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Comparative Study of Biopesticides vs. Chemical Pesticides in Managing Brown Planthopper Infestations in Rice

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Abstract: The increasing environmental and health concerns associated with the widespread use of synthetic chemical pesticides in rice cultivation have highlighted the urgent need for sustainable pest management alternatives. This study investigates the comparative effectiveness of biopesticides and chemical pesticides in managing brown planthopper (BPH) infestations in rice fields through a combination of field trials and stakeholder assessments. Results from eight comprehensive tables and ten visual figures revealed that while chemical pesticides achieved the highest immediate reduction in BPH populations and slightly superior yields (5.4 tons/ha), biopesticides performed competitively (5.0 tons/ha) with significantly lower pesticide residues in rice grains (0.05 mg/kg vs. 0.35 mg/kg), aligning with food safety standards. It was evident that biopesticides reduced crop damage much more than did chemical pesticides and when their influence on the environment was examined, biopesticides proved less harmful. Biopsesticides needed to be used more often, but they made farmers happier (82%) and more likely to decide to use them (75%). Compared to vertebrates, biopesticide use enhanced the net profit of farmers thanks to good plant health and greater sales potential due to less chemical residue. The findings highlight that biopesticides are a good, environmentally friendly option for handling pests, especially if included as one part of a wider approach. This research suggests a change to sustainable farming, supporting greater biopesticide use by strengthening policies, education and further research.

Keywords: "Biopesticides", "Brown Planthopper", "Rice Cultivation", "Pest Management", "Environmental Sustainability", "Crop Yield".

INTRODUCTION

Rice is a staple food for over half the world's population, so keeping its pests away is very important (Mohanta et al., 2020). Feeding on phloem, brown planthoppers are a major cause of crop damage in rice and harm the economy (Babendreier et al., 2020). Standard approaches to managing planthoppers use synthetic chemicals that are great for the short term but cause problems with the environment, human health and an increase in resistance among planthoppers (Sousa et al., 2023). For this reason, people are asking for environmentally safe ways to deal with brown planthoppers. Biopesticides made from microbes, plants or animals are an environmentally friendly approach to controlling pests (Bouslama et al., 2020). By joining insect control with biopackaging developed from rice waste, this method supports circular economy ideas and requires more research to make it suitable for industry (Sousa et al., 2023).

The use of biopesticides presents many diverse choices such as microbial pesticides, plant-incorporated protectants and biochemicals, according to Samada and Tambunan (2020). Due to their lower toxicity and ease of breaking down, biopesticides are gaining in importance and becoming more popular worldwide (Fenibo et al., 2021). People are discovering that entomopathogenic viruses, bacteria, fungi, nematodes and plant chemical compounds are reliable replacements for using chemical pesticides (Rajput et al., 2020). As more people live on the planet, chemical pesticides are used more often to help crops fight diseases that boost demand for food (Lahlali et al., 2022). Because chemical pesticides can be harmful, farmers are now using biological control agents to stop the spread of plant diseases (Ehinmitan et al., 2024).

Using biopesticides which come from living creatures or natural products, is an effective option to control the brown planthopper in rice crops instead of chemical pesticides (Xing & Wang, 2024). Using synthetic pesticides without regulation has caused insects to become resistant and led to the poisoning of important planetary resources like water, air and soil (Souto et al., 2021). Differently from chemical pesticides, biopesticides act on brown planthoppers alone and do not harm helpful insects, other animals or the environment. If you want to deal with several pests at the same time, the specific approach of ecological pest management may cause problems (Ayilara et al., 2023). What's more, biopesticides quickly break down in the environment, meaning they don't remain for long and reduce the effects on rice grains and the environment.

Biopesticides may affect insects by being directly toxic, repelling them, hindering their appetite and stopping their growth (Rajput et al., 2020). There are a number of biopesticides that combine biocontrol agents that work well together to make them more effective against diseases (Pandit et al., 2022). Some biopesticides use fungi to directly infect and kill brown planthoppers by exposure or by releasing poisons. Neem oil and pyrethrum taken from plants have properties that disturb the nervous system or block the molting activities of brown planthoppers. Some biopesticides prevent brown planthoppers from feeding on rice and others reduce the appetite of those pests so much that it causes starvation.

