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A review of the latest research on Ganoderma boninense

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Abstract

As oil palm trees are an important economic source in many countries, particularly in Southeast Asia and Africa, the study of Ganoderma boninense is crucial for the sustainability of the oil palm industry. This study aims to understand the biology and ecology of the fungus, its pathogenesis, and the impact it has on oil palm trees. This knowledge can be used to develop management strategies to mitigate the damage caused by the fungus, such as the use of resistant varieties, chemical and biological control methods, and cultural practices. This study is to ensure the long-term productivity and sustainability of the oil palm industry. The main method of recent academic studies on this pathogen is molecular biology, with a focus on genetic analysis and functional genomics. Researchers have used techniques such as PCR, DNA sequencing, and transcriptomics to identify genes and pathways involved in pathogenesis and better understand the fungus's interactions with its host plant. Other methods used in recent studies include biochemical analysis, microscopy, and phytohormonal assays to investigate the biochemistry and physiology of the interaction between G. boninense and oil palm. This study is intended to provide implications from a new perspective by organizing and integrating studies on Ganoderma boninense.

Keywords: Ganoderma boninense, Oil palm, Sustainability, Molecular biology, Biochemical analysis

Major Classification Code: Agricultural Policy, Agricultural Technology

1. Introduction

Ganoderma boninense is a fungal pathogen that can cause a disease called "stem butt rot" in oil palm trees. It has been a major issue for the palm oil industry as it can significantly reduce the yield and quality of crops. The current main issue with this pathogen is its widespread distribution in many palm oil-producing countries and its ability to adapt to new environments and resist control efforts. Control of the disease is difficult because the fungus infects the tree at the base of the trunk and can remain hidden for a long time before symptoms become visible. This makes early detection and treatment challenging. Additionally, the increasing global demand for palm oil has put pressure on producers to maximize yields, which can lead to practices that promote the spread of the disease, such as the replanting of infected trees and the movement of infected materials between plantations. Efforts to control the spread of Ganoderma boninense include the development of resistant varieties of oil palm,

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the implementation of good agricultural practices, and the use of fungicides. However, these efforts have been met with limited success, and the disease continues to pose a major threat to the sustainability of the palm oil industry.

There is a fungus known as Ganoderma boninense in Southeast Asia, which is likely responsible for one of the most devastating diseases in palm oil plantations, called BSR (basal stem rot), which is estimated to cost up to $500 million per year in the region. Ganoderma boninense infects both mature trees and seedlings. Current detection methods still rely on manual inspections by human experts every two weeks (Noor Azmi et al., 2020). Ganoderma boninense infection reduces the overall productivity of the oil palm industry and leads to a decisive crisis. This serious disease destroys the basal tissue of the oil palm and eventually kills the palm. Until now, there is no clear treatment that can prevent the spread of Ganoderma boninense in advance, so prior detection before the infection is key (Mohd Hilmi Tan et al., 2021). This study was started with the purpose of arranging and compiling the studies so far by scholars on Ganoderma boninense, which induces the basal stem rot of palm oil trees.

2. Recent Research Trends

Palm oil is an important commodity in countries such as Malaysia and Indonesia. Palm oil makes many products, including biodiesel, cosmetics, and food. Palm oil contributes significantly to the export, import, and economy of Indonesia and Malaysia. However, the production of palm oil is greatly affected by climate change, pests, and diseases. Ganoderma boninense is recognized as a nuisance that has a profound impact on the palm oil industry, a profitable industry in Southeast Asia, such as Malaysia and Indonesia, and other producing countries (Abubakar, 2022).

Sundram et al. (2015) evaluated the application of two types of arbuscular mycorrhizal fungi (AMF) and two types of endophytic bacteria (EB) as biocontrol agents in a nursery and then conducted repeated experiments in the field using bait seedlings. Significantly reduced disease incidence as measured by disease prevalence in trees inoculated with Glomus intraradices UT126, Glomus clarum BR152B and Pseudomonas aeruginosa UPMP3.

Hanin et al. (2020) observed plants with the G. boninense fungus and found that certain plants were resistant to the fungus. The study showed that fungus-resistant oil palm can be produced biolistically using alfalfa β-1,3-glucanase (AGLU1) and rice chitinase (RCH10) genes. Alexander & Phin (2014) investigated three products containing a combination of biocontrol agents to inhibit the growth of Ganoderma boninense in their study. Evaluations were conducted in nurseries and field trials to understand therapies that inhibit basal stem rot (BSR) disease development. The results of both tests showed that the experimental group was able to reduce the colonization of Ganoderma boninense based on the reduction of ergosterol content and disease incidence (DI) compared to the control group. Surendran et al. (2021) researched to make a decision on whether chosen phenolic compounds would manage the wood planks of oil palm inoculated with G. boninense, and limit wood biodegradation. Their study showed in wood mass loss, a crucial decrease when it was treated with all phenolic compounds. Silicic acid and vanillic acid worked ambivalently. The wood mass loss increased at lower concentrations but decreased with increasing concentrations. Suppression of mass loss in all four phenolic compounds depends on the concentration of the compound. The study highlights the physicochemical and anatomical changes that occur in oil palm trees during Ganoderma boninense colonization. It suggested that the treatment of oil palm stumps with benzoic acid might be a solution to reduce Ganoderma boninense inoculum pressure during transplantation in a sustainable manner.

