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Test of the Effectiveness of Metarhizium Anisopliae Fungus on Immaculate Mortality of Coconut Plant Pest (Brontispa sp)

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ABSTRACT

One of the main pests that pose a serious threat to coconut plants is the coconut janur beetle (Brontispa sp.), especially Brontispa longissimi. This study aimed to evaluate the effectiveness of Metarhizium anisopliae against the mortality of coconut pest imago (Brontispa sp.); determine the most effective concentration of M. anisopliae suspension in causing imago mortality; estimate the lethal concentration 50% (LC50); and determine the lethal time 50% (LT50) of Brontispa sp. imago. A Completely Randomized Design (CRD) was applied with five treatments: P0 (control), P1 (5% M. anisopliae suspension), P2 (10%), P3 (15%), and P4 (20%). Each treatment was replicated four times, resulting in 20 experimental units. Data were analyzed using analysis of variance (ANOVA) with Minitab version 12.0. Duncan's multiple range test was conducted for post hoc analysis, while LC50 and LT50 values were determined using probit analysis. The results showed that M. anisopliae suspension was effective in increasing the mortality of Brontispa sp. imago. The most effective concentration was 15%. The LC50 value was observed at a concentration of 5%. The LT50 values indicated that 50% mortality occurred on day 12 at concentrations of 5% and 10%, while at concentrations of 15% and 20%, it occurred faster, on day 9.

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1. INTRODUCTION

Coconut plants (*Cocos nucifera* L.) is one of the plantation commodities that has high economic and social value (Arunachalam et al., 2025), especially in tropical countries like Indonesia (Vaulina et al., 2024). Coconut not only serves as a source of food, but also as an industrial raw material (copra, coconut oil, and their derivative products), thus making a significant contribution to people's income and the country's foreign exchange (Lata & Osborne-Naikatini, 2025). However, the productivity of coconut plants still faces various obstacles, especially due to plant pest organism (OPT) attacks, which can reduce yields quantitatively and qualitatively (Defitri, 2025).

One of the main pests that pose a serious threat to coconut plants is the coconut janur beetle (*Brontispa* sp.), especially *Brontispa longissimi* (Navasero et al., 2018). This pest attacks the part of the young leaves that are still rolling (janur), both in the larval stadia and imago (Pasaru et al., 2021). The feeding activity of this pest on the mesophilic tissue causes the formation of elongated brown patches that then fuse

together, so that the leaves appear burned, dry, and fail to open normally (Ramasamy & Ravishankar, 2018). The impact of a heavy attack can inhibit the process of photosynthesis, cause a decrease in production, and even lead to plant death (Viret & Gindro, 2025). With the characteristic of the attack hidden within the leaf folds, controlling these pests becomes relatively difficult conventionally (Egonyu et al., 2022).

Pest control *Brontispa* sp. So far, it generally still relies on synthetic chemical insecticides (Ahmad et al., 2026). Although effective in the short term, the continuous use of chemical insecticides can cause a variety of problems, including pest resistance, population resurgence, environmental pollution, and negative impacts on non-target organisms, including natural enemies (Ahmad et al., 2026). Therefore, a more environmentally friendly and sustainable control approach is needed, one of which is through the use of biological control agents (APH) (Chaudhary et al., 2024).

Entomopathogenic fungi *Metarhizium anisopliae* is one of the biological agents that has been widely researched and applied in the control of various types of insect pests (Jiang et al., 2020). The fungus works through direct infection of the insect's cuticle, then develops inside the host's body and causes death (Włóka et al., 2022). A number of studies show the potential *M. anisopliae* in controlling various important pests. Riaz et al. (2026) reports that *M. anisopliae* Effective in controlling uret in gogo rice plants. Further research shows that this fungus is also capable of causing high mortality in larvae *Lepidiota stigma* Third instar (Gindin et al., 2026). Prastowo et al. (2022) Reporting effectiveness *M. anisopliae* against larvae *Oryctes rhinoceros* in coconut plants, while Susanti et al. (2012) showed the success of this fungus in controlling green ladybug pests (*Nezara viridula*) on long beans (Bugeme et al., 2025). Although these studies show great potential *M. anisopliae* As a biological control agent, most research still focuses on larval stadia or on pest species other than *Brontispa* sp. In addition, studies that specifically examine the effectiveness of *M. anisopliae* Against Stadia Imago *Brontispa* sp. It is still very limited. In fact, stadia imago has an important role in the spread and reproduction of pests, so control of this stadia is crucial in suppressing the population as a whole.