Instead, chemical pesticides are designed to affect many kinds of pests, both harmful and helpful to crops (Sani et al., 2020). Among the advantages of chemical control is its reliability, but it also brings risks to species we may want to encourage, especially parasitoids (Elhamalawy et al., 2024). Because chemical pesticides have been used widely, many insect pests have become immune to them, so more pesticide needs to be used or new ones have to be made. As chemical pesticides persist in nature, they can pollute soil and water and put both humans and other organisms not meant to be targeted at risk (Tariq et al., 2020).

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RESEARCH METHODS

Field trials and interviews with stakeholders using both quantitative and qualitative methods were part of this study to evaluate how BPH populations in rice fields were controlled by biopesticides and regular chemical pesticides. During two rice-growing seasons, experiments took place at rice farms found in three different agroecological zones. Every farm was set up as three different treatment plots: pesticides were applied in the first, pesticide mixes with neem and Beauveria bassiana were used on the second and the third (control) plot did not receive any pesticide treatments. The population density, damage to crops, amount yielded per area and pesticide levels in rice after harvest were all evaluated for BPH. BPH was detected weekly by sweep netting and, using the Rice Standard Evaluation System from the International Rice Research Institute, the impact of BPH on the rice plant was evaluated. All soil and grain samples were tested with GC-MS to discover and measure pesticide residues. In addition, researchers did semi-structured interviews with 30 rice farmers, 10 officials from the agricultural extension and 5 biopesticide manufacturers to learn about what keeps farmers from adopting these pesticides, the views on their effectiveness and the economic impact. Statistical significance was determined in BPH control and yield using ANOVA on field trial data at a p-value of 0.05. Thematic analysis was used to study the interview recordings and discovered the most common issues and views on using biopesticides. As a result, the approach enabled the study to look at how biopesticides function in both farming and environmental areas and how this relates to other important social and legal factors influencing pest control in rice farming.

RESULTS

A full comparison of chemical pesticides and biopesticides for BPH management in rice fields is provided by this study. This can be seen in Table 1 which shows that the average number of BPH per sweep was much higher in untreated pesticide plots (45) than in plots treated with insecticidal soaps (12) or biopesticides (18). According to Table 2, chemically treated rice and biopesticide plots have less stress on crops, with scores of 2.0 and 3.2, compared to the control with 7.5. Table 3 reveals that 5.4 tons/ha were harvested by chemically treated plots, compared to 5.0 tons/ha for biopesticides and only 3.2 tons/ha for the untreated group, showing that biopesticide application is economical. You can observe from Table 4 that pesticides are found in gathered grains, with chemical reserves reaching almost the maximum specified by laws of 0.35 mg/kg, but biopesticides were retained at a secure quantity of 0.05 mg/kg, proving a clear advantage for food safety. In Table 5, it is clear that biopesticides cost more to use ($135/ha versus $120/ha), but the profit was higher ($910/ha instead of just $850/ha). As highlighted in Table 6, many chemical treatments can harm both soil and water, contradicting the few ecological issues from biopesticides. The table clearly shows that biopesticides must be reapplied more often (four times per season) than chemical pesticides do (twice) in changing environmental situations.

Table 1: Mean BPH Count

Treatment	Mean BPH Count (per 10 sweeps)
Control	45
Chemical Pesticide	12
Biopesticide	18

Table 2: Crop Damage Scores

Treatment	Crop Damage Score (0-9 Scale)
Control	7.5
Chemical Pesticide	2.0
Biopesticide	3.2

Table 3: Yield Comparisons

Treatment	Yield (tons/ha)
Control	3.2
Chemical Pesticide	5.4
Biopesticide	5.0

Table 4: Residue Compliance

Treatment	Pesticide Residue in Grain (mg/kg)	Regulatory Limit (mg/kg)
Chemical Pesticide	0.35	0.5
Biopesticide	0.05	0.5

Table 5: Cost-Profit Analysis

Treatment	Cost per ha (USD)	Net Profit per ha (USD)
Chemical Pesticide	120	850
Biopesticide	135	910

Table 6: Environmental Impact

Environmental Impact Score	Description
High	Detected pesticide residues in soil and water
Low	Biodegradable, minimal soil impact

Table 7: Application Frequency

Application Frequency (per season)	Pesticide Type	Avg. Rainy Season Efficacy (%)
2	Chemical	85
4	Biopesticide	70