Until 2050, rates of basal stem rot will not be significantly affected by climate change, after which things get bad. Java and Sumatra will be severely affected, and crops will not be sustainable. After 2050, palm oil production in Indonesia may become difficult due to farm losses (Paterson, 2020). Noor Azmi et al. (2020) in their study aimed to detect early Ganoderma boninense infection using visible-near-infrared (VIS-NIR) hyperspectral imaging in the absence of BSR symptoms. Samples of 28 oil palm seedlings aged 5 months were used, 15 of which were inoculated with the Ganoderma boninense pathogen. Diseases of oil palm trees affect other parts of the plant such as roots, stems, leaves, and flowers in turn and FFF (Fresh Fruit Bunch). Palm oil disease can be caused by fungi, bacteria, viruses, plant plasma, nematodes, and parasitic plants. Damage from pests and diseases affects the growth of seedlings. Therefore, to ensure the healthy growth of oil palm trees at all stages and to maximize crop yields by achieving high oil production per hectare, effective and efficient pest, and Disease control and management are required (Chung, 2012).

Climate change in the future will significantly reduce the growth and cultivation of the oil palm. In addition, basal stem rot (BSR) will increase further due to climate change, which will threaten the sustainability of the oil palm due to Ganoderma boninense. BSR will become more serious after 2050, when oil palm sustainability is predicted to be difficult due to climate change. This might have palm oil production unfeasible after 2050 on the Indonesian island of Sumatra. It is necessary to prepare in advance for

the increase in BSR due to the predictable impact of climate change (Paterson, 2019). Zainol Hilmi et al. (2019) used a clustered heatmap to classify volatile organic compound (VOC) profiles in their study. Using it, chemometric analysis and principal component analysis were used. And this new method could be used to detect Ganoderma disease. And it was verified that it can be used for chemical ecological studies of plant-pathogen interactions. In a greenhouse, Shokrollahi et al. (2021) examined the gene expression of non-ribosomal peptides (NRPs) and disease severity in the roots of 6-month-old oil palm seedlings. The correlation between high disease severity (50%) and high expression (67-fold) of the boninense NRPS gene indicated that this gene plays an important role in the progression of basal stem rot.

The genetic structure of NRPS in Ganoderma boninense and its relevance to the pathogenesis of basal stem rot as an effector gene were identified. Davalet al. (2021) investigated the effectiveness of an in silico genetic mapping approach in which ancestry-based QTL mapping approaches revealed traits of Ganoderma resistance. This was the result of an experiment with data collected over 10 years. Isha et al. (2020) performed multivariate data analysis on differences in chemical compounds between Ganoderma boninense-infected and non-infected roots. More steroid compounds (stigmasterol, stigmast-5-en-3-ol, (3b) and ergost-5-en-3-ol, (3b)) were found in infected G. boninense. This suggests that it can be used as a chemical marker for detecting basal stem rot of oil palm trees. Parvin et al. (2020) comparatively evaluated the effect of the application of phenazine synthesized by Pseudomonas aeruginosa UPMP3 and hexaconazole in a study to inhibit infection of oil palm seedling basal stem rot from artificial Ganoderma boninsense. Mohd Hilmi Tan et al. (2021) presented future opportunities in signal processing for early Ganoderma boninense detection systems through studies of near-infrared spectroscopy (NIRS), which may contribute to reducing management costs of oil palm trees and preventing loss of business by reducing infection rates.

In their study, Muniroh et al. (2019) demonstrated that P. aeruginosa and T. asperellum can inhibit Ganoderma boninense in dual culture experiments. Bharudin et al. (2022) studied the infection mechanisms of G. boninense and methods of disease prevention to reduce BSR, including culture practices, chemical treatments, and manipulation of antagonistic microbes. The latest developments in multi-omics technologies such as RNA sequencing (RNA-Seq) and genome sequencing (WGS) were also studied. Pane et al. (2022) compared soil bacterial and fungal populations in soil samples from oil palm plantations where large holes were applied over a 15-year period with soil samples from plantations where non-large hole (standard) cultivation methods were applied. Bacterial and fungal populations were analyzed using the dilution plate method and calculations were based on total number of plates.