On the other hand, quantitative information related to toxicological parameters, such as 50% lethal concentration (LC50) and 50% lethal time (LT50), especially in the imago *Brontispa* sp., has not been widely reported. In fact, these parameters are very important for determining the effective dosage and uptime efficiency of biological agents in field applications. The absence of this data causes the use of *M. anisopliae* in the integrated coconut pest control program is not optimal. Based on this description, there is a clear research gap, namely the lack of a comprehensive study on the effectiveness of *M. anisopliae* on imago mortality of *Brontispa* sp. and the lack of quantitative data on LC50 and LT50 in these pests. Therefore, this study has novelty in evaluating the effectiveness of various concentrations of *M. anisopliae* on imago mortality of *Brontispa* sp., as well as determining the optimum concentration and parameters of LC50 and LT50 experimentally. The results of this study are expected to make a scientific contribution to the development of more effective, measurable, and sustainable biological control strategies, as well as support the implementation of integrated pest control (PHT) on coconut plants.

2. METHODS

This study is an experimental study using a Complete Random Design (RAL). The research will be carried out in May 2026 at the Garden Management Unit of the Service and Biological Laboratory, Agriculture and Plantation Service of East Nusa Tenggara Province. The main ingredient used is *Metarhizium anisopliae mushroom isolate* obtained from the Biological Laboratory. The test insects in the form of *imago Brontispa* sp. were collected from Tarus Village, Central Kupang District, Kupang Regency, then kept and tested in the laboratory. The tools used include autoclaves, laminar air flow cabinets, petri dishes, analytical scales, measuring cups, measuring flasks, erlenmeyer, test tubes, micropipettes, Neubauer improved type haemocytometer, binocular microscopes, insect microscopes, pH meters, hygrometers, thermometers, magnetic stirrers, hand sprayers, as well as glass equipment and other laboratory supports.

The experiment was structured using RAL with five suspension concentration treatments *M. anisopliae*, namely (Riaz et al., 2026):

1. P0: control (no treatment)
2. P1: suspensi *M. anisopliae* 5%
3. P2: suspensi *M. anisopliae* 10%
4. P3: suspensi *M. anisopliae* 15%
5. P4: suspensi *M. anisopliae* 20%

Each treatment was repeated four times so that 20 units of experiments were obtained. Each experimental unit consisted of 10 imago *Brontispa* sp.

Whole The glass tool is sterilized using an autoclave at a temperature 121°C for 15 minutes at pressure 15 psi. The culture media is also sterilized using an autoclave under the same conditions. Tools The heat-resistant ones are sterilized using 70% alcohol or other suitable disinfection methods. The entire inoculation and culture handling process is carried out aseptically in a laminar air flow cabinet that has been sterilized with UV irradiation and sprayed with 70% alcohol before use. The equipment used during the inoculation process is sterilized directly using a flame (*flame sterilization*) to prevent contamination (Sharif et al., 2019).

Isolation *Metarhizium anisopliae* inoculated on sterile Potato Dextrose Agar (PDA) media under aseptic conditions. The inoculum is taken from stock cultures using sterile ose needles, then grown on the surface of PDA media in a petri dish. Cultures are incubated at temperature 25 ± 2 °C for 7 – 14 days until a colony is formed with optimal growth and produces mature conidia (characterized by a characteristic green color). During the incubation period, the culture is observed periodically to ensure no contamination occurs. Colonies that have grown optimally are then used as a spore source for the manufacture of suspensions at a later stage (Riaz et al., 2026).

