trade policies (Schneider & Asch, 2020). Climate plays a pivotal role, with monsoons dictating yields in many regions. Excessive water usage, deforestation, and chemical inputs have posed sustainability challenges. As urbanization and climate change threaten traditional rice farming landscapes, there's an urgent need for innovative, sustainable practices (Eliazer Nelson et al., 2019). Innovations such as the System of Rice Intensification (SRI) are emerging to address these challenges. Globally, the rice trade is highly politicized, with countries holding reserves to prevent food shortages. The balance between ensuring food security, maintaining economic stability, and upholding ecological sustainability is central to the global discourse on rice production (Glover, 2011).

Rice holds a significant place in Nepal's agricultural landscape, contributing to both food security and cultural practices. As a staple diet for a majority of its population, rice is cultivated across the Terai plains, hills, and even some mountain regions (Kakshapati et al., 2022; Gadal et al., 2019). A report published by MoALD in 2023 revealed the cultivation of rice on 1.48 million hectares of land, resulting in a total production of 5.13 million tons, with an average yield of 3.47 tons per hectare in Nepal (MoALD, 2023). The diverse topography and varying climate conditions result in a variety of rice types, tailored to specific altitude and rainfall conditions. While the Terai belt, with its flatlands and ample water sources, produces the bulk of Nepal's rice, hill and mountain terraces demonstrate the resilience of farmers in adapting to challenging terrains. However, Nepal's rice production faces multiple challenges (Chandio et al., 2021). Despite the potential of the Terai region, outdated farming practices and lack of access to modern technology limit yield enhancements. Water scarcity, exacerbated by changing monsoon patterns due to climate change, further impacts yields (Karki et al., 2021). Additionally, while the government has introduced subsidies and support for rice farmers, infrastructure challenges and market inefficiencies hamper growth. Still, there's an increased emphasis on organic and traditional rice varieties, attracting niche markets and promoting sustainability (Gadal et al., 2019). Furthermore, community-based approaches and indigenous knowledge play a crucial role in preserving and enhancing rice cultivation in Nepal amidst changing global and environmental dynamics (Chandio et al., 2021).

Further, Yadav et al. (2023a) indicated that 52.4% of rice crop losses result from damage caused by various pathogens, animal pests, and weeds. Yellow stem borer (YSB) is also a significant pest that affects rice cultivation, causing substantial yield losses globally and in Nepal (Nyaupane, 2022). Internationally, YSB has been a concern in many rice-growing countries of Asia, where traditional and high-yielding rice varieties are equally vulnerable. Infestation leads to "dead hearts" in young plants and "whiteheads" in older ones, both resulting in reduced grain production. Global trade, climate change, and monoculture practices have inadvertently facilitated the spread and intensity of this pest (Kattupalli et al., 2021). In the Nepalese context, the challenge is magnified due to the country's reliance on rice as a staple and its central role in agricultural livelihoods. The diverse topography of Nepal, spanning the Terai plains to hilly terraces, offers varied habitats for YSB (Choudhary et al., 2022). While modern pesticides and control measures are available, many farmers, especially in remote areas, rely on traditional methods, which might not be as effective against severe infestations. The limited resources and lack of access to advanced agricultural practices exacerbate the problem (Chandio et al., 2021).

Both globally and in Nepal, integrated pest management (IPM) practices, which combine cultural biological, botanical, and chemical methods, are being promoted as sustainable solutions (Roopwan et al., 2023; Kakshapati et al., 2022; Kafle et al., 2014). Further, Sharma et al. (2022) and Yadav et al. (2023b) stated that effective screening of invasive pests can greatly assist in identifying and controlling these organisms. Continued research, farmer education, and international cooperation are vital to tackle the YSB challenge effectively. Farmers employ a multi-faceted approach to combat the Yellow Stem Borer (YSB) menace in rice fields. One prevalent method is the use of resistant rice varieties, bred specifically to reduce susceptibility to YSB. Alongside, cultural practices like adjusting planting dates can disrupt the life cycle of the borer, thereby reducing its impact. Yadav et al. (2022a) and Yadav et al. (2022b) reported that the proper understanding of lifecycle and behavior of pests is crucial for effective pest management; the more information available about their lifecycle and behavior, the greater the likelihood of successful management. Furthermore, pheromone traps are used to monitor and reduce adult YSB populations (Katti, 2021). Biological control, involving the introduction of natural predators like *Bacillus*, has gained traction as an eco-friendly alternative to control YSB populations. This environmentally friendly method minimizes harm to beneficial insects and reduces the need for chemical interventions. However, its effectiveness can be influenced by factors like local biodiversity and climate conditions (Estiati, 2020). Derived from plants, botanical pesticides are naturally occurring insecticides. Neem, for instance, acts as a repellent and antifeedant against YSB. While botanical pesticides are biodegradable and less toxic to non-target organisms, their efficacy can sometimes be lower than chemical counterparts, requiring frequent applications (Adhikari et al., 2020). Chemical Pesticides remain a common choice for rapid and effective control. Chemical formulations target various YSB life stages, ensuring reduced infestation. However, their overuse can lead to resistance in pest populations. Additionally, non-judicious application poses environmental risks, potentially harming beneficial organisms and contaminating water sources. While chemical pesticides are available, their use is approached with caution due to environmental and health concerns, pushing for an increased focus on integrated pest management (Sah & Sharma, 2023; Mishra et al., 2021). Further, Yadav et al. (2023c) reported a rising trend among farmers towards adopting integrated pest management approaches for controlling pests in their crops. Thus, by exploring the most effective measures against YSB, this study addresses potential yield losses which in turn, aids for economic security of the community. Given these precedents, it's paramount to evaluate alternative methods, such as biological and botanical pesticides, in the Ratuwamai context. This research will offer insights into sustainable pest control measures that uphold ecological balance, benefiting both current and future generation.

