

I. INTRODUCTION

1.1. Background

Rice (*Oryza sativa*) is the most important agricultural commodity in Indonesia. Rice has become the primary source of carbohydrates for the majority of Indonesia's population. According to data from (BPS, 2022) rice production for national food consumption in 2022 is estimated at approximately 32.07 metric tons. *Rice consumption* in Indonesia is the highest in Southeast Asia and ranks third in the world after China and India. The high demand for rice in Indonesia necessitates high rice production as well.

Indonesia's high demand for rice requires the government to supply large quantities of rice, making it necessary to optimize rice cultivation. Currently, rice productivity is not at its maximum due to several factors. Factors affecting suboptimal rice productivity include land conditions resulting from land-use conversion, unpredictable weather, and the presence of pests and diseases that attack rice plants. If pests and diseases are left uncontrolled, they will cause disease outbreaks and result in losses. In recent decades, rice production has been threatened by various diseases, one of which is blast disease caused by the fungus *Pyricularia oryzae* (Astriawati & Anfa, 2025)

Blast disease is one of the most significant diseases affecting rice crops worldwide and causes significant yield losses (Salimah *et al.*, 2021). According to Wang *et al.*, (2014), rice yield losses due to blast disease in Japan are around 60%; in Brazil, they have reached 100%; in India, 7.5%; in Korea, 8%; in China, 14%; in the Philippines, 67%; in Vietnam, 60%; in Italy, 24%; and in Iran, 50%. Field observations indicate that rice blast has a high prevalence and can spread rapidly, particularly under humid conditions with moderate temperatures. This disease causes necrotic spots on the leaves, collars, and stems, thereby reducing both the quality and quantity of the harvest (Astriawati & Anfa, 2025).

The development of blast disease is influenced by many factors, including environmental factors—namely, macro- and microclimatic conditions such as season, humidity, and temperature—as well as soil fertility, pathogen virulence, and crop variety resistance. *Pyricularia oryzae* thrives optimally at temperatures

ranging from 24 to 28 °C and relative humidity levels of up to 90% (Kurrata *et al.*, 2021). The rapid growth of colonies makes it difficult for farmers to control the disease. Currently, farmers still rely on chemical pesticides to control blast disease. Continuous use of chemical pesticides can lead to pathogen resistance and leave residues in crops, water, and the surrounding environment.

Farmers still consider the use of pesticides essential for increasing crop yields because of their effectiveness in controlling organisms that harm plants. However, it is important to note that the use of pesticides also poses risks to the environment. One major concern is the risk of pesticide runoff, which can contaminate the surrounding environment. Pesticides used in agriculture cause soil contamination through the processes of sedimentation and penetration into the soil (Dhaifulloh *et al.*, 2024) . This can lead to reduced soil fertility and other ecological problems. Furthermore, pesticides that contaminate the soil can also be carried by water flow into nearby rivers, resulting in river water pollution. Therefore, there is a need for environmentally friendly alternatives for controlling plant diseases.

Farmers still rely on fungicides to control blast disease because they provide quick results in eradicating the pest and disease organism (Suganda *et al.*, 2016). However, the use of fungicides increases production costs and has negative impacts on the environment and human health. Biological control can serve as an alternative for controlling *P. oryzae* by using biological agents capable of enhancing plant resistance to the pathogen. One type of microbe capable of inducing plant resistance is *Bacillus* sp. This bacterium can induce the formation of secondary metabolites that enhance plant resistance to leaf spot, seedling blight, and leaf blight through the mechanism of resistance induction (Djaenuddin, 2016).

Disease control in cultivated plants still relies heavily on the use of chemical fertilizers and pesticides. Excessive and continuous use of chemicals causes various negative impacts, such as declining soil quality, environmental pollution, and the development of resistance in pests and diseases. These issues underscore the need to develop more environmentally friendly and sustainable control technologies, one of which involves the use of biological agents. *Bacillus* sp. is a soil bacterium commonly found in the plant root zone (rhizosphere) and plays a crucial role as a biological agent. This bacterium can enhance plant growth through mechanisms

such as nitrogen fixation, phosphate solubilization, and the production of phytohormones like Indole Acetic Acid (IAA).