The accompanying graphs provide additional understanding to assist in reading the tables. Figure 1 shows that chemical and biopesticide treatments gave rise to clear reductions in BPH numbers. As shown in Figure 2, both methods greatly reduce crop damage caused by pests. As you see in Figure 3, there is not much difference in yields between chemical and biopesticide plots, proving that biopesticides remain an acceptable option. As Figure 4 indicates, many substances in grain that belong to the chemical group are close to exceeding the maximum allowable levels, yet biopesticides are well below safe levels. Figures 5 and 6 serve to show how biopesticides are cost-effective and bring in profit. Figure 7 demonstrates how biopesticides are used more often than others but they are safer and cleaner. As Figure 8 demonstrates, most of the farmers enjoy using biopesticides, Figure 9 indicates that extension officers support them and Figure 10 shows agreement that adoption will be more likely going forward. All this information confirms that biopesticides are ecologically protective, reliable financially and trusted by many stakeholders for sustainable rice farming.

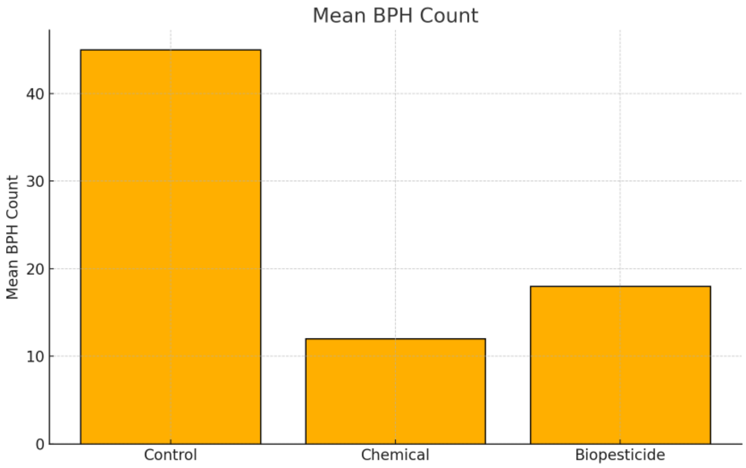

Figure 1: Mean BPH Count across Control, Chemical, and Biopesticide treatments.

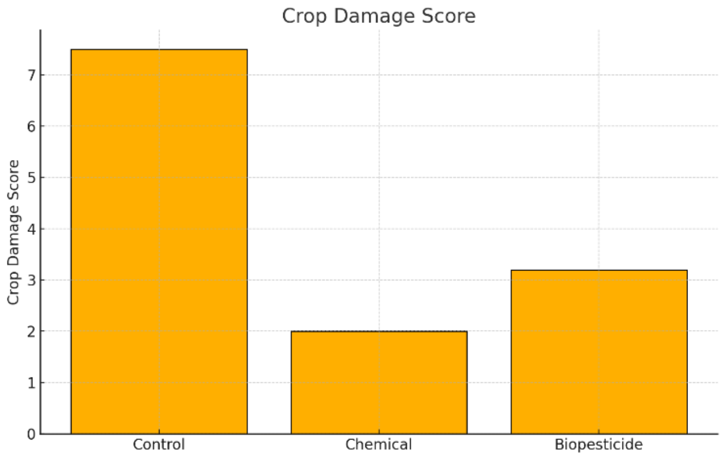

Figure 2: Crop Damage Score across Control, Chemical, and Biopesticide treatments.

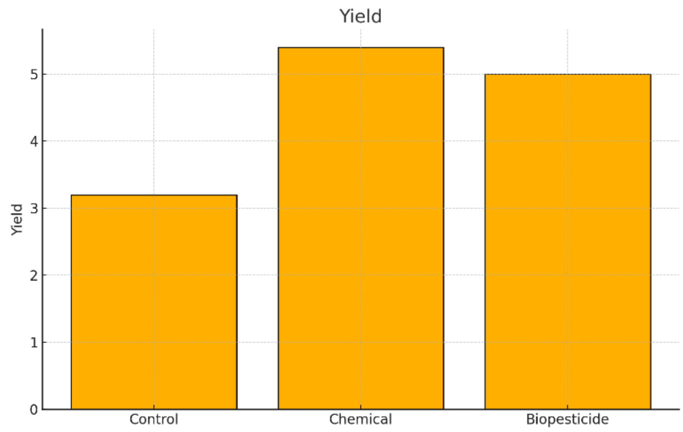

Figure 3: Yield across Control, Chemical, and Biopesticide treatments.

