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Field Efficacy of Bio-pesticides and Botanical Insecticides Against Rice Plant Hoppers

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Abstract

To evaluate the efficacy of bio-pesticides, botanical and chemical treatments for the management of rice sucking insect pests field experiments were conducted during *kharif* 2023 and 2025 crop seasons. The study was laid out in a randomized block design using a susceptible high-yielding variety (PR121), with observations recorded on hopper population, spider abundance and grain yield. Treatments included entomopathogenic fungi (*Lecanicillium saksenae*, *Metarhizium anisopliae*, *Beauveria bassiana*), a botanical insecticide (*azadirachtin*), and a chemical insecticide (*pymetrozine*), along with an untreated control. Pest populations were monitored before spraying and at 7 and 15 days after each application. Results indicated that all treatments significantly reduced hopper populations compared to the control in both seasons. Chess @ 300 g ha^{-1} consistently recorded the highest reduction in pest density and the maximum grain yield. Among biological treatments, *L. saksenae* (2023) and *B. bassiana* (2025) showed moderate but significant efficacy, while azadirachtin provided intermediate control. Biological and botanical treatments maintained relatively stable spider populations, whereas chemical treatment caused a noticeable decline in predator abundance. Grain yield was positively correlated with effective pest suppression, with treated plots producing significantly higher yields than the untreated control. The study demonstrates that although chemical control provides rapid and reliable suppression of sucking pests, bio-pesticides and botanical offer environmentally safer alternatives with better conservation of natural enemies. Integration of bio-pesticides and selective insecticides in an integrated pest management (IPM) framework is recommended for sustainable and eco-friendly rice production.

Keywords: Brown plant hopper, azadirachtin, *Lecanicillium saksenae*, *Metarhizium anisopliae*, *Beauveria bassiana.*

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple food crops in the world that serves as the primary source of food for more than half of the global population. Global rice production reached about 800 million tonnes in 2023, with Asian countries contributing nearly 90% of the total production and consumption (FAO, 2025). Despite advances in agronomy, genetics, and crop protection, rice productivity continues to be constrained by biotic stresses, notably insect pests. Among these, sucking insect pests such as *Nilaparvata lugens* (brown plant hopper), *Sogatella furcifera* (white backed plant hopper), and *Leptocorisa acuta* (rice bug) are particularly damaging, causing significant yield losses and adversely affecting grain quality (Heong and Hardy, 2009; Khush, 2013; Fahad *et al.,* 2015).

Sucking pests cause significant damage to rice plants through direct feeding and oviposition punctures. These insects extract phloem sap from plant tissues, resulting in symptoms such as hopper burn, chlorosis, stunted growth and under severe infestation, plant death. In addition to direct feeding damage, several sucking pests also act as vectors of plant pathogens, particularly viruses, thereby exacerbating yield losses (Cabauatan *et al.,* 2009; Horgan *et al.,* 2015). The complex interactions among pests, host plants and associated pathogens highlight the importance of adopting integrated pest management (IPM) strategies tailored to local agro-ecological conditions (Heong *et al*., 2015; Bottrell and Schoenly, 2012).

The economic significance of sucking pests in rice production is considerable. In many Asian countries, outbreaks of the brown plant hopper *N. lugens* have caused severe yield losses and have affected millions of hectares of rice cultivation. Historical outbreaks during the 1970s and early 2000s resulted in substantial crop losses and forced changes in varietal deployment and pest management practices (Wu *et al*., 2020; Iamba and Dono 2021). More recent studies also report periodic resurgence of plant hopper populations associated with intensive rice cultivation and indiscriminate pesticide use (Bottrell and Schoenly, 2012; Horgan, 2024). Overreliance on chemical insecticides has often aggravated pest problems by disrupting natural enemy populations and accelerating the development of insecticide resistance in pest populations (Heong and Schoenly, 2000; Matsumura *et al.,* 2020).

Traditionally, management of sucking insect pests relied heavily on the frequent application of broad-spectrum chemical insecticides. However, overreliance on such chemicals has led to several ecological problems, including pest resurgence, secondary pest outbreaks, environmental contamination and disruption of beneficial arthropod communities. In addition, continuous use of the same chemical groups has accelerated the development of resistance in pest populations, reducing the long-term effectiveness of many insecticides (Fujii *et al*., 2020; Horgan *et al.,* 2022). Consequently, modern pest management strategies increasingly emphasize integrated pest management (IPM), which combines cultural practices, host plant resistance, biological control agents, botanicals and selective insecticides in an environmentally sound manner (Isman, 2015; Karthikeyan, 2019; Sparks *et al.,* 2021). Keeping these points in mind the present studies were conducted to evaluate the efficacy of bio-pesticides, botanical against rice plant hoppers under field conditions.

