Borneo Journal of Resource Science and Technology (2024), 14(2): 108-117
DOI: https:doi.org/10.33736/bjrst.7024.2024

Antagonistic Potential of a Phosphate Solubilizing Bacteria (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) Against the Patogent Fungus *Ganoderma* sp. Isolated from Basal Stem of Oil Palm (*Elaeis guineensis* Jacq.) with Rot Disease

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Received: 25 April 2024 Accepted: 6 September 2024 Published: 31 December 2024

ABSTRACT

Ganoderma sp. is a pathogenic fungus whose attack can cause basal stem rot disease of oil palm (*Elaeis guineensis* Jacq.). Disease control using phosphate solubilizing bacteria (PSB), namely *Bacillus cereus* can be an alternative to biological control. The purpose of this study was to determine the antagonistic ability of PSB (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) in inhibiting the growth of *Ganoderma* sp. BP1 and changes in hyphal morphology of *Ganoderma* sp. BP1 after antagonistic testing. The research was conducted from January to May 2023 at the Microbiology Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Tanjungpura University, Pontianak. Antagonist testing used a completely randomized design (CRD) with the treatments consisted of *Ganoderma* sp. BP1 (negative control), 1% hexaconazole fungicide (positive control), PSB isolates PS1.1, PS1.2 and PS1.4. The test method used the dual culture on *Sabouraud Dextrose Agar* (SDA) media with each treatment repeated four times so that 20 experimental units were obtained. The results showed that PSB isolate PS1.4 had strong inhibition with an inhibition zone diameter of 11.01 mm, while isolates PS1.1 and PS1.2 had moderate inhibition with inhibition zone diameters of 9.43 mm and 9.45 mm, respectively, against *Ganoderma* sp. BP1. Hyphal morphology changes in of *Ganoderma* sp. BP1 that occurred after the antagonist test consist of lysed hyphae, twisted hyphae, hook-like hyphal tips, curly hyphae, bulbous hyphae, branched hyphae and bent hyphal ends.

Keywords: Antagonistic test, *Bacillus cereus,* biological control, *Ganoderma* sp., inhibition zone, phosphate solubilizing bacteria (PSB).

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is a leading plantation commodity in Indonesia, especially West Kalimantan. Based on the economic sector, this plantation crop is useful as a producer of edible oil, industrial oil and biofuel (biodiesel) (Rosmegawati, 2021). The problem faced by oil palm plantations in Indonesia to date is the increasing attack of basal stem rot disease (BSR) caused by the pathogen *Ganoderma boninense*. Losses caused by *G. boninense* attacks can reach 50% (Prasetyo *et al*., 2008). The attack of *G. boninense* causes the death of more than 80% of the entire population in several plantations in Indonesia, and the result of the transmission of this pathogen causes a decrease in oil palm production per unit area (Susanto *et al*., 2013).

Basal stem rot is a soil borne fungus that attacks old and young plants (Ummi, 2018). The fungus *G. boninense* can attack oil palms at the nursery and production stages. Oil palms that are not handled properly at the beginning of their growth/nursery, the pathogen will spread throughout the planting area (Semangun, 2008). Efforts to control the pathogen *G. boninense* are still being developed to overcome the BSR problem.

The most common effort to control the pathogen *G. boninense* is using synthetic pesticides, but the unwise use of pesticides will cause environmental residues, various health problems, and other ecological balance disorders (Istikorini, 2002). The use of environmentally friendly biological agents is an effort that can be made, one of which is using phosphate solubilizing bacteria (PSB). Plants that

experience phosphorus (P) nutrient deficiency make plants susceptible to disease, so the use of PSB can be used as a biocontrol that can improve root health and plant growth through its protection against disease so that it plays an important role in suppressing plant diseases (Sela *et al*., 2022).

Bacteria that act as phosphate solvents in soil have been found, including those from the *Bacillus* genus (Ekowati *et al*., 2022). The *Bacillus* genus is able to compete with pathogens by producing several secondary metabolites such as antibiotics, siderophores, bacteriocins and extracellular enzymes, inducing plant resistance compounds and producing antibiotic compounds such as chitinase enzymes that can hydrolyze fungal cell walls (Javandira *et al*., 2013). Exposure to these antimicrobial compounds can cause the hyphae of pathogenic fungi to become abnormal in the form of lysed hyphae, twisted hyphae, curled hyphae, dwarf hyphae, branched hyphae and twisted hyphae, meaning that these antagonistic bacteria are able to compete with pathogenic fungi (Asril, 2011).

Research on biological control in the research of Mahmud *et al*. (2020) showed that *T. virens* has a high inhibition against *G. boninense* of 73.5% in vitro. Fitriatin *et al*. (2020) stated that the phosphate solubilizing microbial group (*Pseudomonas mallei*, *P. cepacea*, *B. subtilis*, *B. megaterium*, *Penicillium* sp. and *Aspergillus niger*) was able to inhibit *Fusarium* sp. antagonistically. Research by Asril *et al*. (2022) stated that PSB with isolate code EF. NAP8 has antagonistic activity against acacia plant pathogenic fungi, namely *Ganoderma philippii* and *Fusarium oxysporum* with a percentage inhibition of 34.44% and 33.33%, respectively.