The spore suspension *of Metarhizium anisopliae* is made by adding sterile aqueducts (containing 0.01% Tween 80 to aid dispersion) into the optimally grown fungal culture, then the colony surface is gently rubbed using sterile ose to release conidia. The suspension is then homogenized using a magnetic stirrer or vortex until an even suspension is obtained. The spore density was calculated using a Neubauer type improved haemocytometer under a microscope with a magnification of 400×. The number of spores is counted on multiple counting boxes, then averaged and converted to the number of conidia per mL using the standard haemocytometer formula:

$$\text{Spore density} = \frac{Nx10^4}{jumlah\ kotak}$$

with N is the number of spores counted.

The spore viability test was carried out by the germination method. A total of 0.1 mL of spore suspension was inoculated on PDA media, then incubated at 25 ± 2 °C for 18 – 24 hours. After incubation, the spores are observed under a microscope, and the germinated spores are counted. Spores are declared to germinate if the length of the germinated tube is at least equal to the diameter of the spore. The percentage of viability is calculated using the formula:

$$Viabilitas\ (\%) = \frac{jumlah\ spora\ berkecambah}{jumlah\ total\ spora} x\ 100$$

The spore suspensions used in the study were those that had a viability of ≥ 90% (Riaz et al., 2026).

Spore stock suspension *Metarhizium anisopliae* whose density has been calculated is then diluted in stages using sterile aqueducts containing 0.01% Tween 80 as a dispersing agent. Dilution is carried out to obtain some level of concentration according to the treatment. The suspension concentration was determined based on the number of conidia per mL (conidia/mL) calculated using a haemocytometer. Next, the suspension is adjusted until it reaches the desired concentration through serial dilution. If the concentration is expressed as a percentage (5%, 10%, 15%, and 20%), then the percentage refers to the volume ratio between the stock suspension and the solvent (v/v). For example, a concentration of 10%

is made by mixing 10 mL of stock suspension into 90 mL of sterile aqueducts, then homogenizing it evenly. Each solution that has been made is homogenized using a vortex or *magnetic stirrer* before use to ensure uniform distribution of spores (Oliva-Cruz et al., 2024).

Imago *Brontispa* sp. used as a test insect was first acclimatized in the laboratory for 24 hours before treatment. Each experimental unit consisted of 10 imago that were placed in a test container that had been fed fresh coconut leaves. The application of treatment is carried out by spraying *Metarhizium anisopliae suspension* according to the concentration of treatment using a hand sprayer until the entire body of the insect is evenly coated. The spray volume is made uniform on each test unit to ensure consistency of treatment. In the control group, the insects were only sprayed using sterile aqueducts containing 0.01% Tween 80. After application, the insects are kept in laboratory conditions with controlled temperature and humidity.

Observations were made daily during the study period to record the number of imago deaths in each treatment. Insects are declared dead when they do not show a response to mechanical stimuli. To ensure death due to fungal infections, follow-up observations were made of the appearance of mycelium on the insect's body. The parameters observed in this study include the percentage of imago daily mortality *Brontispa* sp., lethal concentration value 50% (LC50), and lethal time 50% (LT50). Percentage mortality was used to evaluate the effectiveness of each treatment, while LC50 and LT50 values were calculated using probite analysis to determine the level of toxicity and speed of action of the fungus *M. anisopliae* against test insects (Riaz et al., 2026).

The percentage of mortality is calculated using the equation:

$$Mortalitas\ (\%) = \frac{a}{b} x\ 100$$

with A = the number of dead imago and b = the number of initial imago.

Mortality data was analyzed using multiple fingerprint analysis (ANOVA) at a 95% confidence level using Minitab software version 12.0. If there is a significant difference, the analysis is followed by the Duncan test to find out the difference between treatments. LC50 and LT50 values were calculated using probite analysis. Lower LC50 and LT50 values indicate a higher level of toxicity or effectiveness of the biological agent tested (Bani, 2025).

3. FINDINGS AND DISCUSSION

3.1. Calculation of Spore Density and Viability

The results of the calculation using haemocytometer showed that Metarhizium anisopliae isolate had a spore density of 4.88×10^8 conidia mL^{-1}. These values indicate that the culture used has an adequate amount of conidia for application as a biological control agent.