MATERIALS AND METHODS

Experimental Location and Design

The research was meticulously conducted in a farmer's field from February to June 2023 at Ratuwamai municipality in Morang district of Nepal. Using a sophisticated Randomized Complete Block Design (RCBD), seven distinct treatments were introduced. These treatments underwent three replicates, culminating in a comprehensive 21 individual plots.

Treatments

Six rigorously selected pesticides and a control without any treatment were subjected to testing. The experiment involved seven different treatment groups namely; T1 involved the use of *Bacillus thuringiensis* var *krustaki* at a rate of 2ml/lit, T2 and T3 involved the application of Azadirachtin and Mugworth leaf extract at a rate of 2ml/lit and 15ml/lit, respectively, T4 used Cypermethrin at a rate of 1.5ml/lit, T5 involved the use of Chloropyriphos at a rate of 2ml/l, T6 utilized Cartap Hydrochloride at a rate of 20kg/ha, while T7 was an untreated control plot.

Table 1. Lists of pesticides applied in research plots.

SN	Generic Name	Trade Name	Notation	Dose
1	*Bacillus thuringiensis var krustaki* 15% SC	Minchu+	T1	2ml/lit
2	Azadirachtin 0.03%	Multineem	T2	2ml/lit
3	Mugworth leaf extract	-	T3	15ml/lit
4	Cypermethrin 10% EC	Cyper-10	T4	1.5ml/lit
5	Chloropyriphos 20% EC	Dhanvan-20	T5	2ml/lit
6	Cartap Hydrochloride 4% G	Cartap	T6	20kg/ha
7	Control	-	T7	-

Plot Dimensions and Planting

A precision layout was employed. Each plot was exactly 2×2 meters squared. To prevent cross-contamination and allow for unhindered maintenance, a buffer zone of 0.5 meters was established between plots. Given the 20 cm spacing both between plants as well as between rows, each plot perfectly accommodated 100 rice plants.

Cultivation Practices

The study focused on "Chaite Dhan-4" variety of spring rice, which is commonly cultivated by farmers in the research location. The Chaite Dhan-4 variety was transplanted from nursery beds to main research field after extensive soil preparation. All plots adhered to regional cultivation practices, which included irrigation frequency, soil fertility management, and weed control. Each pesticide was systematically applied using knapsack sprayer at two pivotal growth stages of the rice plants, timed with the pest population reaching its economic threshold level. The first treatment aimed at the vegetative phase, while the second targeted the reproductive phase, with a strict 20-day interval to ensure consistent growth response. The crop was harvested when most of the crops had reached 80% maturity stage, and crop cutting was conducted manually using sickles.

Data Collection and Observation

Dead Hearts % & White ear Heads %

Initial data for dead hearts were taken one day prior to the first spray of pesticides from ten randomly selected hills of each individual plots. Subsequent observations were then noted on 5, 10, and 15 days after first treatment application. For white ear heads, similar post-second application counts were taken. White ear heads were initially observed one day before the second application of pesticides. Further observations were made on 5, 10, and 15 days after the second spray. The percentage of dead hearts and white heads was calculated, and the mean was determined:

Dead Hearts % = (Number of dead hearts / Total number of tillers) x 100.

White ear Head % = (Number of white ear head / Total number of tillers with panicle) x 100. (Chatterjee & Mondal, 2014)

Plant Height and Number of tillers

Once the rice plants reached their full length in terms of growth, their height was measured from the base to the tip, and the number of tillers or side shoots branching from the main plant was counted.

Filled grains % and Unfilled grains %

At the pinnacle of their maturity, rice plants were gently subjected to panicle cutting, allowing for an accurate count of both filled and unfilled grains.

Filled Grains % = (Number of filled grains / Total number of grains) * 100

Unfilled Grains % = 100 – filled grains %

Test Weight and Grain Yield

Ensuring minimal grain loss, the harvested rice was subjected to assessments. Moisture content of the harvested crops was measured using a moisture meter, and the yield was calculated from the 1 m^2 sections of each plot. The test weight was carefully documented, ensuring a consistent moisture content of 13% across samples.

Test Weight = Weight of 1000 Grains

Statistical Analysis

The data collected over the span of the research months was diligently entered into MS Excel for initial scrutiny. Parameters such as dead hearts %, natural enemies/predators count, white ear heads %, plant height, filled grains % and unfilled grains %, test weight, and grain yield per hectare formed the foundation for analysis. To meet the assumptions of the statistical tests, data underwent necessary transformations: square root for dead hearts % and white ear heads %, and arc sine for filled and unfilled grain percentages as given by Gomez & Gomez (1984). The final analysis was executed in R-Studio, using relevant statistical tests to determine significant differences among treatments.