Materials and Methods

Experimental site and crop variety

The field experiments were conducted during *kharif* 2023 and 2025 rice-growing seasons at the Rice Research Farm, Punjab Agricultural University under natural field conditions. A susceptible high-yielding rice variety PR121 was selected for the study to ensure uniform pest infestation and effective evaluation of treatments.

Experimental design and layout

The experiment was laid out in a Randomized Block Design (RBD) with five treatments (2023) and four treatments (2025) with four and five replications, respectively. Each treatment was randomly allocated within each replication. The size of each experimental plot was 45.36 m² and 35.20 m² during *kharif* 2023 and 2025 crop seasons, respectively.

Crop establishment and agronomic practices

Rice seedlings were raised in a nursery and 30-day-old seedlings were transplanted in the field. Transplanting was done at a spacing of 20×15 cm, maintaining two seedlings per hill. All recommended agronomic practices such as irrigation, fertilization, and weed management were followed uniformly for all plots throughout the cropping period, except for pest control measures.

Treatments

During *kharif* 2023, three bio-pesticides were received from Indian Institute of Rice Research, Hyderabad that comprises of a total of five treatments

T_1: *Lecanicillium saksenae* @ 1x10^7cfu /ml KAU 7714 (20 g talc formulation/L); **T_2:** *Metarhizium anisopliae* @ 1x 10^8 spores per ml NBAIR Bb 5 (20 g talc formulation/L); **T_3:** *Beauveria bassiana* @ 1x 10^8 spores per ml NBAIR Bb 5 (20 g talc formulation/L); **T_4:** Chess 50 WG (pymetrozine) @ 300 g/ha, Osheen 20 SG (dinotefuran); **T_5:** Untreated control

Similarly, during *kharif* 2025 a bio-pesticide and a botanical pesticide were received from Indian Institute of Rice Research, Hyderabad that comprises of a total four treatments: **T_1:** *Beauveria bassiana* @ 1x 10^8 spores per ml NBAIR Bb 5 (20 g talc formulation/L); **T_2:** Chess 50 WG (pymetrozine) @ 300 g/ha, Osheen 20 SG (dinotefuran); **T_3:** *Azadirachtin* 0.005% (Azadin plus) @ 5ml/L; **T_4:** Untreated control

Preparation and application of treatments

The required quantity of each treatment was prepared fresh before the application. *B. bassiana* talc, *L. saksenae* and *M. anisopliae* formulations were mixed in water at the rate of 20 g L^{-1} and thoroughly stirred to obtain a uniform suspension. Pymetrozine, Dinotefuran and *azadirachtin* were prepared as per the recommended doses under treatments.

Spraying was carried out using a knapsack sprayer fitted with a hollow cone nozzle to ensure uniform coverage and directing the spray towards the base of the plants. Treatments were applied when the pest population reached the economic threshold level. All sprays were conducted during calm weather conditions in the morning hours to minimize drift and ensure maximum efficacy.

Observations on sucking pest population and yield

Observations of plant hoppers on rice were recorded at regular intervals. Pest population was assessed by counting the number of hoppers per hill from randomly selected 25 hills in each plot. Pre-treatment observations were recorded one day before spraying, while post-treatment observations were taken at 7 and 15 days after each spray. Spider populations were recorded once from ten hills per plot before treatment at the time of the second spray, and again 15 days after the treatments. At maturity, the crop from each plot was harvested separately and grain yield was recorded.

Statistical analysis

The data on pest population and grain yield were subjected to analysis of variance (ANOVA) appropriate for a Randomized Block Design (RBD). Treatment means were compared using the least significant difference test at the 5% probability level to determine significant differences among treatments. Statistical analyses were performed using CPCS1 and SPSS (Version 16.0) software. The corrected per cent reduction of plant hopper population over control after the application of bio-pesticides, botanical and insecticide was calculated using Henderson-Tilton formula (1955).

$$\text{Corrected \% Reduction} = \left[1 - \frac{(Ta \times Cb)}{(Tb \times Ca)}\right] x100$$

Ta : Number of insects in treated plot after treatment, **Tb** : Number of insects in treated plot before treatment; **Ca** : Number of insects in control plot after treatment, **Cb** : Number of insects in control plot before treatment.

