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Efficacy of different chemical and botanical pesticides against rice Ear Head Bug (*Leptocorisa acuta* Thunberg, Hemiptera: Alydidae) in rice Superzone, Nepal

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ABSTRACT

Rice, a staple crop for over half the world's population, plays a crucial role in global food security. However, the rice ear head bug (*Leptocorisa acuta*), a major pest, causes significant yield losses by feeding on developing grains, reducing their quality and quantity. This field trial, conducted from February 16 to June 12, 2024, at the Rice Superzone in Baniyani, Jhapa, Nepal evaluated the efficacy of various chemical and botanical pesticides for managing the rice ear head bug. The experiment comprised seven treatments and three replications, incorporating both chemical and botanical interventions. Imidacloprid 17.8% SL emerged as the most effective treatment, yielding a significant reduction in bug populations post-spray, achieving a high yield of 5.79 tons ha^{-1}, and resulting in the highest number of filled grains per panicle (115.57) with minimal unfilled grains (31.03). In comparison, untreated control plots exhibited the lowest yield, highest bug populations, and greater crop damage. This study highlights Imidacloprid's potential for effective pest control and productivity enhancement in rice cultivation. Future research could explore integrating botanical pesticides, such as Multineem and Bakaino-based options, with chemical treatments to promote sustainable pest management practices while maintaining crop yields.

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1. Introduction

Rice (*Oryza sativa* L.) is a staple crop of immense economic and cultural significance, particularly in Asian countries like Nepal (Mehata et al., 2023), where it contributes to food security and the livelihood of millions importance (Rajput et al., 2020; Fukagawa and Ziska, 2019). Belonging to the family Poaceae, rice's genus Oryza originated in tropical and subtropical regions of Asia and Africa. Archaeobotanical evidence suggests rice was first domesticated approximately 8,000-10,000 years ago in the Yangtze River Basin in China, evolving into a fundamental crop for ancient and modern civilizations alike (Chen et al., 2006). In Nepal, rice is cultivated across diverse agro-ecological zones, from the Terai plains to mid-hill regions, with an annual cultivation cycle consisting of key practices such as puddling, transplanting, and irrigation (Glover, 2011). According to Ghimire et al. (2024), Nepal produces over 5 million metric tons of rice annually, contributing significantly to the country's GDP. Rice remains a critical food source, supplying nearly 40% of the nation's caloric intake and 25% of its protein (MoALD, 2023).

The ecological and economic value of rice in Nepal, however, is threatened by numerous factors, among which pest infestations are of particular concern (Gadal et al., 2019). One major pest is the rice ear head bug (*Leptocorisa acuta*), notorious for its capacity to damage grains during the crucial milky and dough stages, leading to significant yield loss (Choudhary et al., 2022). Feeding on developing grains, *L. acuta* reduces both yield and grain quality, resulting in economic setbacks for farmers. Various environmental conditions, such as high humidity and temperature, create favorable breeding conditions for the pest, posing an ongoing challenge to sustainable rice production in the region (Kattupalli et al., 2021). Effective management of *L. acuta* and other rice pests is pivotal for ensuring food security in Nepal. Crop losses due to pest infestations have a cascading effect on national productivity and GDP. Integrated Pest Management (IPM) strategies, including the use of chemical and botanical pesticides, are essential for minimizing these losses while ensuring the crop's profitability (Kafle et al., 2014). However, the excessive use of synthetic pesticides can pose health risks to consumers, harm beneficial insects, and lead to the development of pest resistance, creating an urgent need to explore alternative and complementary solutions (Choudhary et al., 2022).

Several factors contribute to rice yield loss beyond pest infestation, including soil nutrient depletion (Mehata et al. 2023), water scarcity, and diseases caused by fungi, bacteria, and viruses (Kattupalli et al., 2021). Climate change compounds these challenges by altering rainfall patterns and increasing the incidence of extreme weather events, which stress the rice crop and enhance pest and pathogen proliferation (Estiati, 2020). Water scarcity, exacerbated by changing monsoon patterns due to climate change, further impacts yields (Karki et al., 2021). In response, research into sustainable pest management solutions is gaining momentum. Chemical pesticides have traditionally been the primary method for pest control; however, issues of residue accumulation, pesticide resistance, and environmental impact necessitate a balanced approach that includes botanical pesticides (Kattupalli et al., 2021).

Chemical pesticides, though effective in rapid pest control, present issues related to ecological health and food safety. Chemical pesticides like pyrethroids and organophosphates target pests efficiently but can disrupt natural ecosystems by affecting non-target organisms, including pollinators and natural predators (Adhikari et al., 2020). Additionally, chemical pesticides often leave residues that persist in the environment and pose health risks to consumers. Conversely, botanical pesticides offer an eco-friendly alternative that aligns with sustainable agricultural practices (Kafle et al., 2014). Derived from plants with natural pesticidal properties, botanical pesticides such as neem oil, pyrethrum, and garlic extracts disrupt pest development and behavior with minimal non-target effects (Mishra et al., 2021).