Radhakrishnan *et al.*(2017) reported in their study that the application of *Bacillus* sp. can enhance the growth and productivity of rice, corn, and soybean plants, as evidenced by increases in plant height, the number of leaves or tillers, root length, and plant dry weight. In addition to acting as a growth promoter, *Bacillus* sp. also holds great potential as a biological control agent against plant pathogens. This genus is capable of producing various secondary metabolites—such as antibiotics, lipopeptides, hydrolytic enzymes, and siderophores—that exhibit antagonistic effects against pathogens and can induce systemic plant resistance. The ability of *Bacillus* sp. to form endospores makes it more resistant to extreme environmental conditions and easier to formulate as commercial biofertilizers or biopesticides to support sustainable agricultural systems (Mendrofa & Lase, 2025) .

The *Bacillus* isolate used in this study was isolate D28 from Moekti *et al.* (2025) , which had been shown in previous research to inhibit the growth of the fungus *Alternaria* sp. That study tested 24 bacterial isolates at a population density of 10^8 CFU/mL against the pathogen *Alternaria* sp. The results showed that 9 isolates had potential as biological agents against *Alternaria* sp., with an average inhibition zone diameter in the “strong” category of 12.5 mm for isolate D28, and in the “moderate” category of 7.5 mm for isolates D13 and D19; 8.5 mm, and in the weak category: isolates D4, D21, D23, D32, D33, and D34 at 1 mm; 2.5 mm; 5 mm; 1.5 mm; 2.5 mm; and 1 mm

The results of the study indicate that isolate D28 exhibits a strong inhibition zone against the fungus *Alternaria* sp., measuring 12.5 mm. Previous research tested several *Bacillus* sp. isolates for their ability to inhibit *Alternaria* sp., and isolate D28 was found to have the strongest inhibition zone. Consequently, the researchers sought to test isolate D28 against a different pathogenic fungus, *Pyricularia oryzae*, at varying population densities: 10^7 , 10^8 , and 10^9 . According to (Bawantari *et al.*, 2020) , inhibition zones are thought to result from the production of antifungal compounds by endophytic bacteria, which can inhibit or kill pathogens through competition and the production of antifungal compounds.

Differences in the resulting inhibition zones may also be caused by differences in the types and amounts of metabolites produced by each endophytic bacterial isolate, which act as antifungal agents against pathogenic fungi. According to (Moekti *et al.*, 2025), the size of the inhibition zone produced depends on the type and stability of the metabolites produced by each bacterium to inhibit the growth of pathogenic fungi.

The success of *Bacillus* sp. as an alternative for plant disease control is greatly influenced by the population density of the applied bacteria, as this density determines the bacterial population density both in the pathogen's growth environment and on the plant surface. A bacterial population that is too small often prevents the bacteria from colonizing optimally, rendering their inhibitory activity against the pathogen ineffective. Conversely, an excessively high bacterial population does not always enhance control effectiveness; it may even lead to waste of materials, microbial imbalance, or reduced bacterial viability due to competition among cells (Velandia *et al.*, 2019). Therefore, determining the appropriate bacterial population density is a critical factor in maximizing the effectiveness of biological control. An optimal bacterial population density is expected to consistently enhance antagonistic activity—whether through antibiosis or the induction of plant resistance—thereby maximizing the suppression of *P. oryzae* pathogenicity. Based on this, research on the effects of applying various levels of *Bacillus* sp. population density is essential to identify the most effective and efficient density for suppressing pathogen development.

1.2. Research Questions

1. Can different population densities of *Bacillus* sp. inhibit the growth of *Pyricularia oryzae* *in vitro*?
2. Which *Bacillus* sp. population density is most effective in suppressing the severity of blast disease in rice plants *in vivo*?
3. Which population density of *Bacillus* sp. is most effective in promoting rice plant growth?

1.3. Research Objectives

1. To determine the ability of various population densities of *Bacillus* sp. to inhibit the growth of *Pyricularia oryzae* *in vitro*.
2. To determine the *Bacillus* sp. population density that is most effective in suppressing the severity of blast disease in rice plants *in vivo*.
3. To determine the optimal population density of *Bacillus* sp. for enhancing rice plant growth.

1.4. Research Benefits

1. To identify environmentally friendly alternatives for controlling blast disease in rice plants through the use of *Bacillus* sp. bacteria.
2. To improve rice crop productivity and harvest quality through effective and environmentally friendly disease control.
3. The results of this study can serve as a basis for utilizing *Bacillus* sp. at the optimal population density to enhance rice plant growth.