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The Effectiveness of Local Beauveria bassiana in Controlling Planthopper Pests in an Environmentally Friendly Agricultural System

Muhammad Riadh Uluputty

muhammadriadhuluputty@gmail.com

University of Pattimura

Christoffol Leiwakabessy

University of Pattimura

Nureny Goo

University of Pattimura

Abraham Talahaturuson

University of Pattimura

Aminudin Umasangaji

University of Pattimura

Paisal Ansiska

University of Pattimura

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Abstract

Brown planthopper (*Nilaparvata lugens*) is one of the most destructive pests in tropical rice farming ecosystems. This study aims to evaluate the effectiveness of *Beauveria bassiana* local isolates as a biological control agent in an environmentally friendly rice cultivation system. The field experiment was conducted using a Randomized Block Design (RBD) with five dose treatments (0, 1×10^6, 1×10^7, 1×10^8, and 1×10^9 spores/mL) and five replications. The parameters observed included planthopper mortality levels, population density, attack intensity, and rice yield. The ANOVA and DMRT results ($p < 0.01$) showed that all treatments had a significant effect on all parameters. Planthopper mortality reached more than 84% on the 28th day, accompanied by a consistent decrease in population and attack intensity. Rice productivity increased from 4.5 tons/ha in the control to more than 6 tons/ha in the treatment. Interestingly, the medium dose was nearly as effective as the high dose after sufficient incubation. These findings confirm that local *B. bassiana* is practical and applicable as a biological agent, supporting sustainable agriculture principles and potentially reducing reliance on synthetic pesticides in Integrated Pest Management (IPM) programs.

INTRODUCTION

Rice farming plays a strategic role in maintaining Indonesia's national food security. As a primary source of carbohydrates, rice is widely cultivated in various ecosystems, from lowlands to rain-fed rice fields. Successful rice production depends heavily on cultivation techniques, water availability, and pest control, particularly the brown planthopper (*Nilaparvata lugens*), one of the most destructive pests and a significant threat to rice production systems. This pest causes direct damage in the form of "hopperburn" and acts as a vector for viral diseases, significantly reducing crop yields (Iamba & Dono, 2021; Timmanagouda & Maheswaran, 2017). In Indonesia, the ability of brown planthoppers to develop resistance to insecticides such as imidacloprid has been scientifically proven, thus worsening its impact on national food security and demonstrating the need for sustainable management strategies (Diptaningsari et al., 2019). Brown planthopper attacks cause direct damage by sucking plant sap, resulting in scorching symptoms or sudden stem drying.

Furthermore, this pest is also a significant vector for viruses such as grassy stunt and hollow stunt, which can exacerbate crop damage. The combination of direct attack and viral infection can cause significant yield losses, even total crop failure (Ghobadifar et al., 2014; Listihani et al., 2022). Therefore, controlling planthopper populations is a critical aspect of rice crop protection systems to maintain sustainable food production.

Conventionally, planthopper control in the field is carried out using chemical insecticides. While this approach provides quick results, it creates various long-term problems, such as pest resistance to insecticides, disruption of natural enemy populations, and environmental pollution from chemical residues (Diptaningsari et al., 2019; Mu et al., 2016). Dependence on synthetic pesticides is also not in line with the principles of sustainable agriculture, which emphasize ecosystem sustainability, food

security, and environmental health (Iamba & Dono, 2021; Sun et al., 2024). In this context, biological control approaches become highly relevant as a more environmentally friendly and sustainable solution. The use of the entomopathogenic fungus *Beauveria bassiana* as a biological control agent for planthoppers offers great potential in a more ecologically friendly rice farming system. This fungus uses a direct infection mechanism in the host insect, penetrating the integument, multiplying within the insect's body, and ultimately causing death. The main advantages of *B. bassiana* include its ability to adapt to tropical environments, its broad host range, and its relative safety for non-target organisms, including humans and pets (Gangaram et al., 2019; Li et al., 2024). In addition, *B. bassiana* can be produced locally at relatively low cost, making it well suited for implementation at the farmer level (Ghobadifar et al., 2014).

Various previous studies have proven the effectiveness of *Beauveria bassiana* in controlling essential pests such as planthoppers, stem borers, and armyworms (Faria & Wraight, 2007; Shah & Pell, 2003). However, most of these studies used commercial isolates or isolates from outside the research area, which may not necessarily be suitable for local agroecological conditions (Bamisile et al., 2021). In fact, the characteristics of local isolates that have naturally adapted to specific environments are very likely to provide higher efficacy and more stable results in field conditions (Mascarin & Jaronski, 2016) Meanwhile, most previous studies have focused on only one or two aspects, such as pest mortality or infection efficacy, without considering the long-term impact on plant health and crop yield (Aggarwal et al., 2016). In sustainable agricultural systems, it is essential to measure the effectiveness of biological agents not only by their ability to reduce pest populations, but also by their contribution to overall crop productivity. This study addresses this gap by evaluating the effectiveness of a local isolate of *B. bassiana* in controlling N. lugens in an environmentally friendly rice farming system. The evaluation was comprehensive, encompassing four key parameters: planthopper mortality rate, population density, plant infestation rate, and yield (tons/ha). These four parameters were chosen to represent the effectiveness of the application not only in terms of biocontrol but also in supporting overall agricultural productivity.