Botanical pesticides are particularly advantageous in managing pests like *Leptocorisa acuta* because they degrade more rapidly in the environment, reducing concerns over residues (Mishra et al., 2021). Studies in IPM have shown that, when used alongside other methods, botanical pesticides effectively reduce pest populations and support healthier ecosystems, aiding in pest control without the negative impacts associated with chemical pesticides (Adhikari et al., 2020). However, their efficacy can vary based on environmental conditions, necessitating ongoing research to optimize application techniques and formulations (Mishra et al., 2021).

Ensuring both effectiveness and sustainability is crucial for the future of rice pest management. Advances in biotechnology and natural product chemistry provide promising opportunities to improve the efficiency of botanical pesticides (Kafle et al., 2014). Additionally, the integration of biopesticides with existing chemical options in rotation or combination can help mitigate resistance development in pests like *L. acuta*. Innovations in precision agriculture and drone-based pesticide applications are revolutionizing pest management, allowing for targeted and efficient applications that reduce pesticide load on the environment (Chandio et al., 2021). Continued research into IPM strategies that leverage the strengths of both chemical and botanical pesticides will be crucial to securing the future of rice production in Nepal and beyond (Adhikari et al., 2020).

The sustainable cultivation of rice in Nepal is vital for food security and economic stability. As pest pressures, especially from *L. acuta*, increase, developing integrated pest management strategies using both chemical and botanical pesticides is essential. This research aims to evaluate the effectiveness of various chemical and botanical pesticides against *L. acuta*, focusing on their impact on pest control and rice yield improvement, to contribute to sustainable pest management practices in Nepal.

2. Materials and methods

2.1. Experimental site

The research was conducted in a farmer's field from 16th February to 12th June of 2024 at rice super-zone located under the Prime Minister Agriculture Modernization Project (PMAMP) PIU, located at Kachankawal-6, Jhapa, Nepal. To precisely identify the site, its specific geographical coordinates are provided as 26°N latitude, 87° longitude and 77 masl altitude. The site lies in the sub-tropical zone of Nepal. It is characterized by three seasons: Rainy, Winter, and Hot Spring. Figure 1 presents the map of the study area. The annual average temperature and rainfall of the study site was 26.79°C and 365.85 mm respectively. The meteorological data of the research area was presented in Figure 2. The variety used for the experiment was 'Hardinath-1', a spring rice first released in Nepal in 2004 by NAARC. This variety ripens in 120 days and has an average productivity of 4.03 mt ha^{-1} (AITC, 2021). Seeds produced in 2080 by Maharani Jhoda Sanakishan Krishi Sahakari Sanstha Limited, located in Gauradaha-5, Jhapa, were used in the experiment. These seeds had an 80% germination rate, 98% purity, and 13% moisture content.