RESULTS

Impact of Pesticides on Dead Hearts Percentage Following the First Spray

Before the application of pesticides at 1 day before 1st spray, the Economic Threshold Level for dead hearts had exceed (mean DH %= 7.61%). Upon the application of the seven different treatments to the spring rice fields, variations were observed in the outcomes concerning dead heart percentages. For *Bacillus* treatment, a day prior to the first spray, we observed a dead heart percentage of approximately 7.89%. This percentage somewhat increased noticeably to 8% just five days after the treatment. By the 10th and 15th day post-spray, the dead heart percentage stabilized at 6.65% and 5.87% respectively, indicating the effectiveness of the treatment in the initial days. Remarkably, the mean percentage of dead hearts after the first spray stood at 6.84%. The Azadirachtin treatment, began with a higher initial dead heart percentage of 7.4%. However, by the 15th day, it had reduced to 6.34%, averaging at 6.68% after the first spray. On the other hand, the Mugwort treatment commenced with a dead heart percentage of 8.98%, which saw a little drop to 8.39% by the fifteenth day. It's evident that while treatments like Cypermethrin, Chloropyriphos and Cartap Hydrochloride had varying levels of impact on dead heart percentages, there was a more pronounced reduction in dead hearts number, especially with Chloropyriphos, which saw a highest drop in DH% from 7.11% before spray to 4.18% by the 15th day. The overall effectiveness of different treatments following the first spray, as indicated by the mean percentage of dead hearts after spraying, showed that Chloropyriphos 20% EC was the most efficient and significantly superior (4.92%) among all treatments in reducing dead hearts. It was followed by Cartap Hydrochloride 4% G and Cypermethrin 10% EC, with percentages of 5.23% and 6.01%, respectively. Bacillus thuringiensis var kurstaki 15% SC showed similar efficacy to Azadirachtin 0.03%. Mugwort demonstrated the least effectiveness, with the highest percentage of dead hearts recorded at 8.58%. The untreated control exhibited 7.69% dead hearts. The mean percentage of dead hearts at 1 day before spraying (dbs) and at 5, 10, and 15 days after spraying (das) is detailed in Table 2 .

Impact of Pesticides on White ear Heads Percentage Following the Second Spray

Before applying pesticides at 1 day before 2nd spray, the Economic Threshold Level for white ear head had neared (mean WH %= 4.93%). Post the second spray, the Bacillus treatment showcased a consistent reduction in white ear heads percentage, from an initial 3.71% a day before the spray to 2.78% by the fifteenth day. Azadirachtin again displayed similar patterns as observed post the first spray, with a continuous decline in both white ear heads percentage from 5.06% to 4.11%. Mugwort recorded much smaller change in white ear head from 6.64% before spray to 6.19% at 15 days after spray. Chemical pesticides such as Cypermethrin, Chloropyriphos and Cartap Hydrochloride were better pesticides in reducing white ear head in spring rice in our study. Among six pesticides used, Cypermethrin was found to have best performances (low mean WH = 2.44%) in terms of declining the white ear head in rice experimental plots after 15 days of spray. This was followed by Cartap Hydrochloride (WH = 2.88%) and Chloropyriphos (WH = 3.39%) which were in par with each other for efficacy. Likewise, biological pesticides like as *Bacillus thuringiensis var* *krustaki* was found to be less effective (WH = 3.39%) than that of other chemical pesticides applied but was in par with Chloropyriphos and Cartap Hydrochloride. However, botanical pesticides such as Azadirachtin and Mugwort were found to have least performances in suppressing pest number with white ear head of 4.74% and 6.69% respectively. The control group have highest level of infestation of 7.78%. The mean white ear head percentage (WH%) at 1 day before spray (dbs) followed by 5, 10 and 15 days after spray (das) is illustrated in Table 3.

Influence of Pesticides on Yield and Yield Attributing Characters

Finally, assessing the impact on yield and its attributing characters, the *Bacillus* treatment resulted in an average plant height (PH) of 88.23 cm. The filled grain percentage (FG%) stood at a promising 78.59%, while the unfilled grains (UG%) were at 21.41%. The test weight (TW) was recorded at 23 gm, with an overall yield per hectare (YH) of 5.11 tons. Similar observations were made for other treatments, with each showcasing unique patterns in terms of yield and its attributing characteristics. There was no notable difference in plant height among the treatments, which could be attributed to genetic characteristics and variations in fertilizer dosages reaching the rice roots. Nonetheless, Cypermethrin 10% EC exhibited superior performance in terms of plant height at 89.15 cm, followed by Azadirachtin 0.03% and Chloropyriphos 20% EC at 88.42 cm and 88.33 cm, respectively. The number of filled grains of rice showed statistically significant differences across the various pesticide treatments (see Table 4). Chloropyriphos 20% EC resulted in the highest number of filled grains at 82.48%, followed closely by Cartap Hydrochloride 4% G at 81.70% and Cypermethrin 10% EC at 80.53%. Bacillus thuringiensis var kurstaki 15% SC, Azadirachtin 0.03%, and Mugwort leaf extract followed suit with 78.59%, 76.57%, and 74.54% filled grains, respectively, while the control exhibited the lowest number of filled grains at 68.11%. Significant variations were also observed in the number of unfilled grains of rice due to different pesticides (see Table 4). Chloropyriphos 20% EC had the lowest number of unfilled grains at 17.52%, followed by Cartap Hydrochloride 4% G at 18.30% and Cypermethrin 10% EC at 19.47%. Bacillus thuringiensis var kurstaki 15% SC, Azadirachtin 0.03%, and Mugwort leaf extract showed 21.41%, 23.43%, and 25.46% unfilled grains, respectively, while the control had the highest number of unfilled grains at 31.89%. Similarly, there were no significant variations in test weight among the six treatments. However, chemical treatments such as Chloropyriphos 20% EC, Cartap Hydrochloride 4% G, and Cypermethrin 10% EC exhibited the highest test weights at 25.67 gm, 24.33 gm, and 23.67 gm, respectively, while the control plots had the least test weight at 20.67 gm. The grain yield was found to be significantly different due to those applied pesticides in our research study. The maximum yield was obtained from Chloropyriphos 20% EC (6.71 ton/ha) in our field which was succeeded by Cartap Hydrochloride 4% G (5.96 ton/ha), Cypermethrin 10% EC (5.59 ton/ha), *Bacillus thuringiensis var krustaki* 15% SC (5.11 ton/ha), Azadirachtin 0.03% (4.79 ton/ha) and Mugworth leaf extract (4.39 ton/ha). The minimum grain yield was recorded in control individual units (4.01 ton/ha). The above description is represented in Table 4:

Table 2. Incidence of dead hearts (DH) before and after first spray of pesticides.