The study was conducted without chemical pesticides, with close monitoring of planthopper population growth and plant responses within 4 weeks of application. Furthermore, this approach provides insight into the temporal dynamics of fungal infection, the speed of plant response to reduced pest pressure, and the consistency of results across different treatment doses (Aggarwal et al., 2016). The assessment was carried out at five different doses of the fungus to determine the threshold of effectiveness and efficiency of the application, as suggested in the bioefficacy test of various concentrations of biological agents under tropical field conditions (Mascarin & Jaronski, 2016). The main scientific contribution of this study lies in the utilization of a largely unexplored local isolate and an integrative approach to evaluating biocontrol results. By demonstrating that local isolates of *B. bassiana* can provide effective control and support crop productivity, this study broadens our understanding of the adaptation of biological agents to tropical agroecosystems and their potential for field-scale use. This research also strengthens the argument that efficient use of biological inputs can be achieved through optimal doses that do not always have to be high, but can instead be tailored to the timing of infection and plant conditions. It is hoped that these findings will provide a scientific basis for developing locally resource-

based biological control strategies. The implications extend beyond increasing agricultural yields and reducing dependence on chemicals to supporting the national agenda for sustainable, environmentally friendly, climate-resilient agriculture.

MATERIALS AND METHODS

Materials and Methods

The primary material in this study was a local isolate of *Beauveria bassiana* obtained from the Agrotechnology Laboratory at the Faculty of Agriculture, Pattimura University. The isolate was cultured on Potato Dextrose Agar (PDA) medium for 10 days at 25 ± 2°C to produce optimal conidia. Spore suspensions were prepared in 0.02% Tween 80 solution and counted using a hemocytometer, then diluted into five concentrations: 0 (control), 1×10^6, 1×10^7, 1×10^8, and 1×10^9 spores/ml. Local rice varieties were used as host plants. The rice fields were managed organically, without synthetic pesticides. The planting system used was a 2:1 legowo row system with a spacing of 25 cm × 12.5 cm to facilitate treatment application and observation.

Sample Preparation

Before treatment, all plots were observed to ensure uniform initial conditions of the planthopper population. *B. bassiana* suspensions were applied to rice plants 30 days after planting (DAP) using a manual sprayer in the morning. Each treatment was applied evenly to the leaf surface. Each experimental unit consisted of a 2 x 2 meter plot, each of which was randomly assigned to the treatments.

Experimental Design and Implementation

This study used a non-factorial Randomized Block Design (RBD) with five treatments and five replications. Observations were made at five different times: day 3, day 7, day 14, day 21, and day 28 after application. Each observation covered all parameters to evaluate the temporal dynamics of the treatment effects.

Observation Parameters

Four main parameters were observed in this study:

1. Planthopper Mortality Rate (%): Measuring the percentage of dead brown planthoppers at each observation time, calculated based on the difference in population before and after treatment.
2. Brown Planthopper Population Density (Individuals per plot): The number of live planthoppers was counted in 10 random clumps per plot as an indicator of the effectiveness of population control.

3. Attack Level (% of leaf area damaged): Determined by visual scoring of leaf damage, then converted into a percentage.
4. Rice Productivity (Ton/ha): The harvest yield is measured from the weight of dry grain per plot, then converted to tons per hectare.

Data Analysis

The obtained data were analyzed using Analysis of Variance (ANOVA) to determine the effect of *B. bassiana* dosage on each parameter. Further testing was performed using Duncan's Multiple Range Test (DMRT) at the 5% significance level (α = 0.05). The analysis was performed using the latest version of SPSS software to ensure the validity of the data processing results.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) was used to evaluate the effect of *Beauveria bassiana* dosage on planthopper mortality. The results are presented in Table 1, which shows that treatments with varying spore dosages had a highly significant impact on the percentage of planthopper deaths (F count = 31.216; p < 0.0001). This finding indicates an essential difference between treatments, suggesting that increasing the dosage of *B. bassiana* enhances biological control effectiveness against planthopper populations.

Table 1
Results of Analysis of Variance (ANOVA) of the Effect of *Beauveria bassiana* Dose on the Mortality Rate of Brown Planthoppers

Source	JK	df	F Count	Sig.
Treatment	54.756.731	4	31.216	0.0000
Error	41.661.033	95		
Total	96.417.764	99		

Table 1 presents the results of the analysis of variance (ANOVA) for the effect of various *Beauveria bassiana* doses on planthopper mortality. Based on these results, the treatment had a highly significant impact on planthopper mortality, as indicated by an F value of 31.216 and a p-value of 0.0000 (< 0.01). This suggests that variations in *B. bassiana* dose result in significant differences in the effectiveness of biological control against planthoppers. Thus, it can be concluded that increasing the concentration of fungal spores directly increases the pest population's mortality rate, supporting the potential use of *B. bassiana* as a biocontrol agent in rice farming systems. Figure 1 shows the average mortality of planthoppers at various *Beauveria bassiana* doses and observation times, with a trend of increasing mortality with increasing dose and application time.

The application of Beauveria bassiana at different concentrations significantly increased the mortality of *Nilaparvata lugens* compared with the control (Table 1). Mortality increased from approximately 23–26% at day 3 to more than 84% at day 28 across all treated plots, whereas the control consistently exhibited low and stable mortality (< 5%). Although the highest dose (1 × 10^9 spores/mL) produced a slightly faster initial response, final mortality at day 28 did not differ markedly from that with lower doses, indicating that increasing spore concentration does not necessarily enhance long-term effectiveness. The rapid increase in mortality during the first two weeks, followed by a plateau, is consistent with previous bioassay studies demonstrating B. bassiana's high colonization efficiency in insect hosts (Chakrabarti & Kumar, 2008). In line with the findings of Meyling et al. (2018), the present results emphasize that the interaction between spore concentration and exposure time plays a more decisive role in infection success than inoculum density alone. This pattern supports the concept of a biological efficacy threshold, beyond which further increases in dose do not result in proportional gains in control performance (Meyling et al., 2018).