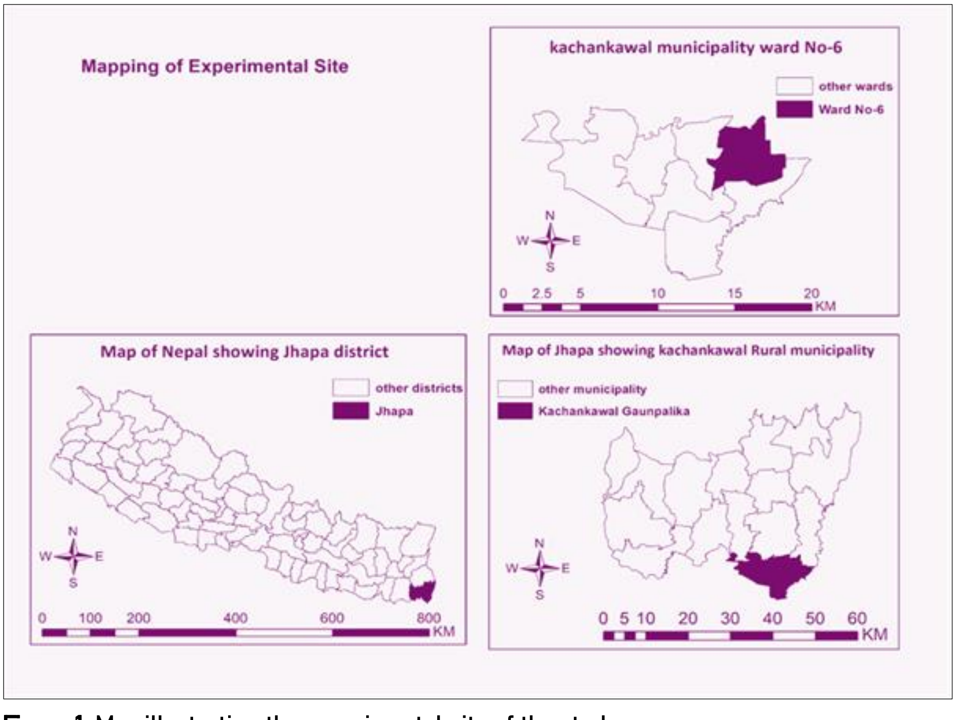

Figure 1. Map illustrating the experimental site of the study

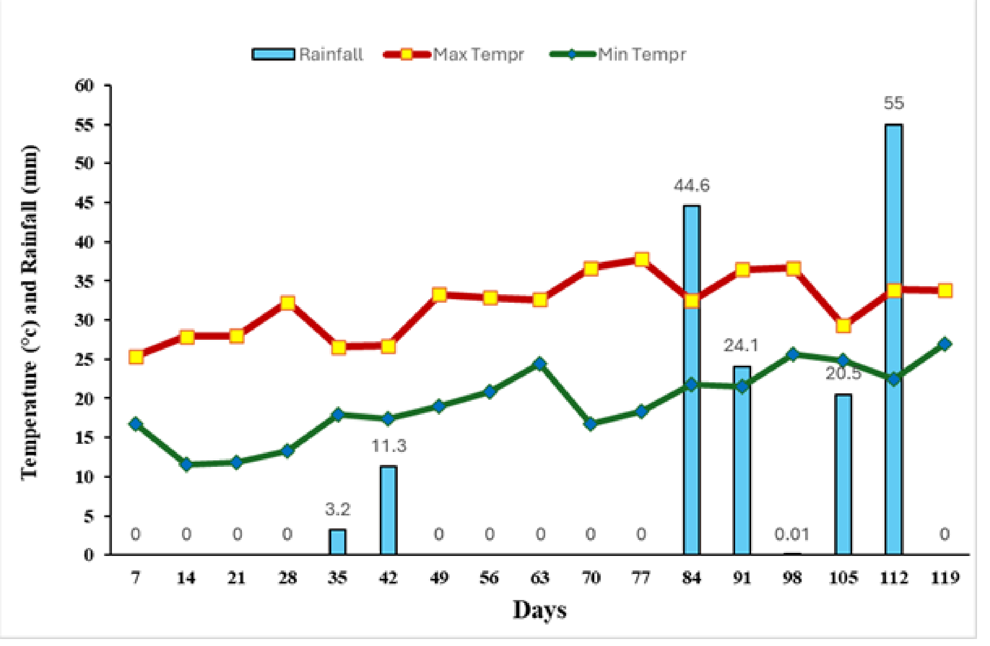

Figure 2. Meteorological data of study site

2.2. Research design

A sophisticated Randomized Complete Block Design (RCBD) was implemented, incorporating seven distinct treatments applied across three replicates. This approach resulted in a total of 21 individual plots for thorough evaluation. The size of each individual plot was 4.0*2.0 m^2. The total area allocated for the experimental field was 238 m^2. The replications were distanced as 1.0 m apart and plant to plant and row to row distances within individual plot were maintained at 20 cm and each individual plot in a replication were maintained at 0.5 m apart respectively. Each plot consists of 200 plants out of which 10 plants were selected randomly for observation and data collection.

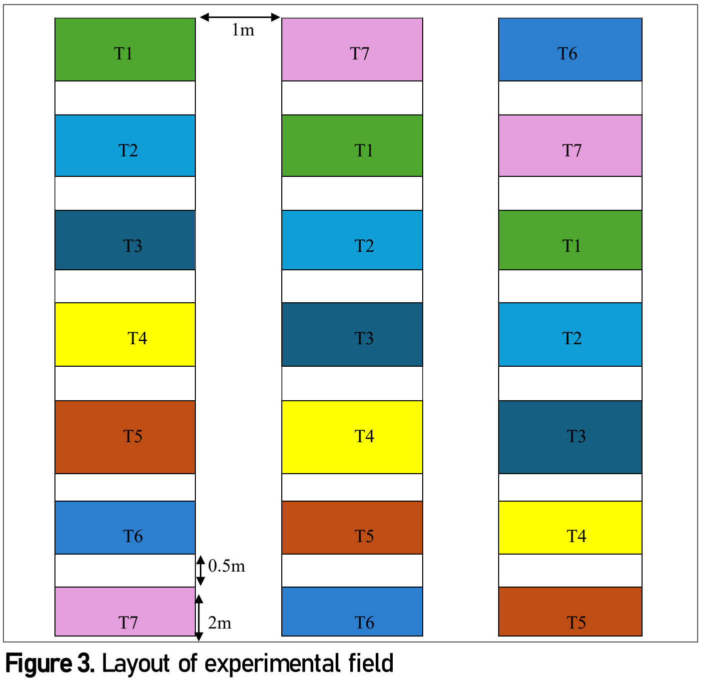

Figure 3. Layout of experimental field

2.3. Treatment details

Table 1 presents the treatments detail with their trade name, formulations and notations used in the study.

Table 1. Treatments detail used in the study

S. N	Treatments	Trade name	Formulation	Notation
1	Chloropyriphos 50% + Cypermethrin 5%EC	G-Sunami	750 mL ha^{-1}	T1
2	Imidacloprid 17.8%SL	Bayer Confidor	140.45 mL ha^{-1}	T2
3	Thiamethoxam a.i 25% w/w	Arrow	100 g m ha^{-1}	T3
4	Azadirachtin 0.03% (Neem Oil)	Multineem	30% per liter	T4
5	Bakaino based pesticide (Melia Azedarach)	Self-prepared	100 mL in 800 mL water	T5
6	Jeevamrut	Self-prepared	100 mL in 800 mL water	T6
7	Control	-	-	T7