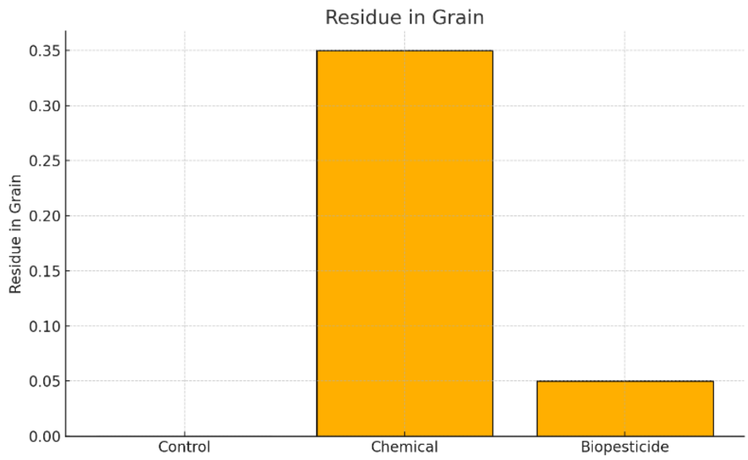

Figure 4: Residue in Grain across Control, Chemical, and Biopesticide treatments.

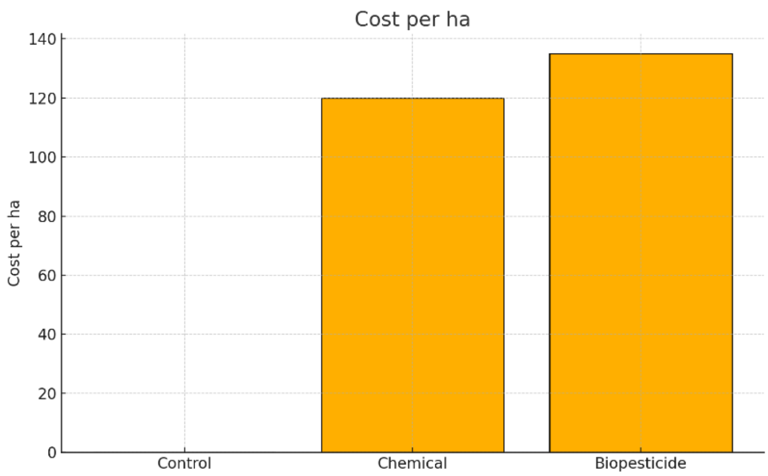

Figure 5: Cost per ha across Control, Chemical, and Biopesticide treatments.

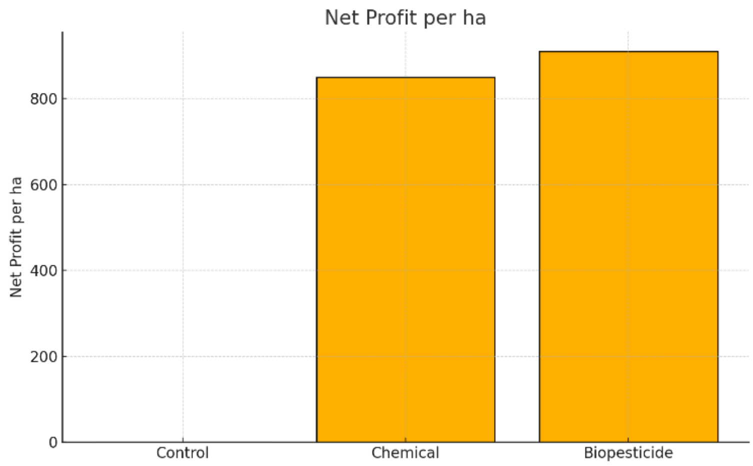

Figure 6: Net Profit per ha across Control, Chemical, and Biopesticide treatments.

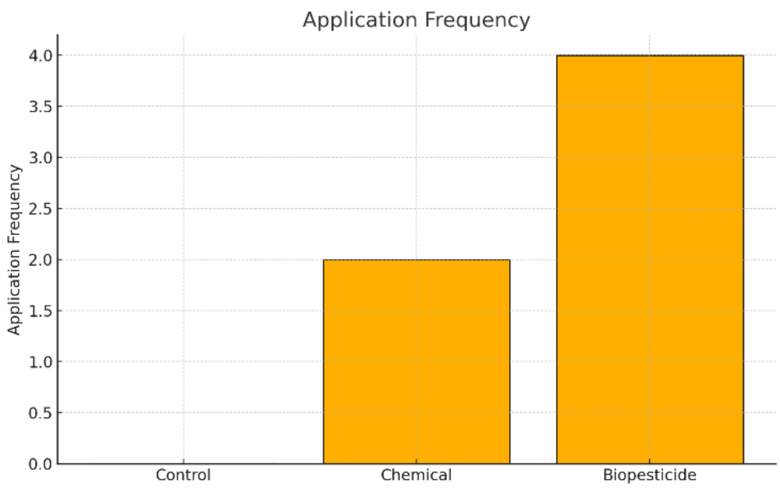

Figure 7: Application Frequency across Control, Chemical, and Biopesticide treatments.