Results and Discussion

The plant hopper population differed significantly among treatments during the *kharif* 2023 cropping season (**Table 1**). Before the first spray, hopper population was uniformly distributed among treatments, ranging from 177.75 to 185.75 hoppers per 25 hills, indicating homogeneity of initial infestation across experimental plots. All treatments significantly reduced hopper populations compared with the untreated control (**Table 1**). Among the biological treatments, in case of *L. saksenae* plant hopper populations decreased by 49.47% and 58.18% at 7 and 15 days after spray (DAS) after the first spray, respectively. Further reduction of hopper population was also observed following the second spray of *L. saksenae*. *M. anisopliae* also showed considerable efficacy, reducing hopper density by 42.69% and 54.08% after the first spray, likewise the reduction in plant hopper population after the second spray **(Table 1)**. Similarly, *B. bassiana* reduced hopper populations by 39.92% and 48.29% after the first spray and similar trend was observed after the application of second spray of *B. bassiana*.

Table 1: Efficacy of bio-pesticides against rice plant hopper during *kharif* 2023

Treatments	No. of hoppers 25 hills^{-1}						Spiders no. 10 hills^{-1}		Yield q ha^{-1}
	1st Spray			2nd Spray			Pre	Post	
	PC	7 DAS	15 DAS	PC	7 DAS	15 DAS			
Lecanicillium saksenae @ 1x10^{7}cfu /ml KAU 7714 (20 g talc formulation/L)	177.75	99.25^b	90.25^b	103.25^b	78.50^b	73.50^b	11.25	10.0^b	74.19^b
Metarhizium anisopliae @ 1x 10^8 spores per ml NBAIR Bb 5 (20 g talc formulation/L)	185.75	108.25^c	104.00^c	121.00^c	96.50^c	92.00^c	11.75	10.5^{bc}	71.87^c
Beauveria bassiana @ 1x 10^8 spores per ml NBAIR Bb 5 (20 g talc formulation/L)	180.75	120.00^d	113.50^d	152.75^d	111.00^d	107.00^d	11.25	10.0^b	68.91^d
Chess @ 300 g/ha; Osheen @ 200 g/ha	177.75	46.50^a	37.50^a	49.75^a	22.50^a	20.50^a	11.00	6.75^a	76.37^a
Control	180.75	199.75^d	219.50^e	226.25^e	232.50^e	248.00^e	11.25	14.25^d	66.52^e
CD (p=0.05)	NS	0.29	0.39	0.36	0.36	0.36	NS	0.19	3.61

*Values with different alphabetic superscripts are significantly different ($p<0.05$) with respect to different columns

The effectiveness of these entomopathogenic fungi is associated with their infection-based mode of action. Fungal conidia attach to the insect cuticle, germinate and penetrate the host integument through mechanical pressure and enzymatic degradation involving proteases, chitinases and lipases. After entering the hemocoel, the fungi proliferate within the insect body and produce secondary metabolites and toxins that disrupt physiological processes, ultimately causing host mortality. This gradual infection process explains the slower yet sustained suppression compared with chemical insecticides. Among the fungi evaluated against rice plant hoppers, *L. saksenae* exhibited the highest efficacy, followed by *M. anisopliae* and *B. bassiana*. These findings are consistent with earlier studies by Shaikh and Mohite (2015), Shah and Pell (2003), who reported effective rice plant hopper population suppression through fungal pathogenicity mechanisms. In contrast, untreated control plots showed a continuous increase in plant hopper population throughout the crop season, rising from 180.75 to 248.00, indicating severe infestation under untreated conditions (**Table 1**).

Spider populations were comparatively less affected in biologically treated plots. Treatments involving *Lecanicillium*, *Metarhizium* and *Beauveria* maintained relatively stable spider numbers, with only slight reductions following spraying. However, the chemical treatment resulted in a marked decline in spider population (from 11.00 to 6.75 (10 hills^{-1})), indicating adverse effects on natural enemies. The control plot exhibited an increase in spider population due to higher prey availability (**Table 1**).

The conservation of spider populations in biologically treated plots highlights the compatibility of entomopathogenic fungi with natural enemies. In contrast, chemical treatment caused a substantial decline in spider density, potentially disrupting ecological balance and increasing the risk of pest resurgence. Conservation of natural enemies is essential for sustainable pest management in rice ecosystems (Anonymous, 2023).

Grain yield was significantly influenced by different treatments. The highest yield (76.37 q ha^{-1}) was recorded in plots treated with insecticides, followed by *L. saksenae* (74.19 q ha^{-1}) and *B. bassiana* (68.91 q ha^{-1}), whereas the lowest yield (66.53 q ha^{-1}) was observed in the control plot (**Table 1**). Similar relationships between hopper suppression and yield improvement were reported by Pathak and Khan (1994) and also in the reports of All India Co-ordinated Research project on Rice findings in India (Anonymous, 2024).