From a biological perspective, the marked increase in mortality during the early observation period reflects the active infection phase of *B. bassiana*. During this phase, fungal spores penetrate the insect integument, proliferate systemically within the hemocoel, and produce toxic metabolites such as beauvericin, leading to physiological disruption of the host. These processes involve cuticular damage, intestinal impairment, and disruption of the internal microbiota, collectively accelerating insect death within 3–7 days after exposure (Baek et al., 2022; L. Zhang et al., 2019). The absence of a comparable mortality increase in the control confirms that the observed effects were attributable to fungal infection rather than external environmental factors. These findings have important implications for the implementation of biological control within Integrated Pest Management (IPM) programs. The comparable final effectiveness of medium and high doses suggests that economically viable, lower spore concentrations can be used effectively when adequate exposure time is ensured. This supports the adoption of locally isolated *B. bassiana* strains as cost-efficient, environmentally friendly alternatives to synthetic pesticides, particularly for small- and medium-scale farming systems. Overall, this study not only confirms the effectiveness of *B. bassiana* against N. lugens but also strengthens the scientific basis for integrating indigenous biological agents into sustainable IPM strategies in tropical agroecosystems.

Population Density of Brown Planthoppers (Individuals per Plot or Specific Area)

An analysis of variance (ANOVA) was conducted to assess the effects of various *Beauveria bassiana* doses on rice planthopper population density. Table 2 presents the results of this analysis, which show that the treatment had a very significant effect on the number of individual planthoppers per plot ($F_{count} = 15.592$; $p < 0.0001$). These results indicate that increasing the dose of *B. bassiana* effectively suppressed the planthopper population in the field.

Table 2
Results of Analysis of Variance (ANOVA) of the Effect of *Beauveria bassiana* Dose on Planthopper Population Density

Source	JK	df	F Count	Sig.
Treatment	58.721.266	4	15.592	0.0000
Error	89.445.732	95		
Total	148.166,998	99		

Table 2 presents the results of the analysis of variance regarding the effect of various doses of *Beauveria bassiana* on the population density of planthoppers. The results indicate that the treatment had a very significant impact on the number of planthoppers per plot or unit area, as indicated by the calculated F value of 15.592 ($p < 0.01$). This shows a significant difference in planthopper population density between the treatments. The considerable decrease in planthopper populations along with increasing doses of *B. bassiana* confirms the biological effectiveness of this entomopathogenic fungus in controlling pests naturally in rice cultivation systems. Figure 2 shows the dynamics of the average population density of planthoppers at various Beauveria bassiana doses and observation times, where all treatment doses caused a progressive decrease in population density, whereas the control showed an increase.

The application of *Beauveria bassiana* significantly reduced the population density of *Nilaparvata lugens* compared with the control. Across all treatment doses (1×10^6–1×10^9 spores/mL), planthopper populations declined sharply over time, whereas the control population increased. For instance, population density decreased from approximately 120 individuals per plot at day 3 to about 30 individuals at day 28 in all treated plots, while the control increased from 113.44 to 139.12 individuals. These results demonstrate the strong suppressive capacity of *B. bassiana* against planthopper populations under field conditions. The rapid decline in population density during the early observation period, followed by convergence at later stages, is consistent with previous studies reporting high efficacy of *B. bassiana* in suppressing insect pest populations (Akello et al., 2009; Meyling et al., 2018; Wraight & Ramos, 2005). Similar to earlier findings, higher doses accelerated population reduction in the initial phase, but final population levels did not differ substantially among treatments. This pattern supports the concept that biological control by entomopathogenic fungi is constrained by an efficacy threshold, beyond which increasing inoculum concentration provides limited additional benefits (Khoobdel et al., 2019).

The pronounced population decline observed between days 3 and 14 reflects the active infection phase of *B. bassiana*. During this phase, fungal spores penetrate the insect cuticle, form internal hyphae, and release toxic metabolites, such as beauvericin and bassianolide, which are recognized as major virulence factors that cause physiological disruption and host mortality (Xu et al., 2009). Recent studies have shown that the production of these metabolites increases significantly during active infection,

confirming their central role in the effectiveness of entomopathogenic fungi (Kim et al., 2023). These findings highlight the high efficacy of locally isolated *B. bassiana* under tropical field conditions, an aspect that remains relatively underexplored in the literature (Lv et al., 2024). The comparable final effectiveness of medium and high doses indicates that medium concentrations (1×10^7–1×10^8 spores/mL) are sufficient to achieve optimal population suppression when adequate exposure time is ensured. From a practical perspective, this supports the use of cost-efficient, locally produced *B. bassiana* as a sustainable biological control strategy within Integrated Pest Management (IPM) programs, reducing reliance on high input doses while maintaining ecological and economic sustainability.

Attack Level (Scoring Attack Intensity or Percentage of Damaged Leaves)

Analysis of variance (ANOVA) of the planthopper attack data, expressed as the percentage of damaged leaves, is presented in Table 3. The results of the analysis showed that the application of various doses of *Beauveria bassiana* had a very significant effect on the intensity of planthopper attacks (F count = 79.197; $p < 0.0001$). This finding confirms that treatment with the biological agent effectively reduces plant damage caused by pests.