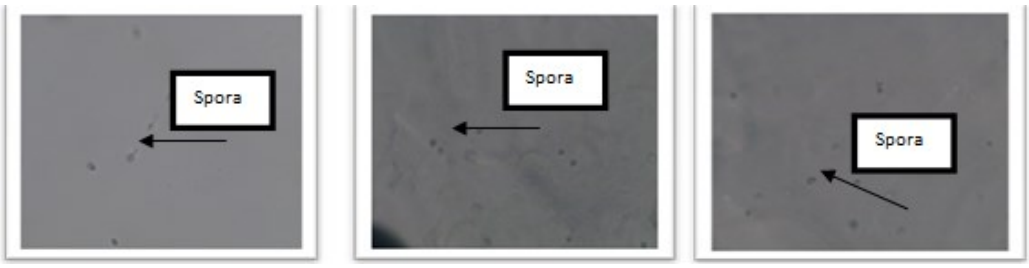


Figure 1. (a) Sample I viability 5 (b). Sample II viability 6 (c) sample III viability 6

The viability test showed an average germination value of conidia of 75.00%. Based on the spore viability category, the value is in the medium category so it is still suitable for use in testing the effectiveness of imago *Brontispa* sp (Riaz et al., 2026).

Variety-based analysis showed that treatment of M. anisopliae concentration had a significant effect on the mortality of imago Brontispa sp. ($P<0.05$). The highest mortality was obtained at concentrations of 20% (100%), followed by 15% (95%), 10% (75%), and 5% (67.5%), while controls showed no mortality.

Table 1. Average mortality of imago *Brontispa* sp over 14 days of observation

Treatment	Detestation				Total (Tail)	Average
(%)	1	2	3	4		Mortalites
0	0	0	0	0	0	0.000±0.000c
5	9	6	6	6	27	6.750±1.500b
10	9	8	5	8	30	7.500±1.732b
15	10	10	10	8	38	9.500±1.000a
20	10	10	10	10	40	10.000±0.000a

Note: the same superscript showed an unreal difference in the DMRT Test (P=0.05).

The Duncan test showed that the 15% and 20% treatments were in the same group and were significantly different than the 5% and 10% treatments. These findings suggest that increased concentrations tend to increase test insect mortality. Increased mortality at higher concentrations suggests that a greater number of conidia increases the chances of adhesion, germination, cuticle penetration, as well as colonization of insects' internal tissues. Although a 20% concentration results in a 100% mortality, statistically no different from a 15% concentration. Therefore, a concentration of 15% can be considered as an optimal concentration that is more efficient to apply.

Prophytic analysis showed an LC50 value of about 5% (CI 4 – 6%), which suggests that the relatively low concentration has been able to cause the death of 50% of the population.

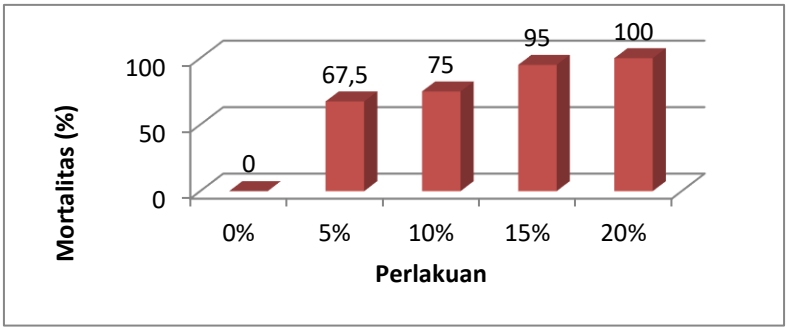


Figure 2. Mortality Percentage *of imago Brontispa* sp at each treatment

The LT50 value shows that the concentrations of 15% and 20% reach 50% mortality in about 9 days, while the concentrations of 5% and 10% take about 12 days. These results suggest that increased concentrations accelerate the process of infection and insect death. The research was conducted in laboratory conditions so that it has not fully described field conditions. The viability of the spores is only 75%, lower than the optimal standard (>90%). In addition, the study was only conducted on stadia imago and the concentration range tested was still limited to 5 – 20%. Metarhizium anisopliae has the potential to be an important component in Integrated Pest Control (PHT) in coconut plants. A concentration of 15% is recommended as an effective and efficient concentration. The findings also provide the scientific basis for the development of bioinsecticide formulations and field testing on stadia of other pests (Velavan et al., 2022).