2.4. Preparation of biopesticides

A Bakaino-based pesticide was prepared using *Melia azedarach* (Bakaino) leaves, which are valued for their pesticidal properties in traditional Nepalese agriculture. Fresh, disease-free green Bakaino leaves were collected in a quantity of 7.2 g (equivalent to 3.0 kg ha^{-1}) to ensure sufficient concentration for effective pest control. The leaves were placed in a plastic bucket designated for fermentation. Additional ingredients to stimulate microbial activity included 0.4 g (100 g ha^{-1}) of yeast powder, 3.6 mL (1.5 L ha^{-1}) of coconut water for natural sugar content, one banana (12 bananas ha^{-1}) as a source of enzymes and additional organic sugars, and 2.4 g of jaggery (1.0 kg ha^{-1}) to further promote fermentation. The mixture was stirred twice a day for 20 days, following a traditional stirring technique: 12 clockwise and 12 anticlockwise rotations. This stirring process ensured proper aeration and distribution of microbial activity within the solution. By the 20th day, the fermented Bakaino mixture was ready for use as an organic pesticide, offering a sustainable alternative for pest management.

Jeevamrut was prepared for pest control by mixing 12 mL of water with 12 g of cow dung and 12 mL of cow urine, providing essential nutrients and beneficial microbes. To stimulate microbial growth, 1.2 g of jaggery and 1.2 g of pulse flour were added. Additionally, 0.6 g of soil from banyan tree roots were included to enhance microbial diversity. For pest control, optional ingredients such as 5-10 g of neem cake, which has natural insecticidal properties, were incorporated, along with 5-10 crushed garlic cloves, known for their pest-repellent effects, and 1.0-2.0 g of chili powder to deter pests through its spicy compounds. Tobacco powder (1.0-2.0 g) was also added to help control pests like aphids. The mixture was stirred twice daily for 7 days, with alternating clockwise and anticlockwise rotations to promote microbial activity. After the fermentation period, the mixture was strained, diluted with water (1:10 ratio), and ready for application. It was sprayed on plants, focusing on the leaves, stems, and soil. This modified Jeevamrut not only provided nutrients to the plants but also served as a natural pesticide, promoting plant resilience and health while reducing reliance on chemical pesticides.

2.5. Cultural practices

The experiment was conducted using the 'Hardinath-1' variety of spring rice, commonly cultivated by farmers in the Rice Superzone, Baniyani, Jhapa. The field was prepared through traditional practices, including plowing, leveling, and bund creation for effective irrigation and drainage. Seedlings were raised in nursery beds and later transplanted into the main field. Standard regional cultivation practices, such as managing soil fertility, irrigation, and weed control, were followed throughout the growing season. Pesticide treatments, including both chemical and botanical options, were applied systematically using a knapsack sprayer when the rice ear head bug (*Leptocorisa acuta*) population exceeded the economic threshold level. Applications targeted two key growth stages: the vegetative and reproductive phases, with a 20-day interval between sprays to ensure consistent pest management. The crop was harvested manually at approximately 80% maturity, ensuring optimal yield assessment.

2.6. Observation and data collection

For data collection, 10 plants from each treatment were selected and marked with red ribbons. Insecticidal treatments were applied periodically and as needed, based on the Economic Threshold Level (ETL) of the pest species at various crop stages. Pest incidence was observed and recorded on the 4th, 7th, and 10th days following insecticidal applications. At harvest, when the rice plants reached full maturity, the panicles were carefully cut to enable an accurate count of both filled and unfilled grains.

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

Unfilled Grains percentage = 100 – filled grains %

2.7. Statistical analysis

The data gathered throughout the research period was carefully recorded in MS Excel for preliminary examination. Statistical analysis, including Analysis of Variance (ANOVA) and mean estimation, was conducted using RStudio version 4.1.1. To compare treatment means, the Least Significant Difference (LSD) test was applied at a 5% significance level. The results of the analysis were presented in tables and figures, with the findings interpreted in the context of relevant literature.

3. Results

3.1 Effect of different chemical and botanical pesticides on rice Ear Head Bug population after first and second sprays

The study evaluated the efficacy of different treatments on reducing rice ear head bug populations (Table 2), showing significant variations across treatments after the first and second sprays ($p < 0.001$). As shown in Figure 4, Imidacloprid 17.8% SL was the most effective treatment, reducing the bug count to zero after both sprays. This was followed by Thiamethoxam a.i 25% w/w, which reduced the bug population to 0.333 after the first spray and 0.667 after the second. Azadirachtin 0.03% also demonstrated effectiveness, lowering the bug count to 1.0 after the first spray and 1.333 after the second. In contrast, Jeevamrut and the control group had poorer performance, with the control showing the highest post-spray bug counts of 6.0 and 7.67 after each spray (Figure 4). The high coefficients of variation (CV), particularly after the first spray (32.07%) and second spray (27.89%), confirmed variability in treatment efficacy. The grand mean of bugs per plot decreased from 11.86 before the sprays to 1.57 and 2.14 after each spray, respectively. LSD (0.05) values of 0.90 and 2.14 further underscore the significant reductions achieved by the treatments, highlighting the effectiveness of Imidacloprid, Thiamethoxam, and Azadirachtin over other options in managing rice ear head bug populations.