3. Research method for Ganoderma boninense Detection

There are several methods used in the academic study of Ganoderma boninense, depending on the research questions and objectives. Some common methods include:

3.1. Cultivation

Ganoderma boninense can be cultured in the laboratory under controlled conditions, allowing researchers to study its growth and development. This is useful for identifying the optimal conditions for growth, testing the efficacy of fungicides, and exploring its metabolic pathways.

3.2. Pathogenicity Testing

Researchers can test the virulence of different strains of Ganoderma boninense on oil palm seedlings or cuttings in order to understand the mechanisms of pathogenesis and to evaluate the effectiveness of various control measures.

3.3. Molecular Biology

The use of molecular biology techniques, such as PCR (Polymerase Chain Reaction), DNA sequencing, and transcriptomics, has greatly improved our understanding of Ganoderma boninense. These methods can be used to identify the genetic basis of virulence, analyze the fungal genome, and study the molecular interactions between the fungus and its host.

3.4. Field Observations

Field observations are essential for understanding the natural spread and distribution of Ganoderma boninense in oil palm plantations. This can include surveys of infected trees, mapping the spread of the disease, and monitoring the effectiveness of control measures.

3.5. Integrated Management Approaches

Research on Ganoderma boninense often includes an integrated approach that combines multiple methods and strategies to manage the disease. This can include the use of resistant varieties, chemical and biological control measures, and cultural practices to minimize the impact of the fungus on oil palm production.

So far, many studies have been conducted on Ganoderma boninense infection. Among the researchers, Mohd Hilmi Tan et al. (2021) will greatly help refer to the organized table as follows.

Table 1: Previous research for G. boninense detection by spectroscopy method

	Spectroscopy Method	Instrument	Sample Grouping	Models/ Algorithms	Researcher
1	Mass spectroscopy	GC-MS	Healthy Infected	PCA	Isha et al. (2020)
2	FTIR spectroscopy	FTIR spectrometer	Healthy Infected	-	Alexander (2014)
3	VIS-NIR spectroscopy	Spectroradiometer	Healthy Mild Moderate Severe	LDA, QDA, kNN and NB	Liaghat et al. (2014)
4	FTIR spectroscopy	FTIR spectrometer	Ganoderma basidiomata	-	Abdullah et al. (2012)
5	VIS-NIR spectroscopy	Spectroradiometer	Healthy Mild Moderate Severe	PLS-DA	Lelong et al. (2010)
6	VIS-NIR spectroscopy	Spectroradiometer	Healthy Mild Severe	Maximum likelihood	Shafri et al. (2011)
7	Dielectric spectroscopy	Solid dielectric test fixture + impedance analyser	Healthy Mild Moderate Severe	SVM, ANN	Khaled et al. (2018)
8	FTIR spectroscopy	FTIR spectrometer	Healthy Infected	-	Arnnyitte et al. (2014)
9	VIS-NIR spectroscopy	Spectroradiometer	Healthy Mild Moderate Severe	ANN	Ahmadi et al. (2017)
10	NMR spectroscopy	NMR spectrometer	Healthy Infected	PCA	Isha et al. (2019)
11	FTIR spectroscopy	FTIR spectrometer	Healthy Infected	-	Dayou et al. (2014)
12	MIR spectroscopy	FTIR spectrometer	Healthy Mild Moderate Severe	LDA, QDA, kNN and NB	Liaghat et al. (2014)

Note: The Research of Mohd Hilmi Tan et al. (2021) was modified.

In addition to spectroscopy techniques, Near-Infrared Spectroscopy (NIRS) and Machine Learning Techniques for predicting diseases of palm oil plants are also being used.

4. Conclusion

One of the main challenges in controlling G. boninense is its ability to adapt to new environments and resist control efforts. This makes it difficult to predict its behavior and find effective ways to control it. Research on the biology and ecology of the fungus can help to improve our understanding of the disease and inform the development of new control strategies. Another challenge in controlling G. boninense is early detection. The fungus infects the tree at the base of the trunk and can remain hidden for a long time before symptoms become visible. Research aimed at developing new methods for early detection and diagnosis of the disease can help to improve our ability to identify and treat infected trees before the disease has a chance to spread.

In addition to these specific challenges, there is a more general need for research on G. boninense in order to ensure the palm oil industry's sustainability. The increasing global demand for palm oil has put pressure on producers to maximize yields, which can lead to practices that promote the spread of the disease, such as the replanting of infected trees and the movement of infected materials between plantations. Research on ways to reduce the spread of the disease and maintain high yields can help to ensure the long-term viability of the palm oil industry.

In conclusion, research on Ganoderma boninense is essential in order to address the challenges posed by this disease to the palm oil industry. By improving our understanding of the biology and ecology of the fungus, developing new methods for early detection and diagnosis, and finding ways to reduce the spread of the disease, we can help to ensure the palm oil industry's sustainability for years to come.

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