Table 3
Results of Analysis of Variance (ANOVA) of the Effect of *Beauveria bassiana* Dose on the Level of Brown Planthopper Attack (Percentage of Damaged Leaves)

Source	JK	df	F Count	Sig.
Treatment	16.060.783	4	79.197	0.0000
Error	4.816.384	95		
Total	20.877.167	99		

Table 3 presents the results of the analysis of variance for the effect of *Beauveria bassiana* dosage on the level of planthopper attack, as measured by the percentage of damaged leaves. The calculated F value of 79.197 with a significance level of 0.0000 ($p < 0.01$) indicates that the *B. bassiana* dosage treatment has a very significant effect on the intensity of attacks. This suggests that higher doses consistently reduce leaf damage from planthopper attacks, supporting the potential of this biological agent as an effective pest control strategy in sustainable agricultural systems.

The application of *Beauveria bassiana* at various concentrations significantly reduced the intensity of *Nilaparvata lugens* attacks on rice plants. Descriptively, the control group (0 spores/mL) experienced an increase in attack intensity from 22.93% on day 3 to 60.31% on day 28, reflecting uncontrolled growth of the planthopper population and the accumulation of progressive plant damage. In contrast, all treatments with *B. bassiana* showed a significant decrease in attack intensity. For example, a dose of 1 ×

10^6 spores/mL reduced the attack rate from 15.21% to 5.33%, while a dose of 1×10^9 spores/mL reduced it from 15.34% to 5.28% at the end of the observation. Consistency of effectiveness was evident at doses ≥ 1×10^7 spores/mL, which maintained stable control through day 28. Biologically, the decrease in attack intensity during the first two weeks (days 3–14) is a critical phase of active infection. During this period, fungal spores begin to attach, penetrate the integument, and develop in the host body. This process reduces the insect's ability to feed, be active, and reproduce before death. For example, at a dose of 1×10^7 spores/mL, the attack intensity decreased from 14.45% to 7.75% in the first two weeks and continued to decline gradually to 5.30% on day 28. In contrast, in the control group, the attack intensity continued to increase linearly, confirming that the decrease in damage in the treatment was due to the pathogenic effects of *B. bassiana* rather than other environmental factors. This finding is consistent with the results of studies showing that *B. bassiana* begins to penetrate the host cuticle within 12–24 hours and causes death within 5–7 days., accompanied by disturbances in the intestinal flora that accelerate death, and systemic infection that spreads to all organs within 72 hours (Baek et al., 2022; X. Zhang et al., 2019).

Analysis of the interaction between dose and observation time revealed a synergistic relationship in reducing attack intensity. Although differences between doses were not yet significant at day 3, attack intensity values became increasingly convergent after day 14, with all treatments showing similar effectiveness approaching the minimum threshold (± 5%). This indicates that the efficacy of *B. bassiana* control is not solely determined by inoculum concentration, but is highly dependent on adequate exposure duration. This implication is essential in field applications, where intermediate doses, such as 1×10^7 spores/mL, can be used as an efficient and economical control strategy. This is in line with findings showing that the success of biological control by *B. bassiana* is strongly influenced by the appropriate combination of dose and exposure time, both in the context of host colonization and synergistic interactions with other control agents (Akello et al., 2009; Meyling et al., 2018). Compared with the results of Faria and Wraight (2007), who reported that the application of *B. bassiana* significantly reduced the intensity of damage by insect pests, this study provides additional field evidence that local isolates perform similarly to commercial strains in tropical agroecological systems. This suggests that the ecological adaptation of local isolates to specific environmental conditions provides stability of infection and high control efficiency without the need for chemical intervention (Faria & Wraight, 2007).

The theoretical implications of these findings strengthen the ecologically based biological control model, which emphasizes that crop damage reduction can be achieved not only through reducing pest populations but also through disrupting host physiology before death. In practice, this study provides a scientific basis for dose recommendations for *B. bassiana* in environmentally friendly rice farming systems, strengthening the role of biological agents in integrated pest management (IPM). Thus, this study fills a gap in the literature on the effectiveness of local *B. bassiana* isolates for systemic pest control and strengthens the argument for using local biological resources to support sustainable agroecosystem resilience. This contribution is not only practical in the context of agricultural technology but also theoretical, broadening understanding of infection dynamics and their implications for reducing crop damage in an ecologically sustainable way.

Rice Harvest Yield or Productivity (Tons/ha or Harvested Dry Grain)

Analysis of variance (ANOVA) for rice yield or productivity, measured in tons per hectare, is presented in Table 4. The results show that treatment with various doses of *Beauveria bassiana* has a very significant effect on increasing plant productivity (F count = 110.836; $p < 0.0001$). This indicates that the effectiveness of biological control against planthoppers directly increases rice yields.

Table 4
Results of Analysis of Variance (ANOVA) of the Effect of *Beauveria bassiana* Dose on Rice Harvest Yield or Productivity (Tons/ha)

Source	JK	df	F Count	Sig.
Treatment	37.182	4	110.836	0.000
Error	7.967	95		
Total	45.149	99		

Table 4 presents the results of the analysis of variance on the effect of *Beauveria bassiana* dosage on rice yields measured in tons per hectare. The calculated F value of 110.836, with a significance level of 0.000 ($p < 0.01$), indicates that the treatment had a highly significant effect on rice productivity. This finding suggests that the application of *B. bassiana* is not only effective in suppressing pest populations but also increases crop yields, thereby strengthening the ecological and economic benefits of using this biological agent in rice cultivation systems. Figure 4 shows the average increase in rice productivity at all *Beauveria bassiana* treatment doses. In contrast, the control group showed lower productivity and tended to decrease at the end of the observation.