Treatments	1 DAS	5 DAS	10 DAS	15 DAS	Pooled
Bacillus thuringiensis var krustaki	7.89^{ab} (2.81)	8.00^{ab} (2.83)	6.65^{ab} (2.58)	5.87^{b} (2.42)	6.84^{abc} (2.61)
Azadirachtin	7.40^{ab} (2.71)	7.53^{ab} (2.73)	6.16^{ab} (2.47)	6.34^{ab} (2.51)	6.68^{abc} (2.57)
Mugworth leaf extract	8.98^{a} (2.97)	9.13^{a} (3.00)	8.22^{a} (2.84)	8.39^{a} (2.87)	8.58^{a} (2.90)
Cypermethrin	8.38^{ab} (2.89)	6.86^{ab} (2.62)	5.97^{ab} (2.44)	5.19^{b} (2.28)	6.01^{bc} (2.45)
Chloropyriphos	7.11^{ab} (2.66)	5.69^{b} (2.38)	4.88^{b} (2.21)	4.18^{b} (2.04)	4.92^{c} (2.22)
Cartap Hydrochloride	7.32^{ab} (2.70)	5.97^{b} (2.44)	5.21^{b} (2.28)	4.52^{b} (2.12)	5.23^{c} (2.28)
Control	6.21^{b} (2.49)	7.00^{ab} (2.64)	7.71^{a} (2.77)	8.39^{a} (2.89)	7.69^{ab} (2.77)
Mean	7.61	7.17	6.40	6.13	6.56
CV	8.287	8.307	9.059	9.141	8.791
SEM	0.051840	0.04893	0.051792	0.05003	0.050018
F-test	ns	ns	*	**	*

Note: Values are the mean of three replications at different days of observation; DAS: Days after spray; CV: Coefficient of variation; ns: non-significant; **: Significant at 1% level of significance; *: Significant at 5% level of significance; SEM: Standard error of mean; Values with the same letters in a column are not significantly different at 5% level of significance by DMRT test and parenthesized values indicate square root transformation values.

Table 3. Incidence of white earheads (WH) before and after second spray of pesticides.

Treatments	1 DAS	5 DAS	10 DAS	15 DAS	Pooled
Bacillus thuringiensis var krustaki	3.71[c] (1.93)	4.17[bc] (2.04)	3.24[bc] (1.80)	2.78[cd] (1.67)	3.39[bc] (1.84)
Azadirachtin	5.06[abc] (2.24)	5.53[ab] (2.35)	4.58[b] (2.13)	4.11[c] (2.02)	4.74[b] (2.17)
Mugworth leaf extract	6.64[a] (2.55)	7.16[a] (2.65)	6.71[a] (2.56)	6.19[b] (2.45)	6.69[a] (2.55)
Cypermethrin	3.91[c] (1.98)	2.93[c] (1.71)	2.44[c] (1.56)	1.96[d] (1.40)	2.44[c] (1.56)
Chloropyriphos	4.83[abc] (2.20)	3.88[bc] (1.97)	3.38[bc] (1.84)	2.91[cd] (1.70)	3.39[bc] (1.84)
Cartap Hydrochloride	4.24[bc] (2.05)	3.34[c] (1.82)	2.88[bc] (1.69)	2.43[cd] (1.55)	2.88[bc] (1.69)
Control	6.11[ab] (2.47)	7.07[a] (2.66)	8.04[a] (2.83)	8.23[a] (2.87)	7.78[a] (1.79)
Mean	4.93	4.87	4.47	4.09	4.47
CV	9.733	9.693	10.571	11.531	10.483
SEM	0.045931	0.04426	0.04741	0.05064	0.04683
F-test	*	***	***	***	***

Note: Values are the mean of three replications at different days of observation; DAS: Days after spray; CV: Coefficient of variation; ***: Significant at 0.1% level of significance; *: Significant at 5% level of significance; SEM: Standard error of mean; Values with the same letters in a column are not significantly different at 5% level of significance by DMRT test and parenthesized values indicate square root transformation values.

Table 4. Effect of pesticides on yield and other plant characters.

Treatments	PH (cm)	FG%	UG%	TW (gm)	Yield (ton/ha)
Bacillus thuringiensis var krustaki	88.23[a]	78.59[d] (62.44)	21.41[d] (27.56)	23.00[a]	5.11[cd]
Azadirachtin	88.42[a]	76.57[e] (61.05)	23.43[c] (28.95)	22.67[a]	4.79[d]
Mugworth leaf extract	85.41[a]	74.54[f] (59.69)	25.46[b] (30.31)	21.33[a]	4.39[de]
Cypermethrin	89.15[a]	80.53[c] (63.81)	19.47[e] (26.19)	23.67[a]	5.59[bc]
Chloropyriphos	88.33[a]	82.48[a] (65.25)	17.52[g] (24.75)	25.67[a]	6.71[a]
Cartap Hydrochloride	85.83[a]	81.70[b] (64.67)	18.30[f] (25.33)	24.33[a]	5.96[b]
Control	85.00[a]	68.11[g] (55.62)	31.89[a] (34.38)	20.67[a]	4.01[e]
Mean	87.19	77.50	22.49	23.05	5.22
CV	2.79	0.2454	0.5376	13.89	7.82
SEM	5.922	0.023	0.023	10.254	0.166
F-test	ns	***	***	ns	***

Note: Values are the mean of three replications at different days of observation; PH: Plant height; FG: Filled grains; UG: Unfilled grains; TW: Test weight; CV: Coefficient of variation; ns: non-significant; ***: Significant at 0.1% level of significance; SEM: Standard error of mean; Values with the same letters in a column are not significantly different at 5% level of significance by DMRT test and parenthesized values indicate arc sine transformation values.