Table 2. Effect of pesticides on rice ear head bug population before and after sprays

Treatment	Bug per plot before 1st spray	Bug per plot after 1st spray	Bug per plot after 2nd spray
Chloropyriphos 50%+Cypermethrin 5%EC	10.667^{bc} (1.76)	1.000^{c} (0.33)	1.333^{bc} (0.00)
Imidacloprid 17.8%SL	10.000^{c} (3.21)	0.000^{d} (0.58)	0.000^{d} (0.00)
Thiamethoxam a.i 25% w/w	12.667^{a} (1.20)	0.333^{cd} (0.33)	0.667^{cd} (0.00)
Azadirachtin 0.03%	11.667^{ab} (1.45)	1.000^{c} (0.58)	1.333^{bc} (0.33)
Bakaino based pesticide	12.667^{a} (0.33)	0.667^{cd} (0.58)	2.333^{b} (0.58)
Jeevamrut	12.667^{a} (0.88)	2.000^{b} (0.00)	1.667^{bc} (0.33)
Control	12.667^{a} (1.86)	6.000^{a} (0.58)	7.667^{a} (0.88)
F-test	NS	***	***
LSD (0.05)	4.87	0.8965843	2.142857
Grand mean	11.86	1.571429	2.142857
SEM (₵)	2.236	0.4115	0.4880
CV	23.097	32.06971	27.88867

Values are mean of three replications CV: Coefficient of variation; ***: Significant at 0.1% level of significance; **: Significant at 1% level of significance; *: Significant at 5% level of significance & parenthesized values indicate square root transformation values

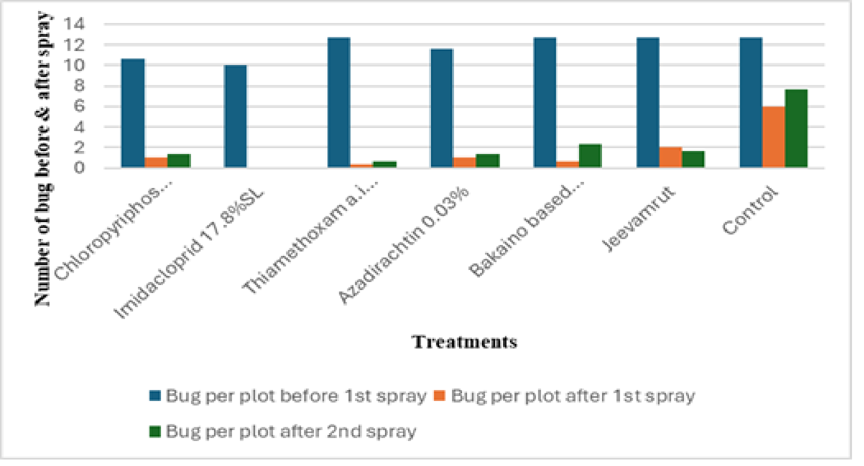

Figure 4. Effect of different treatments on bug population after 2nd spray

3.2. Effect of different treatments on panicle infection before and after pesticide sprays

Table 3 provides a detailed summary of the effects of various treatments on the number of infected rice panicles before and after sprays, with visual representations in Figure 5 enhancing these findings. Initial panicle counts and infection levels before the first spray did not vary significantly across treatments ($p > 0.05$). However, significant reductions in infection rates were observed following both the first ($p < 0.01$) and second sprays ($p < 0.001$), as shown in Figure 6 and 7. Imidacloprid 17.8% soluble liquid (SL) was the most effective treatment, reducing infected panicles to 1.633 after the first spray and 3.133 after the second. Thiamethoxam active ingredient (a.i) 25% wettable powder (w/w) and Chlorpyriphos 50% + Cypermethrin 5% Emulsifiable Concentrate (EC) followed closely, with Thiamethoxam maintaining infection levels at 2.633 and 3.367 and Chlorpyriphos + Cypermethrin at 2.600 and 3.500 after each spray. Moderate efficacy was observed with Azadirachtin 0.03%, and Bakaino-based pesticide, while Jeevamrut and the control treatment exhibited higher infection rates, with the control reaching 5.933 and 8.733 infected panicles after each spray. The coefficients of variation (CV) of 14.91% after the first spray and 11.04% after the second suggest moderate variation in treatment efficacy. Least Significant Difference (LSD) at 5% significance level values of 0.922 and 0.964 further underscore the significant infection reduction achieved by the top-performing treatments. The data in Table 3, supported by Figure 5 , highlight Imidacloprid 17.8% SL, Thiamethoxam a.i 25% w/w, and Chlorpyriphos 50% + Cypermethrin 5% EC as the most effective options for managing panicle infections in rice.