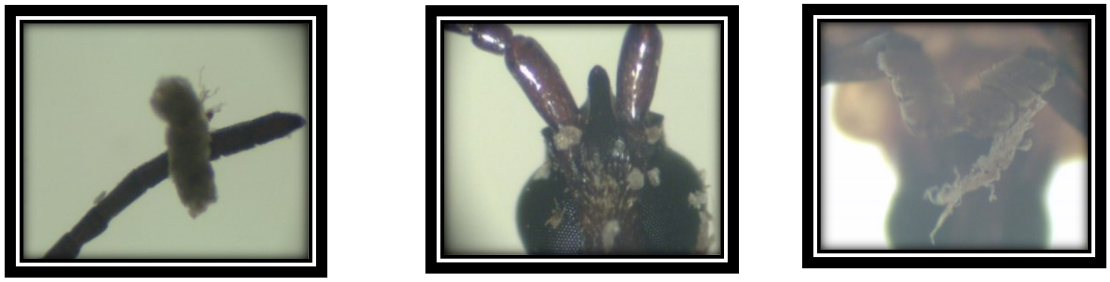
3.2. Morphology and Mechanism of Infection of Brontispa sp Insects After the Application Process of Metarhizium anisopliae Fungi

Based on the results of observations after application *Metarhizium anisopliae*, there is a change in behavior and morphology in the imago *Brontispa* sp. which indicates the presence of an entomopathogenic fungal infection. Behavioral changes are indicated by decreased movement activity and flying ability, reduced eating activities, and the tendency of the imago to stick to the wall or surface of the maintenance container. These symptoms became more pronounced as the infection progressed until the insect finally died.

Observed behavioral changes are in line with the phenomenon *summit disease*, which is the typical behavior of insects infected with entomopathogenic fungi to move to a higher position and attach their

bodies to a surface before dying. According to Evans et al. (2018), this behavior is one of the characteristics of entomopathogenic fungal infections and is thought to play a role in increasing the chances of spore spread to the surrounding environment. Thus, the behavioral changes that occur in the imago *Brontispa* sp. In this study, it corroborates the indication that insect deaths are caused by infection *M. anisopliae*.

Infected insects *Metarhizium anisopliae* shows the growth of hyphae on the cuticle surface of the body as an early sign of infection. The hyphae then penetrate the cuticle layer and enter the body cavity of the insect (*hemocoel*). Once inside *hemocoel*, fungi form a yeast cell-like structure known as blastospores (*yeast-like hyphal bodies*). This structure multiplies rapidly through the formation of shoots and spreads to various tissues of the insect's body (Evans et al., 2018).



(a). Caput (b). Antenna (c). Limbs

Figure 3. Morphology and Infection of *Metarhizium anisopliae* Fungi in the Body of Insects

During the infection process, blastospores utilize hemolymph and insect body tissues as a source of nutrients for fungal growth and development. As a result, the physiological functions of the insect are impaired, metabolic activity decreases, and eventually the insect dies. In the advanced stages, the insect's body becomes stiff and dries out so that it looks like a mummy. In addition, *M. anisopliae* It produces a variety of secondary metabolites and toxic compounds that accelerate host death as well as inhibit the growth of other microorganisms, especially bacteria, in the bodies of dead insects. Under favorable environmental conditions, the fungus will grow out through the cuticle and form a mycelium on the surface of the insect's body, while in conditions that are less favorable for saprophytic growth, the development of the fungus tends to be limited within the host's body (Bugeme et al., 2025).

3.3. Lethal Consent LC50 (Suspension Concentration of M. anisopliae Fungus Causing 50% Death of Imago *Brontispa* sp).

The results of probite analysis showed that the increase in the concentration *of Metarhizium anisopliae* suspension had an effect on the mortality rate of imago *Brontispa* sp. The LC50 value was obtained at a concentration of 5%, with a *lower confidence limit* of 4% and an *upper confidence limit* of 6%. The results showed that the 5% concentration was a concentration that was statistically capable of causing the death of 50% of the *imago population of Brontispa* sp. tested. The confidence range indicates that the effective concentration to achieve 50% mortality is estimated to be in the range of 4–6%.