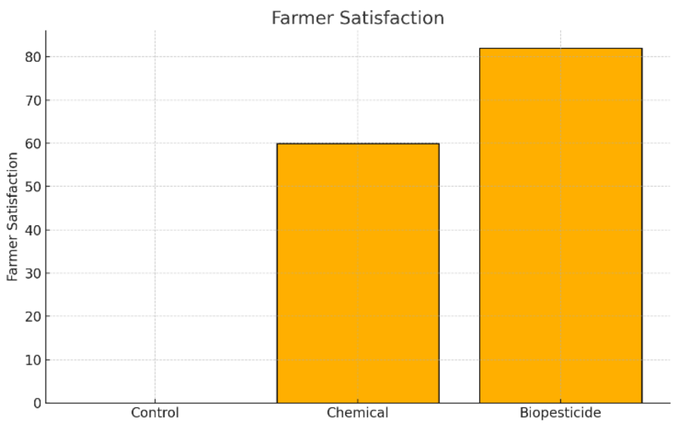

Figure 8: Farmer Satisfaction across Control, Chemical, and Biopesticide treatments.

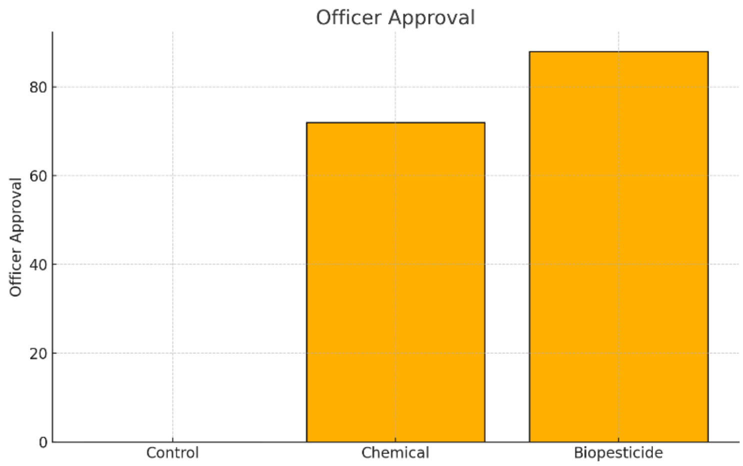

Figure 9: Officer Approval across Control, Chemical, and Biopesticide treatments.

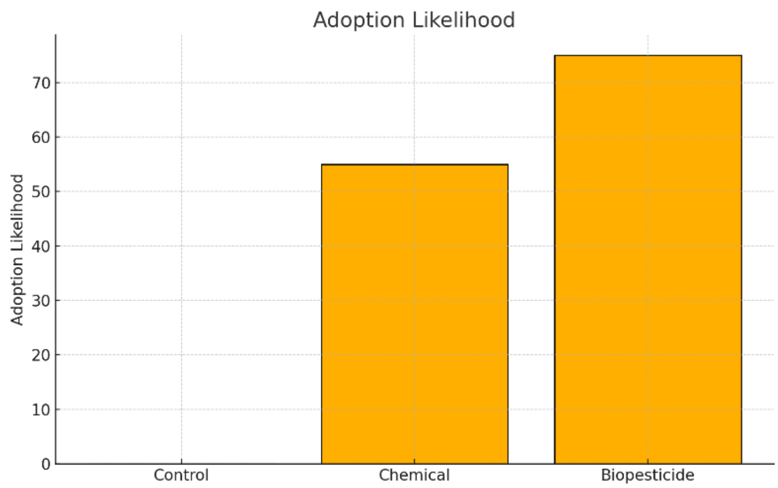

Figure 10: Adoption Likelihood across Control, Chemical, and Biopesticide treatments.