Table 3. Effect of treatments on panicle infection before and after pesticide sprays

Treatments	Total no of panicles before 1st spray	No of infected panicles before 1st spray	No of infected panicles after 1st spray	No of infected panicles after 2nd spray
Chloropyriphos 50%+Cypermethrin 5%EC	13.87^a (0.57)	1.24^a (0.24)	2.60^c (0.50)	3.50^c (0.66)
Imidacloprid 17.8%SL	13.74^a (1.21)	1.37^a (0.50)	1.63^d (0.69)	3.13^c (0.64)
Thiamethoxam a.i 25% w/w	14.00^a (0.20)	1.20^a (0.35)	2.63^c (0.52)	3.36^c (0.79)
Azadirachtin 0.03%	13.87^a (1.22)	1.20^a (0.17)	3.96^b (0.67)	4.86^b (0.86)
Bakaino based pesticide	12.77^a (0.50)	1.37^a (0.18)	3.46^{bc} (0.38)	5.00^b (0.54)
Jeevamrut	12.67^a (0.66)	1.44^a (0.18)	4.10^b (0.23)	5.80^b (0.38)
Control	12.77^a (0.30)	1.57^a (0.20)	5.93^a (0.27)	8.73^a (0.52)
F-test	NS	NS	**	***
LSD (0.05)	1.882	0.925	0.922	0.964
Grand mean	13.380	1.338	3.476	4.914
SEM (₵)	0.864	0.424	0.423	0.442
CV	7.909568	38.87239	14.910	11.035

Values are mean of three replications CV: Coefficient of variation; ***: Significant at 0.1% level of significance; **: Significant at 1% level of significance; *: Significant at 5% level of significance; Values with the same letters in a column are not significantly different at 5% level significance by DMRT test & parenthesized values indicate square root transformation values.

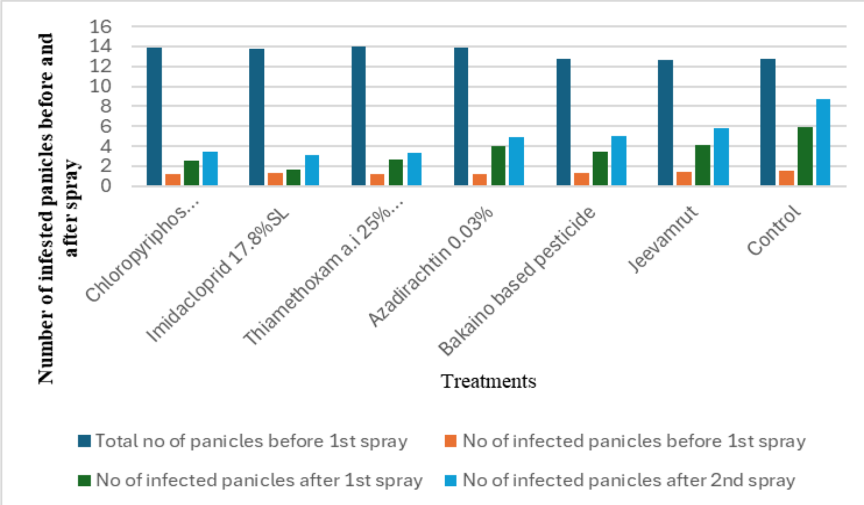

Figure 5. Effect of treatments on number of infested panicles before and after spray

3.3. Pesticide impact on yield components in rice

Table 4 illustrates the impact of different treatments on the number of filled and unfilled grains per panicle and yield (t ha^{-1}) in rice, with these results visually represented in Figure 6 and 7. Significant differences across treatments were observed in filled grains per panicle ($p < 0.01$) and both unfilled grains and yield ($p < 0.001$). Among the treatments, Imidacloprid 17.8% soluble liquid (SL) was the most effective, achieving the highest count of filled grains per panicle (115.57) and the lowest unfilled grains (31.03), resulting in the top yield of 5.790 t ha^{-1}. Chlorpyriphos 50% + Cypermethrin 5% Emulsifiable Concentrate (EC) closely followed, with 107.34 filled grains, 35.23 unfilled grains, and a yield of 5.733 t ha^{-1}. Thiamethoxam active ingredient (a.i) 25% wettable powder (w/w) also showed strong performance, with 114.54 filled grains and a yield of 5.183 t ha^{-1}. Azadirachtin 0.03% and Bakaino-based pesticide exhibited moderate efficacy, while Jeevamrut and the control group performed poorly. The control treatment resulted in the fewest filled grains (94.97) and the highest unfilled grains (63.03), along with the lowest yield (4.217 t ha^{-1}). The coefficients of variation (CV) for filled and unfilled grains per panicle were relatively low (5.56% and 5.18%), while yield displayed moderate variation (9.99%), reflecting consistent results across replications. Least Significant Difference (LSD) values of 10.42, 3.94, and 0.866 for filled grains, unfilled grains, and yield, respectively, underscore the superior performance of the top treatments. In summary, as shown in Table 4 and Figure 6 and 7, Imidacloprid 17.8% SL, Chlorpyriphos 50% + Cypermethrin 5% EC, and Thiamethoxam a.i 25% w/w are the most effective treatments for increasing filled grains per panicle and enhancing yield in rice.