The data suggests that while certain treatments like Chloropyriphos and Cypermethrin demonstrate a substantial reduction in pest impact, but it might require a more balanced approach, considering both pest control and ecological impact. The efficacy of treatments also has a pronounced influence on the yield and its attributing characters.

DISCUSSION

The varying degree of pest incidence and their responses to different six pesticides in spring rice plants highlight the delicate balance between pest management and environmental sustainability in our experiment. Of those six treatments plus a control applied, all three chemical pesticides were dominant in controlling pest population indicated by minimum dead hearts percentage (4.92%) in chloropyriphos 20% EC and minimum white ear head percentage (2.44%) in cypermethrin 10% EC. Our findings were in consistent with that of Roopwan et al. (2023) and Kakshapati et al. (2022) which pointed chemical treatments to be most effective in suppressing yellow stem borer other than biological and botanical treatments in short term totally can be attributed to active nature and rapid mode of action of pesticides used as well with better yields. However, Yadav et al. (2022c) highlighted that botanical pesticides play a significant role in reducing pest infestations sustainably. Furthermore, chlorpyriphos is a common organophosphate pesticide employed in controlling a variety of pests in different crops.

In a field experiment by Karki et al. (2023), Chlorpyriphos 20 EC @ 2ml/litre was identified as more effective in reducing yellow stem borer incidence in spring rice compared to other treatments. This was further supported by Sawant et al. (2019) and Karki et al. (2023) in line with our experiment. While chemical pesticides have shown significant reductions in borer pests, biological agents like Bacillus and botanical pesticides such as azadirachtin have also been effective in the long term. Commercial formulations containing Bacillus thuringiensis have proven to be a viable alternative for controlling various insect pests as mentioned in different papers (Sah & Sharma, 2023; Estiati, 2020; Balasubramamiam and Kumar, 2019; Kumari et al., 2019). The treatment involving Bacillus demonstrated a gradual decrease in dead heart and white earhead occurrences throughout the observation period in our experiment. The toxins produced by this bacterium can damage the gut tissues of the larvae, causing gut paralysis, which leads to cessation of feeding and ultimately the death of the larvae due to starvation and damage to the mid-gut epithelium (Chatterjee & Mondal, 2014).

In our recent research, Bacillus thuringiensis var kurstaki was found to be less effective against rice yellow stem borer, resulting in a gradual reduction in insect incidence and a decrease in the occurrences of dead heart and white ear heads in the field, albeit with mild yield impacts compared to other chemical pesticides used. However, its efficacy may be compromised in populations of yellow stem borers that have developed resistance to the bacterium's insecticidal proteins (Rajput et al., 2020). Research by Roopwan et al. (2023), Adhikari et al. (2020), Madhu et al. (2020) and Ogah et al. (2011) supported neem oil/azadirachtin as an effective alternative remedy against yellow stem borers. In contrast, Azadirachtin, though less proficient against dead hearts, exhibited a modest reduction in pest population. Dougoud et al. (2019) and Hashemitassuji et al. (2014) highlighted the effectiveness of neem-based pesticide due to its disruption on insect metabolism, causing female infertility, hindering molting, and possessing antifeedant properties. Mugwort's performance aligns with recent studies by Kakshapati et al. (2022) and Gao et al. (2020), underscoring its natural insect-repelling qualities, albeit necessitating careful monitoring of broader ecological implications.

However, Hashemitassuji et al. (2014) concluded that environmental factors such as temperature, humidity, and precipitation affected the efficacy of the pesticides, resulting in an increase in pest populations even after treatment in line with our research. Even though the outcomes of various treatments varied, Kaur and Singh (2021) demonstrate how important it is to evaluate the short-term yield benefits of each treatment against any potential long-term ecological implications. It's crucial to take into account the fact that pests will eventually become resistant to particular chemical treatments. For instance, despite having demonstrated that cypermethrin showed notable immediate effectiveness, as has been shown for other pesticides used in rice farming, its long-term performance may be called into question if pests become resistant (Norton et al., 2010). In addition to rendering treatments ineffective, this kind of resistance can cause pests to resurface in worse forms. Although our findings shed light on the treatments' immediate efficacy, more research must take a comprehensive approach that takes into account cultural dynamics, economic viability, resistance patterns, and wider environmental and health impacts (Yadav et al., 2024). Such extensive research in the future guarantees that the solutions are not only useful in the long run but also effective in the immediate term.

CONCLUSION

Rice cultivation in Ratuwamai, Morang, Nepal, faces the persistent challenge of the yellow stem borer (YSB). Our study evaluates biological, botanical, and chemical pesticides, revealing Bacillus and Azadirachtin as potent and ecologically sensitive options. These alternatives reduce pest impact while preserving beneficial predator populations, marking a sustainable approach crucial for optimal yields and ecological balance. Despite immediate benefits, chemical pesticides like Cypermethrin and Chloropyriphos pose ecological risks, emphasizing the need for a nuanced perspective. Beyond field boundaries, considerations extend to environmental and health impacts. Balancing short-term gains with long-term sustainability is vital. This study offers a blueprint for rice cultivation—harmonizing productivity with sustainability through continuous research, community collaboration, and integrating modern science with traditional wisdom. The goal: productive and sustainable fields, fostering harmonious coexistence with nature.

COMPLIANCE WITH ETHICAL STANDARDS

Peer-review

Externally peer-reviewed.