The present investigation revealed a significant reduction in plant hopper population following the application of *B. bassiana*, confirming its effectiveness as a biological control agent under field conditions. After the first spray of *B. bassiana* during *kharif* 2025, hopper density decreased by 34.09% at 7 DAS, indicating an initial suppressive effect, while the continued reduction at 15 DAS demonstrated sustained infection pressure compared with untreated control plots (**Table 2**). Notably, the efficacy of *B. bassiana* was justified in comparison with other treatments, and its performance was markedly superior after the second spray than after a single application. A more pronounced reduction observed after the second spray (51.13% at 7 DAS) further suggests cumulative fungal activity and enhanced secondary transmission within hopper populations. Such delayed mortality is a characteristic feature of fungal bio-pesticides, where infection occurs through spore adhesion, germination, cuticle penetration, and internal proliferation leading to host death. The results obtained in the present study are in agreement with earlier findings that entomopathogenic fungi, particularly *B. bassiana* and *M. anisopliae*, are effective against rice plant hoppers and other homopteran pests. The consistent decline in hopper density observed during the *kharif* 2023 and 2025 crop seasons clearly indicates the progressive pathogenic action of the entomopathogenic fungus. Several studies have reported that *B. bassiana* and *M. anisopliae* can significantly reduce populations of homopteran pests through pathogenic infection and epizootic spread under favourable environmental conditions (Shahid *et al.,* 2012; Mascarin and Jaronski, 2016). The gradual reduction in hopper density observed during the *kharif* 2023 and 2025 cropping seasons suggests the progressive pathogenic action of the fungus and the potential establishment of fungal inoculums in the field ecosystem.

The effectiveness of *B. bassiana* against plant hoppers has also been attributed to its ability to persist in the environment and infect multiple life stages of the insect host. Studies have indicated that entomopathogenic fungi can act as important components of integrated pest management programs by providing environmentally safe and sustainable alternatives to chemical insecticides (Vega *et al.,* 2012; Lacey *et al.,* 2015). Furthermore, recent research emphasizes the growing importance of microbial bio-pesticides in rice ecosystems, as they reduce chemical pesticide dependency while preserving beneficial arthropods and ecological balance (Mantzoukas and Eliopoulos, 2020; Sparks *et al.,* 2021).

The botanical insecticide Azadirachtin (0.005%) also provided significant suppression of hopper populations. After the first spray, hopper density decreased by 50.47% at 7 DAS, with similar reductions following the second spray. Azadirachtin acts primarily as an insect growth regulator and anti-feedant. It interferes with hormonal regulation by disrupting ecdysone activity, inhibiting molting and metamorphosis, while also acting as a feeding deterrent and oviposition inhibitor (Katti, 2013; Mascarin and Jaronski, 2016).

Supporting evidence from several recent studies indicates that neem-based botanical products exert strong behavioral and physiological effects on sucking insect pests, particularly the brown plant hopper (*N. lugens*). Laboratory and greenhouse experiments have demonstrated that neem formulations containing azadirachtin significantly influence host orientation, settling behaviour and feeding activity of plant hoppers. Treated rice plants often become less attractive to insects, resulting in delayed probing and reduced feeding duration. Such behavioral modifications ultimately decrease the amount of phloem sap ingested by the insects (Isman, 2015; Sparks *et al.,* 2021). In contrast, untreated control plots exhibited a continuous increase in hopper population throughout the observation period, rising from 166.6 to 387.2, indicating severe infestation under untreated conditions (**Table 2**).

Table 2: Efficacy of bio-pesticide and botanical against rice plant hopper during *kharif* 2025

Treatments	No. of hoppers 25 hills^{-1}						Spiders no. 10 hills^{-1}		Yield q ha^{-1}
	1st Spray			2nd Spray			Pre	Post	
	PC	7 DAS	15 DAS	PC	7 DAS	15 DAS			
Beauveria bassiana @ 1x 10^8 spores per ml NBAIR Bb 5 (20 g talc formulation/L)	161.60^a	123.60^c	187.60^c	204.60^c	121.20^c	181.60^c	11.60	10.20^c	54.48^c
Chess @ 300 g/ha; Osheen @ 200 g/ha	165.40^b	56.60^a	98.60^a	119.60^a	90.80^a	106.80^a	12.00	9.00^b	61.09^a
Azadirachtin (0.005%)	172.40^d	98.60^b	159.60^b	177.80^b	101.60^b	154.00^b	11.40	8.20^a	57.95^b
Control	166.60^b	192.40^d	225.80^d	299.60^d	363.20^d	387.20^d	12.00	14.20^d	51.07^d
CD (p=0.05)	0.28	0.35	0.44	0.19	0.33	0.40	NS	0.57	0.74