Table 4. Effect of different treatments on filled grains, unfilled grains, and yield

Treatments	Filled grains/panicle	Unfilled grains/panicle	Yield (t ha^{-1})
Chloropyriphos 50%+Cypermethrin 5%EC	107.34^{ab} (1.92)	35.23^{d} (10.76)	5.73^{a} (0.17)
Imidacloprid 17.8%SL	115.57^{a} (2.21)	31.03^{e} (6.19)	5.79^{a} (0.27)
Thiamethoxam a.i 25% w/w	114.54^{a} (2.36)	35.53^{d} (2.43)	5.18^{ab} (0.78)
Azadirachtin 0.03%	101.90^{bc} (1.71)	41.30^{c} (1.98)	4.51^{bc} (0.07)
Bakaino based pesticide	102.02^{bc} (2.10)	43.67^{c} (2.30)	4.26^{bc} (0.26)
Jeevamrut	101.41^{bc} (1.52)	48.73^{b} (2.27)	4.22^{c} (0.22)
Control	94.97^{c} (1.78)	63.03^{a} (1.63)	4.217^{c} (0.36)
F-test	**	***	***
LSD (0.05)	10.42	3.94	0.866
Grand mean	105.39	42.65	4.88
SEM (₵)	4.78	1.801	0.397
CV	5.56	5.18	9.993

Values are mean of three replications CV: Coefficient of variation; ***: Significant at 0.1% level of significance; **: Significant at 1% level of significance; *: Significant at 5% level of significance; Values with the same letters in a column are not significantly different at 5% level significance by DMRT test & parenthesized values indicate square root transformation values

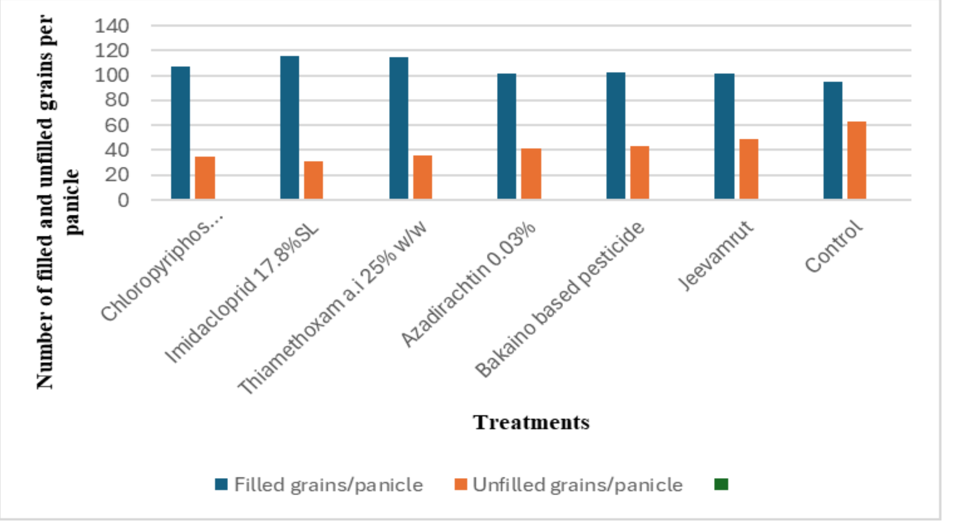

Figure 6. Effect on total number of filled and unfilled grains per panicle

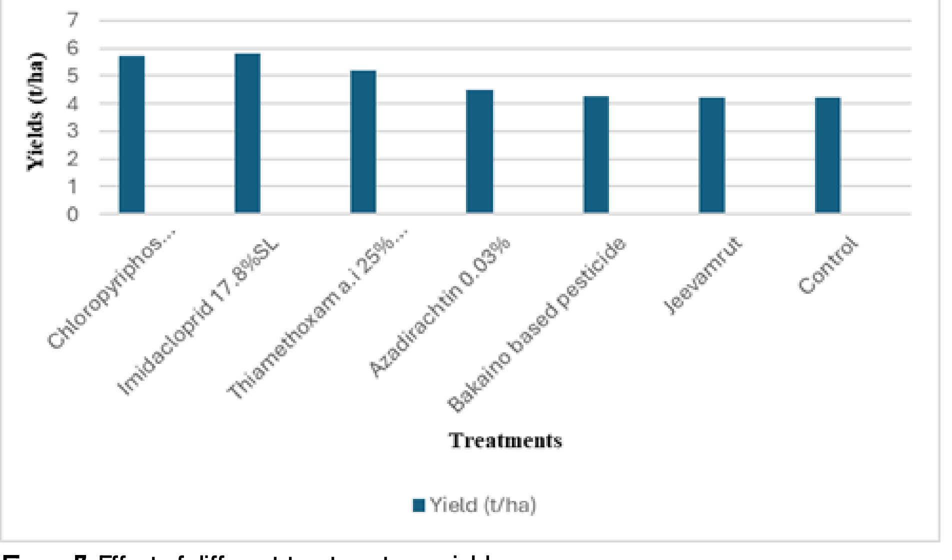

Figure 7. Effect of different treatments on yield

4. Discussions

The study demonstrated the significant efficacy of Imidacloprid 17.8% SL, Thiamethoxam 25% w/w, and Chlorpyriphos 50% + Cypermethrin 5% EC in controlling *Leptocorisa acuta*. Imidacloprid, with its systemic action, showed a complete reduction in pest populations and led to the highest yield (5.79 t ha^{-1}), aligning with findings by Meena et al. (2024) and Kumari et al. (2019). The interaction between Imidacloprid application and yield improvement highlights its efficiency in managing rice ear head bug populations, where its neurotoxic effect not only reduced pest pressure but also enhanced plant growth and grain filling (Mahapatra et al., 2017). Similarly, Thiamethoxam effectively controlled pest populations with a 75% reduction, corroborating Rajput et al. (2020), and improved rice grain development, with a yield of 5.183 tha^{-1}. The interaction between Thiamethoxam and yield is evident from its rapid knockdown effect and prolonged residual efficacy, which significantly reduced panicle infection and supported better grain filling. The combination of Chlorpyriphos+Cypermethrin, providing broad-spectrum pest control, also demonstrated a significant reduction in both pest numbers and panicle infection, as reported by Adhikari et al. (2020) and Ogah et al. (2011).