The application of *Beauveria bassiana* at various concentrations significantly increased rice productivity compared with the control. The control plots consistently yielded 4.21–4.80 tons/ha throughout the observation period. In contrast, all *B. bassiana* treatments resulted in higher yields, with the highest dose (1×10^9 spores/mL) reaching 6.22 tons/ha at day 3 and maintaining productivity above 5.90 tons/ha until day 28. These results indicate a strong association between effective biological control of planthopper populations and increased rice yield. The observed yield improvement is consistent with previous studies reporting positive agronomic effects of *B. bassiana*-based pest control. For example, *B. bassiana* application significantly increased chickpea yields by reducing *Helicoverpa armigera* infestation and pod damage (Younas et al., 2016). Similarly, Russo et al. (2019) demonstrated that endophytic colonization of *B. bassiana* in maize not only suppressed herbivory but also enhanced plant growth and grain yield (Russo et al., 2019). Comparable responses were reported in long bean, where *B. bassiana* application improved plant physiology and increased CO_2 assimilation and biomass accumulation (Pachoute et al., 2021). Together, these studies corroborate the yield-enhancing potential observed in the present work.

The sustained yield increase at medium to high doses reflects the indirect physiological benefits of *B. bassiana* application. By suppressing planthopper feeding activity, *B. bassiana* reduces damage to photosynthetic tissues and alleviates physiological stress, thereby enhancing photosynthetic efficiency and biomass accumulation. In addition, endophytic interactions between *B. bassiana* and host plants have been shown to promote root development, maintain plant growth under herbivore pressure, and support overall plant vigor (Russo et al., 2019; Zitlalpopoca-Hernandez et al., 2017). These mechanisms collectively explain how biological control can translate into stable yield gains without direct growth stimulation inputs. The findings demonstrate that a locally isolated *B. bassiana* strain can significantly enhance rice productivity under tropical paddy conditions without chemical inputs. Importantly, medium doses achieved yield levels comparable to the highest dose, highlighting their potential as a cost-effective and resource-efficient option for field-scale application. This study fills a critical gap in the literature by documenting the indirect yield benefits of biological control in pesticide-free systems. It strengthens the scientific basis for integrating *B. bassiana* into sustainable intensification and Integrated Pest Management (IPM) programs, particularly for small- and medium-scale rice farming systems.

Impact of Beauveria bassiana Application on Agricultural Ecosystem Balance

The application of *Beauveria bassiana* significantly enhanced the biological control of *Nilaparvata lugens*, a significant pest in tropical rice cultivation. Across all tested doses (1×10^6–1×10^9 spores/mL), planthopper mortality increased consistently from approximately 23% at day 3 to more than 84% at day 28. Notably, medium doses achieved efficacy levels comparable to higher doses after sufficient incubation, indicating that exposure duration plays a critical role in control success and that effectiveness is not solely dependent on inoculum concentration. The sustained reduction in population density and attack intensity over four weeks demonstrates *B. bassiana's* capacity to suppress planthopper population dynamics in a stable, sustainable manner. These findings are consistent with previous studies reporting that *B. bassiana* infection can reduce insect growth rates, feeding activity, and reproductive potential, thereby exerting long-term pressure on pest populations. Similar population-level effects have been observed in other insect pests, including *Spodoptera litura* and *Myzus persicae*, in which infection reduced feeding, mobility, and reproduction (Karaca et al., 2024; Kim et al., 2023). The present results extend these observations to tropical rice systems, confirming that locally applied *B. bassiana* can provide population suppression comparable to that reported under controlled or non-rice cropping systems.

Biologically, *B. bassiana* acts not only as a direct lethal agent but also as a disruptor of the pest life cycle. Following infection, fungal development within the host disrupts feeding behavior, movement, and reproductive capacity, leading to a cumulative decline in the population over time. This mode of action explains the progressive increase in mortality and the stabilization of population suppression observed throughout the experimental period, highlighting B. bassiana's role as a regulator of pest dynamics rather than merely a short-term toxic agent. The increase in rice productivity from approximately 4.5 tons/ha in the control to 5.8–6.2 tons/ha in treated plots demonstrates the indirect agronomic benefits of effective biological control. By protecting plant tissues from planthopper damage, *B. bassiana* application

enhances photosynthetic efficiency and nutrient utilization, supporting stable yield performance across the growing period. Similar yield-enhancing effects associated with endophytic colonization by *B. bassiana* have been reported in several crops, including improved plant growth, root development, and biomass accumulation (Pachoute et al., 2021; Ramakuwela et al., 2020; Russo et al., 2019; Thakur et al., 2024). From a practical standpoint, the use of locally adapted *B. bassiana* isolates offers a cost-effective, ecologically selective, and sustainable option for field-scale application. This study provides strong empirical support for integrating *B. bassiana* as a primary component of environmentally friendly Integrated Pest Management (IPM) strategies, particularly in tropical agroecosystems facing increasing biotic stress.

CONCLUSIONS AND SUGGESTIONS

This study demonstrates that the application of a locally isolated *Beauveria bassiana* effectively controls brown planthopper (*Nilaparvata lugens*) populations in environmentally friendly rice cultivation systems. Across all tested doses (1×10^6–1×10^9 spores/mL), *B. bassiana* significantly increased pest mortality while reducing population density and attack intensity, with the highest effects observed at day 28. Plant infestation levels declined to approximately 5% in treated plots, compared with more than 60% in the control, and yields increased by more than 6 tons/ha at higher doses. A key novel finding is that medium doses achieved control efficacy comparable to higher doses when sufficient exposure time was allowed, indicating that infection duration is as critical as inoculum concentration. These results highlight the strong potential of local *B. bassiana* isolates as cost-effective, environmentally safe biological control agents and support their integration into sustainable rice production and Integrated Pest Management (IPM) programs without compromising productivity.