Conflict of interest

The authors declare that they have no competing, actual, potential or perceived conflict of interest. Author contribution All authors contributed equally in the paper formation. All the authors read and approved the final manuscript. All the authors verify that the text, figures, and tables are original and that they have not been published before.

Ethics committee approval

Ethics committee approval is not required.

Funding

No financial support was received for this study.

Data availability

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

REFERENCES

Abhilash, P. C., & Singh, N. (2009). Pesticide use and application: an Indian scenario. *Journal of Hazardous Materials*, *165*(1-3), 1–12. https://doi.org/10.1016/j.jhazmat.2008.10.061

Acharya, P., Regmi, P. P., Gauchan, D., KC, D. B., & KC, G. B. (2020). Benefit Cost Analysis of Small Farm Machineries Used for Rice Cultivation in Nepal. *International Journal of Applied Sciences and Biotechnology*, *8*(4), 448–453. https://doi.org/10.3126/ijasbt.v8i4.31928

Adhikari, K., Bhandari, S., Niraula, D., & Shrestha, J. (2020). Use of neem (Azadirachta indica A. Juss) as a biopesticide in agriculture: A review. *Journal of Agriculture and Applied Biology*, *1*(2), 100–117. https://doi.org/10.11594/jaab.01.02.08

Balasubramamiam, M., & Kumar, K. (2019). Bioefficacy of neem formulations against the rice yellow stem borer S. incertulas (Walk.). *Journal of Entomology and Zoology Studies*, *7*(3), 1145–1149.

Chandio, A. A., Jiang, Y., Ahmad, F., Adhikari, S., & Ain, Q. U. (2021). Assessing the impacts of climatic and technological factors on rice production: Empirical evidence from Nepal. *Technology in Society*, *66*, 101607. https://doi.org/10.1016/j.techsoc.2021.101607

Chatterjee, D. (1947). Botany of the Wild and Cultivated Rices. *Nature*, *160*(4059), 234–237. https://doi.org/10.1038/160234a0

Chatterjee, S., & Mondal, P. (2014). Management of rice yellow stem borer, Scirpophaga incertulas Walker using some biorational insecticides. *Journal of Biopesticides*, *7*(supp), 143–147.

Chen, Y. H., & Romena, A. (2006). Feeding patterns of Scirpophaga incertulas (Lepidoptera: Crambidae) on wild and cultivated rice during the booting stage. *Environmental entomology*, *35*(4), 1094-1102.

Choudhary, D., Banskota, K., Khanal, N. P., McDonald, A. J., Krupnik, T. J., & Erenstein, O. (2022). Rice Subsector Development and Farmer Efficiency in Nepal: Implications for Further Transformation and Food Security. *Frontiers in Sustainable Food Systems*, *5*. https://doi.org/10.3389/fsufs.2021.740546

Das, S. K. (2013). Mode of action of pesticides and the novel trends – A critical review. *International Research Journal of Agricultural Science and Soil Science*, *3*(11), 393–401. https://doi.org/10.14303/irjas.2013.118

Dougoud, J., Toepfer, S., Bateman, M., & Jenner, W. H. (2019). Efficacy of homemade botanical insecticides based on traditional knowledge. A review. *Agronomy for Sustainable Development*, *39*(4). https://doi.org/10.1007/s13593-019-0583-1

Eliazer Nelson, A. R. L., Ravichandran, K., & Antony, U. (2019). The impact of the Green Revolution on indigenous crops of India. *Journal of Ethnic Foods*, *6*(1). https://doi.org/10.1186/s42779-019-0011-9

Estiati, A. (2020). Development of Bt rice potential for yellow stem borer control. *Journal of Crop Science and Biotechnology*, *23*(5), 395–403. https://doi.org/10.1007/s12892-020-00025-w

Feola, G., & Binder, C. R. (2010). Identifying and investigating pesticide application types to promote a more sustainable pesticide use. The case of smallholders in Boyacá, Colombia. *Crop Protection*, *29*(6), 612–622. https://

doi.org/10.1016/j.cropro.2010.01.008

Fu, J., Huang, Z., Wang, Z., Yang, J., & Zhang, J. (2011). Pre-anthesis non-structural carbohydrate reserve in the stem enhances the sink strength of inferior spikelets during grain filling of rice. *Field Crops Research*, *123*(2), 170–182. https://doi.org/10.1016/j.fcr.2011.05.015

Fukagawa, N. K., & Ziska, L. H. (2019). Rice: Importance for Global Nutrition. *Journal of Nutritional Science and Vitaminology*, *65*(Supplement), S2–S3. https://doi.org/10.3177/jnsv.65.S2

Gadal, N., Shrestha, J., Poudel, M. N., & Pokharel, B. (2019). A review on production status and growing environments of rice in Nepal and in the world. *Archives of Agriculture and Environmental Science*, *4*(1), 83–87. https://doi.org/10.26832/24566632.2019.0401013

Gao, S., Zhang, K., Wei, L., Wei, G., Xiong, W., Lu, Y., Zhang, Y., Gao, A., & Li, B. (2020). Insecticidal Activity of Artemisia vulgaris Essential Oil and Transcriptome Analysis of Tribolium castaneum in Response to Oil Exposure. *Frontiers in Genetics*, *11*. https://doi.org/10.3389/fgene.2020.00589

Glover, D. (2011). Science, practice and the System of Rice Intensification in Indian agriculture. *Food Policy*, *36*(6), 749–755. https://doi.org/10.1016/j.foodpol.2011.07.008

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John wiley & sons.