This treatment yielded 5.733 t ha^{-1}, with its interaction reducing *L. acuta* infestation early in the grain-filling stage, leading to improved photosynthetic efficiency and better energy allocation to the plant. The moderate efficacy of Azadirachtin 0.03% and Bakaino-based pesticides demonstrated partial control, which is consistent with Akter et al. (2020) and Ghimire et al. (2024). Azadirachtin reduced pest populations by 40%, though its efficacy diminished over time, which may have limited its impact on yield, while Bakaino-based pesticides, derived from *Melia azedarach*, showed moderate pest suppression (40-55%) with bi-weekly applications. These botanical pesticides, while less effective than chemical options in pest knockdown, provided an eco-friendly alternative with reduced environmental impact, supporting integrated pest management (IPM) strategies as highlighted by Hoesain et al. (2021). The interaction between these botanical treatments and yield was less pronounced, showing lower yield improvements compared to chemical treatments. The Jeevamrut treatment showed limited effectiveness, with only a 20-30% reduction in pest populations, consistent with the findings by Somdutt et al. (2023). The organic formulation's efficacy largely depended on microbial activity and environmental conditions, which limited its practical effectiveness in high-infestation scenarios like *L. acuta* infestations in rice. Moreover, the coefficients of variation (CV) values of 32.07% and 27.89% post-first and second sprays indicate variability in treatment effects, often attributed to environmental factors or differential pest resistance development, as observed by Srinivas et al. (2023). The significant reductions in infected panicles achieved by the top three chemical treatments (Imidacloprid, Thiamethoxam, and Chlorpyriphos + Cypermethrin) were in line with studies by Akter et al. (2020) and Srinivas et al. (2023), who observed that these chemicals not only reduce pest populations but also prevent secondary damage in rice panicles, improving overall plant health. The observed yield increases, with Imidacloprid 17.8% SL reaching 5.79 t ha^{-1} and Thiamethoxam 5.183 t ha^{-1}, support conclusions by Meena et al. (2024) who documented similar yield gains when effective pest control was coupled with strategic pesticide applications. The direct relationship between reduced *L. acuta* infestation and better panicle development and grain filling was evident in this study. Imidacloprid and Thiamethoxam were particularly effective in facilitating proper nutrient translocation, while Chlorpyriphos + Cypermethrin also showed similar positive interactions, improving grain development. The differential unfilled grain counts and yield improvements (5.79 t ha^{-1} for Imidacloprid and 5.733 t ha^{-1} for Chlorpyriphos + Cypermethrin) are in line with outcomes reported by Madhu et al. (2020), who attributed these effects to improved photosynthetic efficiency and energy allocation when *L. acuta* pressure is minimized early in the grain-filling stage. In summary, this study's findings reinforce the effectiveness of chemical pesticides Imidacloprid 17.8% SL, Thiamethoxam 25% w/w, and Chlorpyriphos 50% + Cypermethrin 5% EC in reducing *L. acuta* populations and improving yield. These pesticides, through their interaction with pest control and plant health, play a key role in enhancing rice productivity. While botanical pesticides like Azadirachtin 0.03% and Bakaino-based pesticides offer a safer, environmentally friendly alternative, their role in integrated pest management is more suitable for moderate pest infestations. The study's results emphasize that chemical pesticides, when integrated into IPM frameworks, contribute to sustainable yield gains and the long-term health of rice ecosystems.

5. Conclusions

This study underscores the effectiveness of various chemical and botanical treatments against rice ear head bug (*Leptocorisa acuta*) in rice. Among the tested options, Chlorpyrifos 50% + Cypermethrin 5% Emulsifiable Concentrate (EC) emerged as the most effective chemical treatment, achieving a substantial reduction in pest populations. Similarly, botanical treatments like Azadirachtin 0.03% and Mugwort (*Artemisia vulgaris*) leaf extract showed strong potential, offering viable eco-friendly alternatives that could reduce chemical pesticide use. The integration of biofertilizers, such as *Bacillus thuringiensis* var. 'Kurstaki', into pest management strategies presents an additional sustainable approach, which may improve pest resistance management while minimizing environmental impact. Future studies should examine the combined use of biofertilizers and botanical pesticides to further enhance efficacy, potentially leading to more sustainable and resilient rice production systems.

Compliance with Ethical Standards

Conflict of Interest

The authors declare that they have no conflict of interest.

Authors' Contributions

Jibisha POUDEL and **Barsha NEUPANE** contributed to Conceptualization, Data curation, Investigation, Methodology, Visualization, Original Draft-Writing, and Review and Editing. **Swagat POUDEL** was responsible for Supervision and Validation.

Ethical approval

Ethical approval was not required for this study as it did not involve experiments or the use of human or animal subjects.

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Data availability

Data is available upon request

Consent for publication

Not applicable.

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