Declarations

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author Contributions Statement

M.R.U. conceptualized the study, designed the methodology, conducted field experiments, performed data analysis, and wrote the original draft of the manuscript. **C.L.** contributed to experimental design, supervised laboratory and field activities, and critically reviewed the manuscript. **N.G.** assisted in data collection, data validation, and statistical analysis. **A.T.** and **P. A.** supported laboratory work, preparation of *Beauveria bassiana* isolates, and contributed to data interpretation. **A.U.** contributed to result interpretation, manuscript revision, and improvement of scientific content. All authors reviewed, edited, and approved the final version of the manuscript.

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Figures

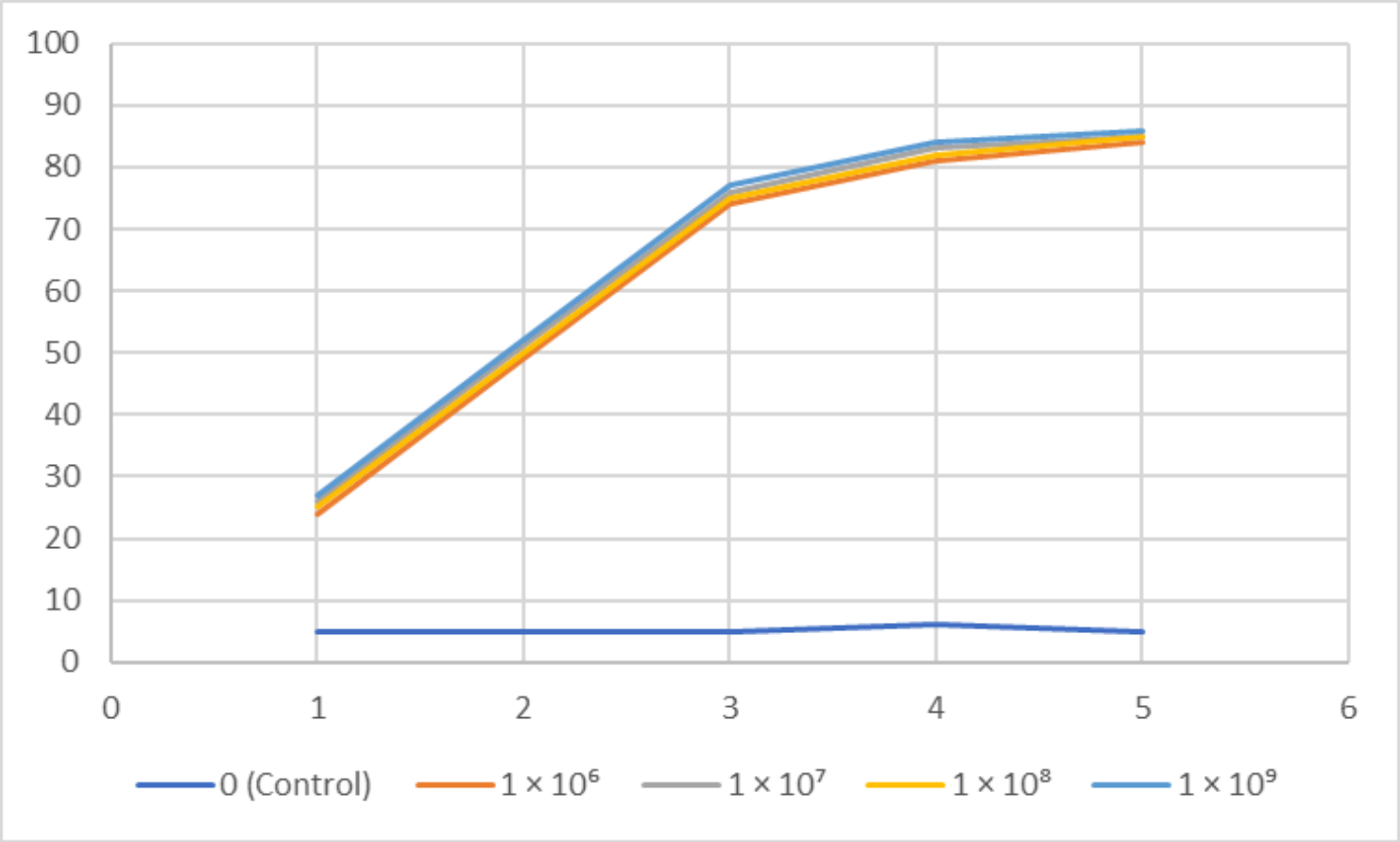


Figure 1

Graph of Average Mortality of Brown Planthoppers Based on *Beauveria Bassiana* Dose