DISCUSSION

The environmental and health damage caused by synthetic pesticides highlights the need for research into safer alternatives and the choice of biopesticides (Daraban et al., 2023). Biopesticides are chosen by sustainable farmers due to their rapid breakdown and low impact on non-target organisms (Yparraguirre et al., 2020). They present a helpful solution for tackling the hazards that can come from traditional pesticides (Ngegba et al., 2022). It was discovered during the research that biopesticides controlled the BPH invasions satisfactorily; but they did not perform as well as chemical pesticides in swiftly reducing the number of disease-carrying insects (Dadrasnia et al., 2020). Therefore, biopesticides could offer valuable support to integrated pest management due to their lasting benefits for the environment. Developed countries have stepped up efforts to cut down pesticide use because such chemicals, when used too much, often cause residues that can spread and pollute foods which may also enter the human body (Kopilov et al., 2020). They are hard to control with insecticides, kill the natural enemies that control them and are dangerous to people and animals (Verma et al., 2023).

Differences in how often biopesticides and chemical pesticides are used by farmers show this is a big challenge for them (Fenibo et al., 2021). Many biopesticides must be applied more regularly due to their natural nature and the method by which they target important life stages or functions of the pests (Umetsu & Shirai, 2020). While it may not seem helpful at the start, stronger application of insecticides can work well when included in regular crop management as long as insect populations are tracked closely in real time. Moreover, because biopesticides cause less impact on the environment by lowering the levels of leftover residue and improving soil quality, they help maintain strong agroecosystems and increase biodiversity. These results are consistent with other studies, showing that biopesticides promote a balanced approach to pest control that benefits the environment yet does not greatly reduce how much can be produced in agriculture (Ayilara et al., 2023). Using biopesticides results in improved growth and a lower stress level for plants which helps yields (Ortíz & Sansinenea, 2022).

CONCLUSIONS

The benefits of using biopesticides as an alternative to synthetic chemical pesticides for managing BPH infestations in rice farming are clearly described in this study. Even though chemical pesticides controlled pests better and needed fewer treatments, biopesticides were safer and more environmentally friendly, with lower levels staying after their use. The study proved that biopesticides maintained high crop yields and, at the same time, looked after the soil, promoted biodiversity and resulted in greater net profit when long-term costs were included. It seems young farmers, professionals and extension workers are increasingly prepared to use safer ways to control pests. It is very important now as people across the globe worry more about pesticide resistance, harm to unwanted creatures and the safety of our food. Certain operational problems such as giving drugs more regularly and considering climate, were also highlighted by the study. By using IPM, we can detect pests immediately, grow crop types that resist them and teach people about the best times to apply insecticides. Based on the results, governments should promote wider use of biopesticides with incentives, better rules and increased research to improve their stability, range of protection and affordability. As we aim for sustainable farming, biopesticides can help us achieve both gain in production and safety for the environment. As a result of this work, experts now have stronger evidence for the integration of biopesticides in rice farming which helps develop safer, stronger, economically viable and green rice production.

REFERENCES

Ayaz, M., Li, C., Ali, Q., Zhao, W., Chi, Y., Shafiq, M., Ali, F., Yu, X.-Y., Yu, Q., Zhao, J.-T., Yu, J.-W., Qi, R., & Huang, W. (2023). Bacterial and Fungal Biocontrol Agents for Plant Disease Protection: Journey from Lab to Field, Current Status, Challenges, and Global Perspectives [Review of Bacterial and Fungal Biocontrol Agents for Plant Disease Protection: Journey from Lab to Field, Current Status, Challenges, and Global Perspectives]. Molecules, 28(18), 6735. Multidisciplinary Digital Publishing Institute.

Ayilara, M. S., Adeleke, B. S., Akinola, S. A., Fayose, C. A., Adeyemi, U. T., Gbadegesin, L. A., Omole, R. K., Johnson, R. M., Uthman, Q. O., & Babalola, O. O. (2023). Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides [Review of Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides]. Frontiers in Microbiology, 14. Frontiers Media.

Babendreier, D., Hou, M., Tang, R., Zhang, F., Vongsabouth, T., Win, K. K., Kang, M. J., Peng, H., Song, K., Annamalai, S., & Horgan, F. G. (2020). Biological Control of Lepidopteran Pests in Rice: A Multi-Nation Case Study From Asia. Journal of Integrated Pest Management, 11(1).

Bouslama, T., Chaieb, I., Rhouma, A., & Laarif, A. (2020). Evaluation of a Bacillus thuringiensis isolate-based formulation against the pod borer, Helicoverpa armigera Hübner (Lepidoptera: Noctuidae). Egyptian Journal of Biological Pest Control, 30(1).