The LC50 value is one of the parameters used to describe the level of effectiveness or virulence of a biological control agent against the target organism. The lower the LC50 value, the higher the effectiveness of the biological agent because the concentration needed to cause 50% of the population mortality is smaller (Saganuwan, 2020). The LC50 value of 5% obtained in this study shows that *M. anisopliae* has a fairly high potential in controlling imago *Brontispa* sp.

The high effectiveness of *M. anisopliae* is thought to be related to the ability of fungal conidia to attach to insect cuticles, germinate, and penetrate the cuticle layer through the activity of enzymes such as chitinase, protease, and lipase. After successfully entering hemocoel, the fungus develops and produces a variety of secondary metabolites, including destructive, which can disrupt the physiological function of the insect, cause tissue damage, decrease metabolic activity, and ultimately result in the

death of the host. Therefore, the lower the concentration needed to achieve 50% mortality, the higher the potential of *M. anisopliae* as a biological control agent against *Brontispa* sp.

3.4. Lethal Time LT50 (The Length of Time it takes for the fungus M. anisopliae to Cause Death 50% of Imago Brontispa sp).

Table 2. Lethal Time 50 (LT50) with treatment of various concentrations of *M. anisopliae* (Day)

Concentration ***Metarhizium anisopliae***	***Lethal time* 50 (Day)**
0%	42,49
5%	12,31
10%	12,14
15%	9,18
20%	9,13

Table 2 shows that the LT50 (*Lethal Time 50*) value differed at each concentration of *Metarhizium anisopliae* tested. The results of probit analysis showed that increased suspension concentrations *of M. anisopliae* tended to accelerate the time needed to cause the death of 50% of *the imago population of Brontispa* sp. The concentrations of 15% and 20% resulted in LT50 values of 9.18 and 9.13 days, respectively, while the concentrations of 5% and 10% took longer, namely 12.31 and 12.14 days.

The difference in LT50 values shows that higher concentrations of fungi are able to accelerate the process of infection and disease development in the test insects. The higher the concentration given, the greater the amount of conidia that come into contact with the surface of the insect's body, so that the chance of adhesion, germination, cuticle penetration, and colonization of host tissue is higher. As a result, the physiological disturbances caused by fungal infections occur faster and lead to the death of insects in a shorter time.

In contrast, at lower concentrations, the amount of conidia available to infect insects is relatively less, so the infection process takes place more slowly. In addition, the success of infection is also influenced by the morphological characteristics of the host, including the thickness of the cuticle which can be an initial barrier to the penetration of fungal hyphae. Therefore, the time it takes to achieve 50% mortality at 5% and 10% concentrations is longer than at 15% and 20% concentrations.

The results of this study are in line with the report Ferreira et al. (2024), which states that the amount of entomopathogenic fungal conidia is closely related to the concentration used. Higher conidia density increases the chances of infection as well as the number of enzymes and secondary metabolites produced during the colonization process, thus accelerating the death of the host insect. Thus, concentration *M. anisopliae* Higher ones not only increase mortality, but also speed up imago death time *Brontispa* sp.

4. CONCLUSION

This study showed that the entomopathogenic fungus *Metarhizium anisopliae* was effective in increasing imago mortality of *Brontispa* sp. at various concentrations tested. Increased concentrations of *M. anisopliae suspensions* tend to increase mortality rates and accelerate the death time of test insects. The concentration of 15% is the most effective and efficient concentration because it is able to cause mortality of 95% and is not significantly different from the concentration of 20% which results in 100% mortality. Prophytic analysis showed that LC50 values were obtained at a concentration of 5% with a confidence limit range of 4 – 6%, which suggests that *M. anisopliae* has a high virulence potential against *imago Brontispa* sp. In addition, LT50 values show that concentrations of 15% and 20% are capable of causing the death of 50% of the imago population in about 9 days, while concentrations of 5% and 10% take about 12 days. The results of this study indicate that *M. anisopliae* has the potential to be developed as a biological control agent in the Integrated Pest Control (PHT) program on coconut plants, especially to suppress the imago population *of Brontispa* sp. effectively and environmentally friendly.