Hashemitassuji, A., Safaralizadeh, M. H., Aramideh, S., & Hashemitassuji, Z. (2014). Effects of *Bacillus thuringiensis* var. *Kurstaki* and Spinosad on three larval stages 1st, 2nd and 3rd of tomato borer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in laboratory conditions. *Archives of Phytopathology and Plant Protection*, *48*(5), 377–384. https://doi.org/10.1080/03235408.2014.893630

Ikeda, K., Sunohara, H., & Nagato, Y. (2004). Developmental Course of Inflorescence and Spikelet in Rice. *Breeding Science*, *54*(2), 147–156. https://doi.org/10.1270/jsbbs.54.147

Kafle, L., GC, Y. D., Yang, J.-T., Bhattarai, S., Tiwari, S., & Katuwal, M. (2014). Integrated Pest Management in Nepal. *The 5th International Conference of Clinical Plant Science At: National Pingtung University of Science and Technology, Pingtung, Taiwan*, 113–124. https://doi.org/10.13140/2.1.2563.2324

Kakshapati, P., Shrestha, R., & Khatiwada, S. (2022). Eco-friendly management of rice stem borer in spring rice (chaite-5). *Journal of Agriculture and Applied Biology*, *3*(2), 159–168. https://doi.org/10.11594/jaab.03.02.09

Karki, E., Sharma, A., & Brown, B. (2021). Farm mechanisation in Nepal's Terai Region: Policy context, drivers and options. *Journal of International Development*, *34*(2). https://doi.org/10.1002/jid.3592

Karki, N., Soti, A., Katel, S., Bhandari, R., Thapa, N., & Yadav, S. P. S. (2023). Field Efficacy of Different Insecticides Against Fall Armyworm (Spodoptera frugiperda JE Smith) in Spring Maize (Zea mays L.). *AgroEnvironmental Sustainability*, *1*(2), 93-104. https://doi.org/10.59983/s2023010202

Kato, T. (1989). Relationship between grain-filling process and sink capacity in rice (Oryza sativa L.). *Japanese Journal of Breeding*, *39*(4), 431–438. https://doi.org/10.1270/jsbbs1951.39.431

Katti, G. (2021). Overview of entomology research under AICRIP –An experiential learning. *Journal of Rice Research*, *14*(2). https://doi.org/10.58297/gytj6236

Kattupalli, D., Barbadikar, K. M., Balija, V., Ballichatla, S., R, A., Padmakumari, A. P., Saxena, S., Gaikwad, K., Yerram, S., Kokku, P., & Madhav, M. S. (2021). The Draft Genome of Yellow Stem Borer, an Agriculturally Important Pest, Provides Molecular Insights into Its Biology, Development and Specificity Towards Rice for Infestation. *Insects*, *12*(6), 563. https://doi.org/10.3390/insects12060563

Kaur, R., & Singh, J. (2021). Toxicity, Monitoring, and Biodegradation of Cypermethrin Insecticide: A Review. *Nature Environment and Pollution Technology*, *20*(5), 1997–2005. https://doi.org/10.46488/nept.2021.v20i05.016

Khush, G. S. (2000). Taxonomy and origin of rice. *Aromatic rices*, 5-13.

Kumari, P., Prasad, R., Jha, S. K., Yadav, M., & Prasad, D. (2019). Bioefficacy of some botanical and chemical insecticides against yellow stem borer Scirpophaga incertulas (Walk.) In rice field at Jharkhand. *Journal of Pharmacognosy and Phytochemistry*, *SP2*, 200–203.

Madhu, B., Warghat, A. N., & Tayde, A. R. (2020). Comparative effect of bio pesticides and neem commercial products on rice yellow stem borer, Scirpophaga incertulas (Walker). *Journal of Entomology and Zoology Studies*, *8*, 758–760.

Meyer, R. S., DuVal, A. E., & Jensen, H. R. (2012). Patterns and processes in crop domestication: an historical review and quantitative analysis of 203 global food crops. *New Phytologist*, *196*(1), 29–48. https://doi.org/10.1111/j.1469-8137.2012.04253.x

Mishra, A. K., Arya, R., Tyagi, S., Grover, D., Mishra, J. P., Vimal, S. R., Mishra, S., & Sharma, S. (2021). Non-Judicious Use of Pesticides Indicating Potential Threat to Sustainable Agriculture. In *Sustainable agriculture reviews* (Vol. 50, pp. 383–400). https://doi.org/10.1007/978-3-030-63249-6_14

MoALD. (2023). *Statistical Information on Nepalese Agriculture 2021/22. Agri Statistics*. MoALD. https://moald.gov.np/wp-content/uploads/2023/08/Statistical-Information-on-Nepalese-Agriculture-2078-79-2021-22.pdf

Muthayya, S., Sugimoto, J. D., Montgomery, S., & Maberly, G. F. (2014). An overview of global rice production, supply, trade, and consumption. *Annals of the New York Academy of Sciences*, *1324*(1), 7–14. https://doi.org/10.1111/

nyas.12540

Norton, G. W., Heong, K. L., Johnson, D., & Savary, S. (2010). Rice pest management: issues and opportunities. *Rice in the global economy: strategic research and policy issues for food security. IRRI, Los Banos*.

Nyaupane, S. (2022). Evaluation of Rice Genotypes Resistance to Yellow Stem Borer, Scirpophaga incertulas (Walker) through Sex Pheromone Trap. *Amrit Research Journal*, *3*(01), 10–15. https://doi.org/10.3126/arj.v3i01.50483

Ogah, E. O., Omoloye, A. A., Nwilene, F. E., & Nwogbaga , A. C. (2011). Effect of Neem Seed Kernel Extracts in the Management of Rice Stem Borers in the Field in Nigeria. *Nigerian Journal of Biotechnology*, *23*, 13–21.