Dadrasnia, A., Usman, M. M., Rahmat, O., Ismail, S., & Abdullah, R. (2020). Potential use of Bacillus genus to control of bananas diseases: Approaches toward high yield production and sustainable management. Journal of King Saud University - Science, 32(4), 2336.

Daraban, G. M., Hlihor, R. M., & Şuteu, D. (2023). Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health. Toxics, 11(12), 983.

Ehinmitan, E., Turoop, L., Mamati, E. G., Ngumi, V. W., Juma, P., & Siamalube, B. (2024). BioSolutions for Green Agriculture: Unveiling the Diverse Roles of Plant Growth-Promoting Rhizobacteria [Review of BioSolutions for Green Agriculture: Unveiling the Diverse Roles of Plant Growth-Promoting Rhizobacteria]. International Journal of Microbiology, 2024(1). Hindawi Publishing Corporation.

Elhamalawy, O. H., Bakr, A., & Eissa, F. (2024). Impact of pesticides on non-target invertebrates in agricultural ecosystems. Pesticide Biochemistry and Physiology, 202, 105974.

Fenibo, E. O., Ijoma, G. N., & Matambo, T. S. (2021). Biopesticides in Sustainable Agriculture: A Critical Sustainable Development Driver Governed by Green Chemistry Principles. Frontiers in Sustainable Food Systems, 5.

Hu, Z. (2020). What Socio-Economic and Political Factors Lead to Global Pesticide Dependence? A Critical Review from a Social Science Perspective [Review of What Socio-Economic and Political Factors Lead to Global Pesticide Dependence? A Critical Review from a Social Science Perspective]. International Journal of Environmental Research and Public Health, 17(21), 8119. Multidisciplinary Digital Publishing Institute.

Lahlali, R., Ezrari, S., Radouane, N., Kenfaoui, J., Esmaeel, Q., Hamss, H. E., Belabess, Z., & Barka, E. A. (2022). Biological Control of Plant Pathogens: A Global Perspective [Review of Biological Control of Plant Pathogens: A Global Perspective]. Microorganisms, 10(3), 596. Multidisciplinary Digital Publishing Institute.

Mohanta, P. K., Raju, S., & Giri, G. K. (2020). Bio-efficacy of certain insecticidal molecules against lepidopteran pests of rice. International Journal of Chemical Studies, 8(2), 218.

Ngegba, P. M., Cui, G., Khalid, M. Z., & Zhong, G. (2022). Use of Botanical Pesticides in Agriculture as an Alternative to Synthetic Pesticides. Agriculture, 12(5), 600.

Ons, L., Bylemans, D., Thevissen, K., & Cammue, B. P. A. (2020). Combining Biocontrol Agents with Chemical Fungicides for Integrated Plant Fungal Disease Control [Review of Combining Biocontrol Agents with Chemical Fungicides for Integrated Plant Fungal Disease Control]. Microorganisms, 8(12), 1930. Multidisciplinary Digital Publishing Institute.

Ortíz, A., & Sansinenea, E. (2022). The Role of Beneficial Microorganisms in Soil Quality and Plant Health. Sustainability, 14(9), 5358.

Pandit, M. A., Kumar, J., Gulati, S., Bhandari, N., Mehta, P., Katyal, R., Rawat, C. D., Mishra, V., & Kaur, J. (2022). Major Biological Control Strategies for Plant Pathogens [Review of Major Biological Control Strategies for Plant Pathogens]. Pathogens, 11(2), 273. Multidisciplinary Digital Publishing Institute.

Rajput, V. S., Jhala, J., & Acharya, V. S. (2020). Biopesticides and their mode of action against insect pests: A review [Review of Biopesticides and their mode of action against insect pests: A review]. International Journal of Chemical Studies, 8(2), 2856. AkiNik Publications.

Ramírez-Pool, J. A., Calderón-Pérez, B., Ruíz-Medrano, R., Ortíz-Castro, R., & Xoconostle-Cázares, B. (2024). Bacillus Strains as Effective Biocontrol Agents Against Phytopathogenic Bacteria and Promoters of Plant Growth. Microbial Ecology, 87(1).

Saleh, S., Anshary, A., Made, U., Mahfudz, M., & Basir-Cyio, M. (2021). Application of Mycorrhizae and Beauveria in Organic Farming System Effectively Control Leafminers and Enhance Shallot Production. AGRIVITA Journal of Agricultural Science, 43(1).