REFERENCES

Ahmad, S., Liu, J., & Tian, L. (2026). Pesticide resistance in mulberry pests: mechanisms, monitoring, and strategies for sustainable management. *Crop Protection*, *208*, 107707. https://doi.org/https://doi.org/10.1016/j.cropro.2026.107707

Arunachalam, V., Paramesh, V., & Salgaonkar, D. C. (2025). Economics, energy budgeting and environmental impact assessment of coconut-based cropping system in the west coast of India. *Current Research in Environmental Sustainability*, *9*, 100289. https://doi.org/https://doi.org/10.1016/j.crsust.2025.100289

Bani, G. A. (2025). *Research Methods* (R. Pohan (ed.); 1st ed.). Innovation Publishing.

Bugeme, D. M., Knapp, M., Ekesi, S., Chabi-Olaye, A., Boga, H. I., & Maniania, N. K. (2025). Efficacy of Metarhizium anisopliae in controlling the two-spotted spider mite Tetranychus urticae on common bean in screenhouse and field experiments. *Insect Science*, *22*(1), 121–128. https://doi.org/10.1111/1744-7917.12111

Chaudhary, R., Nawaz, A., Khattak, Z., Butt, M. A., Fouillaud, M., Dufossé, L., Munir, M., Haq, I. ul, & Mukhtar, H. (2024). Microbial bio-control agents: A comprehensive analysis on sustainable pest management in agriculture. *Journal of Agriculture and Food Research*, *18*, 101421. https://doi.org/https://doi.org/10.1016/j.jafr.2024.101421

Defitri, Y. (2025). Coconut Plants (Cocos Nucifera L.) And Some Pests And Diseases That Attack Them. *International Journal of Multidisciplinary Sciences and Arts*, *4*, 73–82. https://doi.org/10.47709/ijmdsa.v4i3.6435

Egonyu, J. P., Baguma, J., Martínez, L. C., Priwiratama, H., Subramanian, S., Tanga, C. M., Anankware, J. P., Roos, N., & Niassy, S. (2022). Global Advances on Insect Pest Management Research in Oil Palm. In *Sustainability* (Vol. 14, Issue 23, p. 16288). https://doi.org/10.3390/su142316288

Evans, H. C., Elliot, S. L., & Barreto, R. W. (2018). Entomopathogenic fungi and their potential for the management of Aedes aegypti (Diptera: Culicidae) in the Americas. *Memorias Do Instituto Oswaldo Cruz*, *113*(3), 206–214. https://doi.org/10.1590/0074-02760170369

Ferreira, J. M., Fernandes, É. K. K., Kim, J. S., & Soares, F. E. F. (2024). The Combination of Enzymes and Conidia of Entomopathogenic Fungi against Aphis gossypii Nymphs and Spodoptera frugiperda Larvae. *Journal of Fungi (Basel, Switzerland)*, *10*(4). https://doi.org/10.3390/jof10040292

Gindin, G., Levski, S., Glazer, I., & Soroker, V. (2026). Evaluation of the entomopathogenic fungi Metarhizium anisopliae and Beauveria bassiana against the red palm weevil Rhynchophorus ferrugineus. *Phytoparasitica*, *34*, 370–379. https://doi.org/10.1007/BF02981024

Jiang, W., Peng, Y., Ye, J., Wen, Y., Liu, G., & Xie, J. (2020). Effects of the Entomopathogenic Fungus Metarhizium anisopliae on the Mortality and Immune Response of Locusta migratoria. In *Insects* (Vol. 11, Issue 1, p. 36). https://doi.org/10.3390/insects11010036

Lata, S. V., & Osborne-Naikatini, T. (2025). Analytical Review on Improving Coconut Production and Management Practices in Fiji. *International Journal of Agronomy*, *2025*(1), 3566049. https://doi.org/https://doi.org/10.1155/ioa/3566049

Navasero, M., MT, Z., & NT, S. (2018). The Coconut Leaf Beetle, Brontispa longissima (Gestro) (Chrysomellidae, Coleoptera), a serious threat to the Philippine coconut industry. In *Proceedings. 39th PMCP Anniversary and Annual Scientific Conference*.