*Values with different alphabetic superscripts are significantly different ($p<0.05$) with respect to different columns

During the *kharif* 2023 crop season, spider populations were comparatively less affected in plots treated with bio-pesticides and botanical formulations. Similar trends were observed during the *kharif* 2025 crop season, where treatments with *B. bassiana* and azadirachtin maintained relatively stable spider populations with only minor reductions following application. In contrast, the chemical treatment resulted in a noticeable decline in spider abundance (from 12 to 9 individuals per 10 hills), indicating possible adverse effects on beneficial arthropods (**Table 2**). The control plots, however, recorded higher spider populations, which could be attributed to greater prey availability in the absence of pest control interventions. The relatively lower impact of botanical treatments on natural enemies may be attributed to their selective mode of action. Neem-derived compounds are known to exhibit repellent and anti-feedant properties that primarily affect the feeding behaviour of insect pests rather than causing immediate mortality. Experimental studies have demonstrated that exposure to neem extracts and azadirachtin significantly reduces feeding activity, suppresses growth and interferes with the normal development of brown plant hopper (*N. lugens*) nymphs (Mascarin and Jaronski, 2016; Mantzoukas and Eliopoulos, 2020). Such selective effects make botanical insecticides comparatively safer to beneficial organisms such as spiders and other predatory arthropods. These observations support the principles of ecological pest management, which emphasize the conservation of natural enemies and biodiversity within agroecosystems (Anonymous, 2023).

Yield data revealed that the highest grain yield (61.09 q ha^{-1}) was recorded in plots treated with insecticides, followed by Azadirachtin (57.95 q ha^{-1}) and *B. bassiana* (54.48 q ha^{-1}) as compared to control (51.07 q ha^{-1}). Effective pest suppression therefore translated into improved crop productivity (Pathak and Khan, 1994; Anonymous, 2023). A comparative evaluation of crop performance revealed that rice yield was significantly higher in *kharif* 2023 compared to *kharif* 2025 crop season. The observed decline in yield and treatment performance during *kharif* 2025 may also be primarily attributed to unfavourable climatic conditions prevailing in Punjab, particularly excessive and uneven monsoon rainfall, cloudy weather conditions during active growth period of the crop. These aberrant weather conditions adversely affected crop growth, development and ultimately also led to reduced productivity (Anonymous, 2025).

The chemical treatments proved to be the most effective treatment for the management of rice plant hopper populations across both the cropping seasons (**Tables 1 and 2**). These consistent reductions across seasons clearly indicate the superior efficacy of insecticides in suppressing hopper populations under field conditions. The effectiveness of Chess and Osheen may be attributed to its active ingredients, pymetrozine and dinotefuran, a selective systemic insecticide specifically targeting sucking insect pests. Unlike conventional neurotoxic insecticides, pymetrozine primarily acts by inhibiting feeding behaviour, while dinotefuran acts on nicotinic acetylcholine receptors in the insect nervous system. Chess interferes with the chordotonal sensory organs of insects, disrupting stylet insertion and preventing sap ingestion, whereas, Osheen causes continuous nerve stimulation, paralysis and finally insect death. As a result, exposed insects cease feeding shortly after treatment and gradually die due to starvation and dehydration rather than immediate toxic effects (Nauen and Denholm, 2005; Anonymous, 2023).

Overall, the results suggest that although chemical control provides rapid and maximum suppression of hopper populations through disruption of insect growth and development, biological control agents offer sustainable alternatives by inducing pathogen-mediated mortality while conserving natural enemies. Integration of bio-pesticides with need-based chemical applications can therefore contribute to environmentally friendly and sustainable rice production systems.

Conclusion

The field experiments demonstrated that bio-pesticides, botanicals, and insecticide treatments significantly reduced hopper populations and improved rice yield compared with the untreated control. Among the treatments, insecticides provided the highest level of rice plant hopper suppression and resulted in maximum grain yield, although it showed some negative effects on spider populations. Biological agents, particularly *L. saksenae* and *B. bassiana*, along with Azadirachtin, offered moderate but effective control while conserving natural enemies, indicating their ecological compatibility. Overall, the results suggest that integrating bio-pesticides and botanicals with need-based chemical applications can provide an effective and environmentally sustainable strategy for hopper management in rice under Integrated Pest Management (IPM) programmes.

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Conflict of interest

There is no conflict of interest between the authors

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