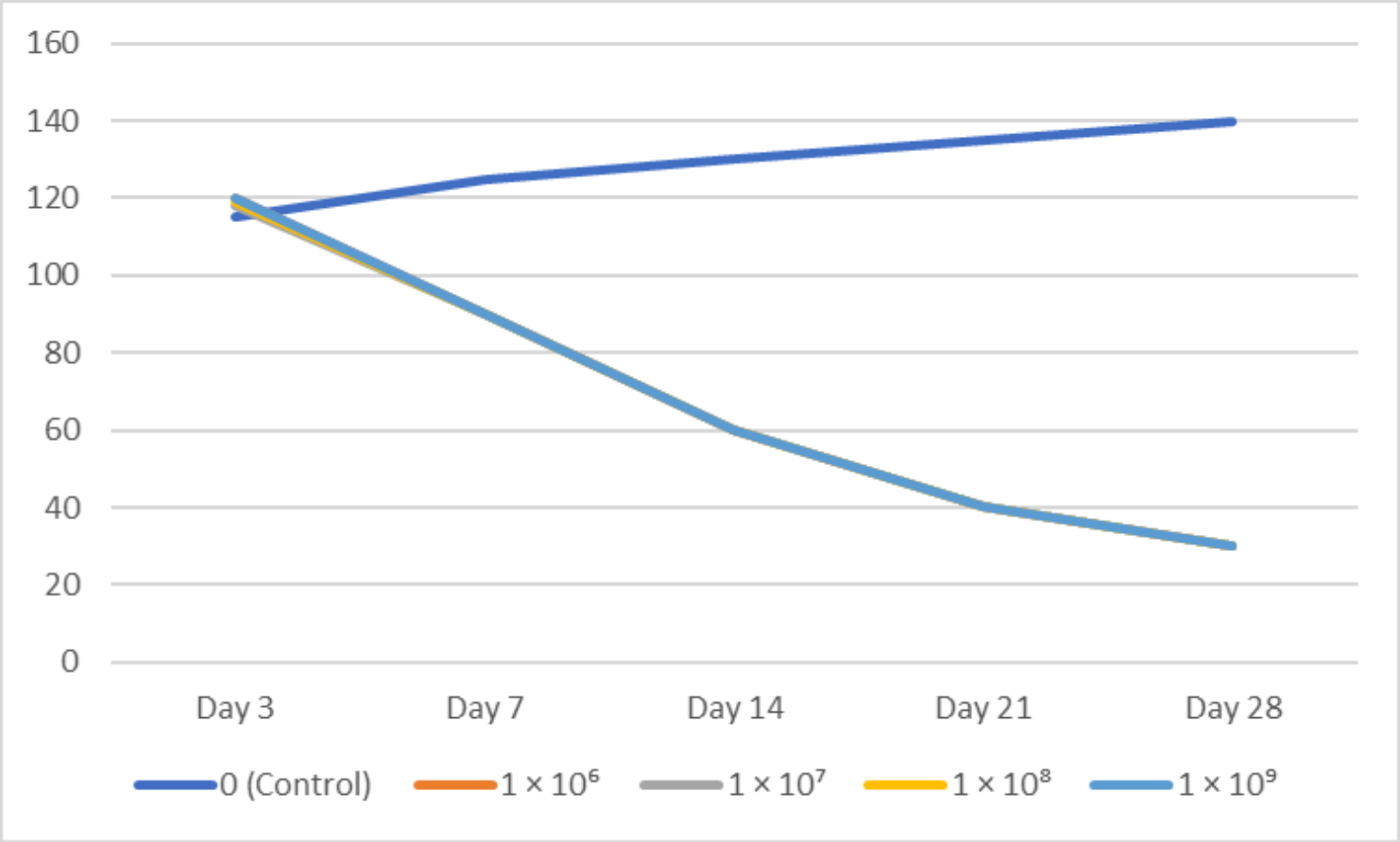


Figure 2

Graph of the average population density of brown planthoppers against the *Beauveria bassiana* dose