Oliva-Cruz, M., Altamirano-Tantalean, M. A., Chuquizuta-Torres, R., Oliva-Cruz, C., Maicelo-Quintana, J. L., Leiva-Espinoza, S. T., Culqui, L., Mendez-Fasabi, L. D., Rojas Ventura, H. M., Corazon-Guivin, M. A., & Juarez-Contreras, L. (2024). Isolation and Characterization of Native Isolates of Metarhizium sp. as a Biocontrol Agent of Hypothenemus hampei in Rodríguez de Mendoza Province—Peru. In *Agronomy* (Vol. 14, Issue 7, p. 1341). https://doi.org/10.3390/agronomy14071341

Pasaru, F., Yunus, M., Toana, M., Edy, N., Anshary, A., & Saleh, S. (2021). Incidence of banana leaf roller and diversity of it is parasitoids in Central Sulawesi, Indonesia. *Biodiversitas Journal of Biological Diversity*, *22*. https://doi.org/10.13057/biodiv/d221138

Prastowo, S., Soeharto, Addy, H. S., & Handoyo, T. (2022). Virulence of Metarhizium isolated from infected Oryctes rhinoceros L. (Coleoptera: Scarabaeidae) larvae around coconut plantations in East Java, Indonesia. *Egyptian Journal of Biological Pest Control*, *32*(1), 146. https://doi.org/10.1186/s41938-022-00642-3

Ramasamy, S., & Ravishankar, M. (2018). *Chapter 15 - Integrated Pest Management Strategies for Tomato Under Protected Structures* (W. Wakil, G. E. Brust, & T. M. B. T.-S. M. of A. P. of T. Perring (eds.); pp. 313–322). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-802441-6.00015-2

Riaz, M., Kafle, L., Chang, T.-Y., & Chen, W.-H. (2026). Characterization and Virulence of Metarhizium anisopliae (Hypocreales: Clavicipitaceae) Isolates from Ecologically Distinct Soils Against Spodoptera litura (Lepidoptera: Noctuidae). *Journal of Insect Science (Online)*, *26*(1). https://doi.org/10.1093/jisesa/ieaf113

Saganuwan, S. A. (2020). Application of median lethal concentration (LC(50)) of pathogenic microorganisms and their antigens in vaccine development. *BMC Research Notes*, *13*(1), 289. https://doi.org/10.1186/s13104-020-05126-x

Sharif, S., Akram Hamasaeed, P., & Ismaeil, A. (2019). Sterilization of Culture Media for Microorganisms Using a Microwave Oven Instead of Autoclave. *Rafidain Journal of Science*, *28*. https://doi.org/10.33899/rjs.2019.159390

Vaulina, S., Titisari, P. W., Zahrah, S., Dewi, I. S., Riau, U. I., & Riau, U. I. (2024). Exploring the relationship between land characteristics and the sustainable growth of coconut cultivation in Indonesia Keywords This study explores land types as a basis for evaluating the sustainability of coconut plantations in Indonesia , focusing on p. *Asian Journal of Agriculture and Rural Development*, *14*(4), 147–166. https://doi.org/10.55493/5005.v14i4.5222

Velavan, V., Dhanapal, R., Ramkumar, G., Karthi, S., Senthil-Nathan, S., Ndomba, O. A., & Kweka, E. J. (2022). Characterization and Evaluation of Metarhizium spp. (Metsch.) Sorokin Isolates for Their Temperature Tolerance. *Journal of Fungi (Basel, Switzerland)*, *8*(1). https://doi.org/10.3390/jof8010068

Viret, O., & Gindro, K. (2025). *Fungal Diseases of Green Organs BT - Science of Fungi in Grapevine* (O. Viret & K. Gindro (eds.); pp. 197–312). Springer International Publishing. https://doi.org/10.1007/978-3-031-68663-4_4

Włóka, E., Boguś, M. I., Wrońska, A. K., Drozdowski, M., Kaczmarek, A., Sobich, J., & Gołębiowski, M. (2022). Insect cuticular compounds affect Conidiobolus coronatus (Entomopthorales) sporulation and the activity of enzymes involved in fungal infection. *Scientific Reports*, *12*(1), 13641. https://doi.org/10.1038/s41598-022-17960-z