Rajput, V. S., Jhala, J., & Acharya, V. (2020). Biopesticides and their mode of action against insect pests: A review. *International Journal of Chemical Studies*, *8*(2), 2856–2862. https://doi.org/10.22271/chemi.2020.v8.i2ar.9184

Roopwan, N., Yadav, U., & Madhu, B. (2023). Efficacy of Biopesticides for the Management of Rice Yellow Stem Borer Scirpophaga incertulas (Walker) in Rice at Prayagraj, U.P, India. International Journal of Plant and Soil Science, 35(18), 888–893. https://doi.org/10.9734/ijpss/2023/v35i183354

Roy, P., Shimizu, N., Okadome, H., Shiina, T., & Kimura, T. (2007). Life cycle of rice: Challenges and choices for Bangladesh. *Journal of Food Engineering*, *79*(4), 1250–1255. https://doi.org/10.1016/j.jfoodeng.2006.04.017

Sah, S., & Sharma, R. (2023). Efficacy of eco-friendly insecticides against yellow stem borer under spring rice crop ecosystem of Saptari district, Nepal. *Archives of Agriculture and Environmental Science, 8*(2), 112-115. https://doi.org/10.26832/24566632.2023.080203

Sawant, V. P., Narangalkar, A., & Varik, G. (2019). Efficacy of chlorpyriphos 75wdg against rice stem borer, Scirpophaga incertulas walker. (Lepidoptera: Pyralidae). *International Journal of Fauna and Biological Studies*, *6*(6), 41–44.

Schneider, P., & Asch, F. (2020). Rice production and food security in Asian Mega deltas—A review on characteristics, vulnerabilities and agricultural adaptation options to cope with climate change. *Journal of Agronomy and Crop Science*, *206*(4), 491–503. https://doi.org/10.1111/jac.12415

Sharma, R., Keval, R., Yadav, S. P. S., & Yadav, B. (2022). Screening of pigeonpea [Cajanus cajan (L.) mill sp.] against blue butterfly, L. boeticus (L.)(Lepidoptera: Lycaenidae) in long duration pigeonpea genotypes. *The Pharma Innovation Journal*, 1511-1514.

Singh, B. B., & Singh, R. (2014). Major rice insect pests in Northeastern UP. *International Journal of Life Sciences Biotechnology and Pharma Research*, *1*(3), 124-143.

Smith, C. W., & Dilday, R. H. (Eds.). (2002). *Rice: origin, history, technology, and production* (Vol. 3). John Wiley & Sons.

Somaweera, K. A. T. N., Suriyagoda, L. D. B., Sirisena, D. N., & De Costa, W. A. J. M. (2016). Accumulation and partitioning of biomass, nitrogen, phosphorus and potassium among different tissues during the life cycle of rice grown under different water management regimes. *Plant and Soil*, *401*(1-2), 169–183. https://doi.org/10.1007/s11104-015-2541-2

Tivet, F. (2001). Leaf Blade Dimensions of Rice (Oryza sativa L. and Oryza glaberrima Steud.). Relationships between Tillers and the Main Stem. *Annals of Botany*, *88*(3), 507–511. https://doi.org/10.1006/anbo.2001.1447

Wang, M., Xia, X., Zhang, Q., & Liu, J. (2010). Life cycle assessment of a rice production system in Taihu region, China. *International Journal of Sustainable Development & World Ecology*, *17*(2), 157–161. https://doi.org/10.1080/13504501003594224

Yadav, S. P. S., Adhikari, R., Bhatta, D., Poudel, A., Subedi, S., Shrestha, S., & Shrestha, J. (2023a). Initiatives for biodiversity conservation and utilization in crop protection: A strategy for sustainable crop production. *Biodiversity and Conservation*, *32*(14), 4573-4595. https://doi.org/10.1007/s10531-023-02718-4

Yadav, S. P. S., Bhattarai, S., Bhandari, S., Ghimire, N. P., Majhi, S. K., Mehata, D. K., ... & Gautam, B. (2023b). Evaluation of host plant resistance against the rice leaf folder (Cnaphalocrosis medinalis) and yellow stem borer (Scirpophaga incertulus) through genotypic screening of rice. *Agrica*, 12(1), 48-56. https://doi.org/10.5958/2394-448X.2023.00006.8

Yadav, S. P. S., Bhattarai, S., Ghimire, N. P., & Yadav, B. (2022b). A review on ecology, biology, and management of a detrimental pest, Tuta absoluta (Lepidoptera: Gelechiidae). *Journal of agriculture and applied biology*, *3*(2), 77-96. http://dx.doi.org/10.11594/jaab.03.02.02

Yadav, S. P. S., Lahutiya, V., & Paudel, P. (2022a). A review on the biology, ecology, and management tactics of helicoverpa armigera (Lepidoptera: noctuidae). *Turkish Journal of Agriculture-Food Science and Technology*, *10*(12), 2467-2476. https://doi.org/10.24925/turjaf.v10i12.2467-2476.5211

Yadav, S. P. S., Lahutiya, V., Ghimire, N. P., Yadav, B., & Paudel, P. (2023c). Exploring innovation for sustainable agriculture: A systematic case study of permaculture in Nepal. *Heliyon*, *9*(5). https://doi.org/10.1016/j.heliyon.2023.e15899

Yadav, S. P. S., Pokhrel, S., Poudel, A., Devkota, S., Katel, S., Bhattarai, N., & Gautam, P. (2024). Evaluation of different insecticides against Liriomyza sativae (Diptera: Agromyzidae) on cucumber plants. *Journal of Agriculture and Food Research*, *15*, 100987. https://doi.org/10.1016/j.jafr.2024.100987

Yadav, S. P. S., Sharma, R., Ghimire, N., & Yadav, B. (2022c). History, Presence, and Perspective of Botanical Insecticides against Insect Pests. *Advances in Agricultural Entomology*, 49-69.