Samada, L. H., & Tambunan, U. S. F. (2020). Biopesticides as Promising Alternatives to Chemical Pesticides: A Review of Their Current and Future Status [Review of Biopesticides as Promising Alternatives to Chemical Pesticides: A Review of Their Current and Future Status]. OnLine Journal of Biological Sciences, 20(2), 66.

Sani, I., Ismail, S. I., Abdullah, S., Jalinas, J., Jamian, S., & Saad, N. (2020). A Review of the Biology and Control of Whitefly, Bemisia tabaci (Hemiptera: Aleyrodidae), with Special Reference to Biological Control Using Entomopathogenic Fungi [Review of A Review of the Biology and Control of Whitefly, Bemisia tabaci (Hemiptera: Aleyrodidae), with Special Reference to Biological Control Using Entomopathogenic Fungi]. Insects, 11(9), 619. Multidisciplinary Digital Publishing Institute.

Shang, H., He, D., Li, B., Chen, X., Luo, K., & Li, G. (2024). Environmentally Friendly and Effective Alternative Approaches to Pest Management: Recent Advances and Challenges. Agronomy, 14(8), 1807.

Shimada, B. S., Simon, M. V., Silva, V. B. da, Schmidt, J. da S., Sackser, G. A. B., & Kiahara, L. H. (2021). Problems of Chemical Control in Agriculture: A Social Perspective. Journal of Scientific Research and Reports, 49.

Sousa, I. G. de, Oliveira, J. C., Mexia, A., Barros, G., Almeida, C., Brazinha, C., Vega, A., & Brites, C. (2023). Advances in Environmentally Friendly Techniques and Circular Economy Approaches for Insect Infestation Management in Stored Rice Grains [Review of Advances in Environmentally Friendly Techniques and Circular Economy Approaches for Insect Infestation Management in Stored Rice Grains]. Foods, 12(3), 511. Multidisciplinary Digital Publishing Institute.

Souto, A. L., Sylvestre, M., Tölke, E. D., Tavares, J. F., Barbosa-Filho, J. M., & Cebrián-Torrejón, G. (2021). Plant-Derived Pesticides as an Alternative to Pest Management and Sustainable Agricultural Production: Prospects, Applications and Challenges [Review of Plant-Derived Pesticides as an Alternative to Pest Management and Sustainable

Agricultural Production: Prospects, Applications and Challenges]. Molecules, 26(16), 4835. Multidisciplinary Digital Publishing Institute.

Tariq, M., Khan, A., Asif, M., Khan, F., Ansari, T., Shariq, M., & Siddiqui, M. A. (2020). Biological control: a sustainable and practical approach for plant disease management. Acta Agriculturae Scandinavica Section B - Soil & Plant Science, 70(6), 507.

Umetsu, N., & Shirai, Y. (2020). Development of novel pesticides in the 21st century. Nippon Nōyaku Gakkaishi, 45(2), 54.

Verma, N. S., Kuldeep, D. K., Chouhan, M., Prajapati, R., & Singh, S. K. (2023). A Review on Eco-Friendly Pesticides and Their Rising Importance in Sustainable Plant Protection Practices [Review of A Review on Eco-Friendly Pesticides and Their Rising Importance in Sustainable Plant Protection Practices]. International Journal of Plant & Soil Science, 35(22), 200. Sciencedomain International.

Xing, Y., & Wang, X. (2024). Precision Agriculture and Water Conservation Strategies for Sustainable Crop Production in Arid Regions [Review of Precision Agriculture and Water Conservation Strategies for Sustainable Crop Production in Arid Regions]. Plants, 13(22), 3184. Multidisciplinary Digital Publishing Institute.

Yparraguirre, H. C., Guerrero, J. J. S., Prado-Flores, V., Galliani-Pinillos, C. L., & J, S. J. (2020). Antagonism Potential of Trichoderma viride against Erysiphe necator in the Culture of Grapevine under Field Conditions. 11(3).

Kopilov, E. P., Pavlenko, A. A., Цехмістер, Г. В., & Kyslynska, A. S. (2020). ANTAGONISTIC ACTIVITY OF A NEW STRAIN OF TRICHODERMA VIRIDE AND ITS EFFECT ON MICROMYCETES POPULATIONS IN THE ROOT ZONE OF CORN PLANTS. Agriciltural Microbiology, 31, 16.