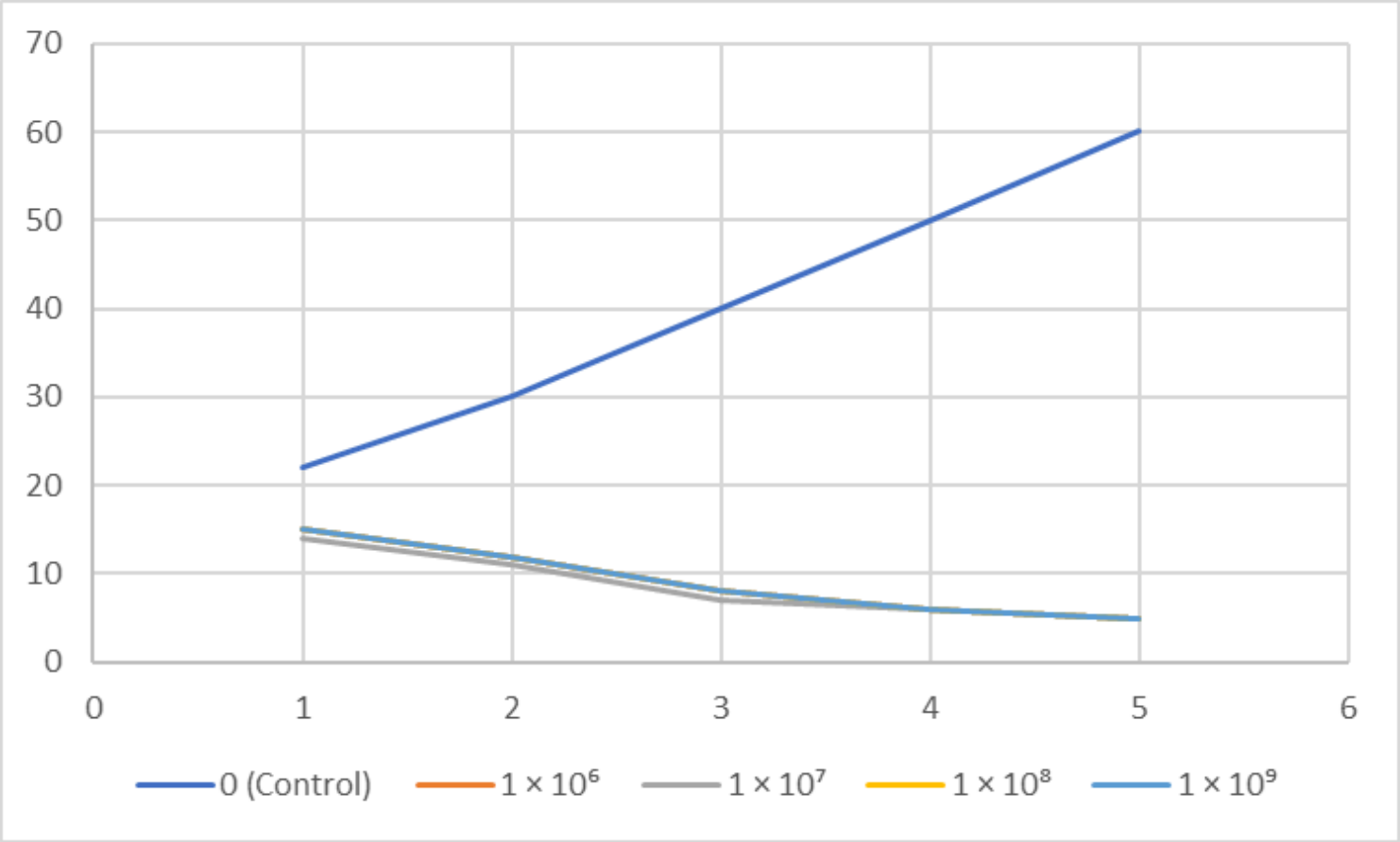


Figure 3

Average Graph of the Level of Brown Planthopper Attack Against the Dose of *Beauveria bassiana*

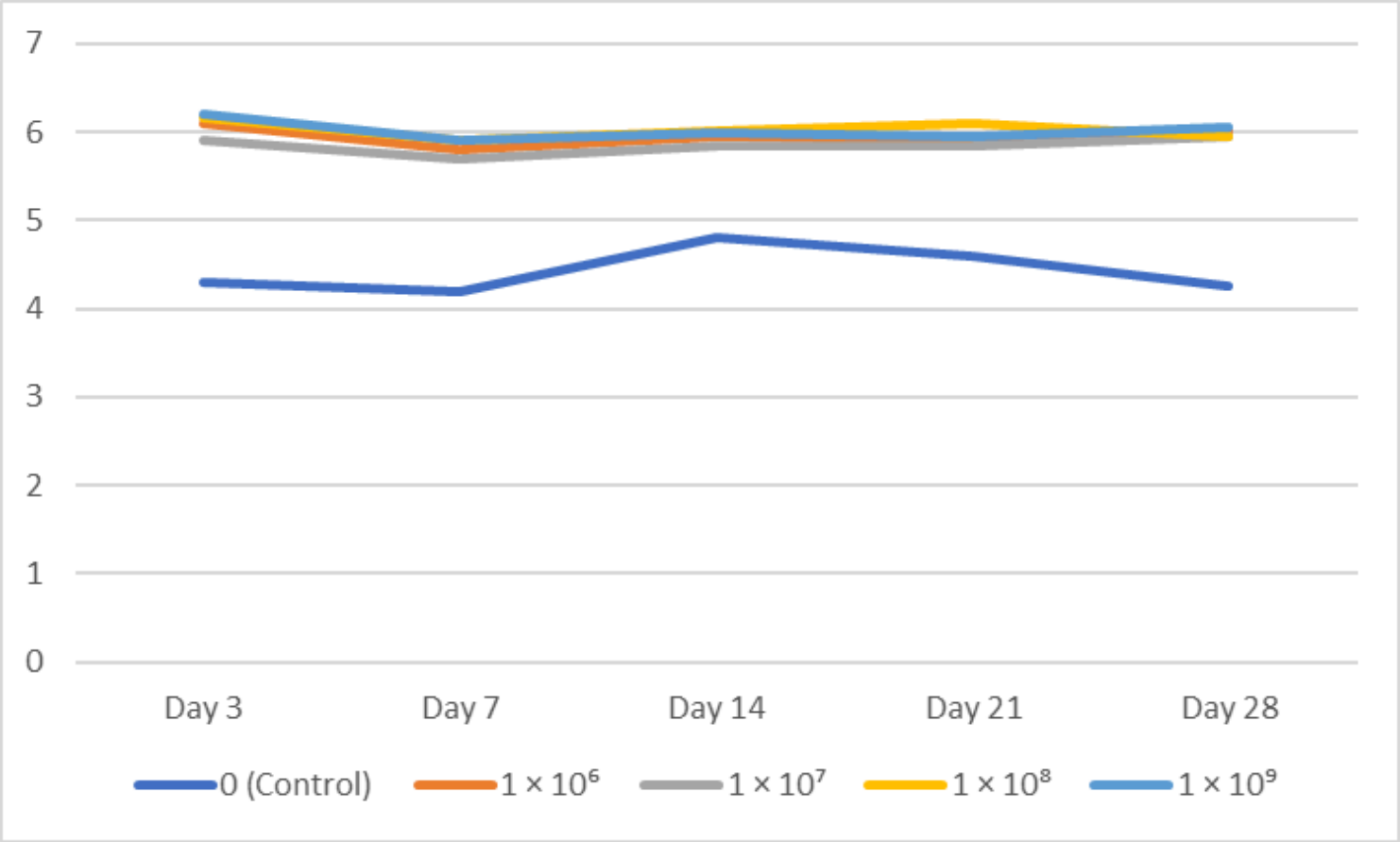


Figure 4

Graph of Average Rice Productivity Against the *Beauveria bassiana* Dose