PSB isolates (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) isolated from peat soil in Teluk Bakung Village, Ambawang District, Kubu Raya Regency were able to dissolve phosphate with a phosphate solvent index ranging from 1.1-2.9 (Khotimah, 2021). Based on this description, it is necessary to further study the local PSB isolates (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) in inhibiting the growth of the fungus *Ganoderma* sp. BP1 isolated from the basal of rotten-symptomatic oil palm trunks in West Kalimantan.

MATERIALS AND METHODS

Media Preparation

A total of four media were used in this study, namely Potato Dextrose Agar (PDA) (Merck) + ciprofloxacin 0.01 g, Pikovskaya's Agar (PA) (HiMedia), Nutrient Broth (NB) (Merck) and Sabouraud Dextrose Agar (SDA) (Merck). PDA as fungal media, PA as media for rejuvenating phosphate-solubilizing bacteria, NB as phosphate-solubilizing bacteria suspension media, and SDA as antagonist test media. The media were sterilized using an autoclave at 121 ˚C pressure 1 atm for 15 minutes (Atlas, 2004; Waluyo, 2008).

Rejuvenation of Phosphate-Solubilizing Bacteria

Isolates of phosphate solubilizing bacteria (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) (collection of Microbiology laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Tanjungpura University by Khotimah, 2021), then inoculated on Pikovskaya's agar media by taking 1 ose of bacterial colonies. The isolate obtained was then scratched into a test tube containing Pikovskaya's agar media. Bacterial isolates that have been scratched on slanted agar media are incubated at room temperature for 24 hours (Yati, 2019).

Rejuvenation *Ganoderma* sp.

The hyphae of *Ganoderma* sp. BP1 (isolated from the basal of oil palm trunks with rotten symptoms in oil palm plantations in Sungai Nipah Village, Teluk Pakedai District, Kubu Raya Regency), were taken and inoculated using a straight ose needle at three points on PDA media in a petri dish, then incubated for 7 days at room temperature (Purnamasari *et al*., 2012).

Preparation of Test Suspension of Phosphate-Solubilizing Bacteria

Culture of phosphate solubilizing bacteria *B. cereus* that has been rejuvenated was taken 1 ose, then inoculated in 50 mL of NB media and incubated at room temperature for 12 hours using a shaker at 120 rpm. The 12-hour-old bacterial suspension was then measured for optical density using a UV-Vis

spectrophotometer with a wavelength of 600 nm until the absorbance value was 0.8-1 (Son *et al*., 2012) with an estimated number of bacteria in the suspension of 1.5×10^8 CFU cells/mL (Claudia *et al*., 2021).

Antagonism Testing of Phosphate-Solubilizing Bacterial Isolate *Bacillus cereus* against *Ganoderma* sp.

The method used refers to Suryanto *et al*. (2016), namely the modified dual culture method using SDA media by observing the direct interaction that occurs between antagonistic agents and pathogens. Culture of *Ganoderma* sp. BP1 was cut using a sterile cork borer with a diameter of 6 mm, then placed on 20 mL of SDA media in the center of the Petri dish (negative control). *Ganoderma* sp. was first grown to ± 20 mm in diameter on the third day (Nisa *et al*., 2020). Sterile Whatman No.1 paper with a diameter of 6 mm was soaked into a suspension of antagonistic bacteria that had an optical density with an absorbance value of 0.8-1 or soaked with 1% hexaconazole fungicide (0.1 mL of fungicide plus distilled water diluted to 10 mL) (positive control) for 30 minutes. The filter paper was then placed on the edge of the petri dish within 3 cm each on the left and right from the center of the fungal colony (Flori *et al*., 2020; Sakinah & Enny, 2014). Observations of the diameter of the antagonism power were observed until *Ganoderma* sp. BP1 in the negative control filled the petri dish (Nisa *et al*., 2020), namely on the sixth day. The scheme of laying the test of antagonistic bacteria and pathogenic fungi can be seen in (Figure 1). Observations of inhibition diameter were measured from the first day after planting into SDA media until the sixth day. How to calculate the diameter of inhibition using the following formula : Diameter of inhibition = $\frac{y-x}{2}$ (Suryanto *et al*., 2016). According to David and Stout (1971), the ability of antagonism can be grouped into four categories of inhibition based on the diameter of the inhibition (Table 1).

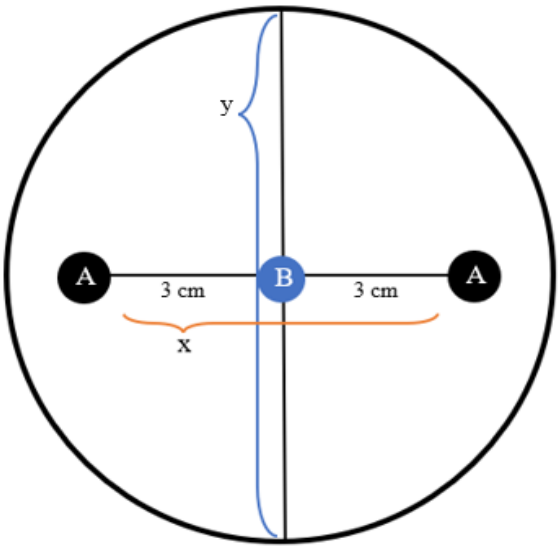

Figure 1. Schematic of the placement of antagonistic bacteria and pathogenic fungi. (A). Filter paper soaked with antagonistic bacteria, (B). Culture of pathogenic fungi (Suryanto *et al*., 2016)

Table 1. Category of inhibition diameter

Diameter of inhibition (mm)	Category (David dan Stout 1971)
> 20 mm	Very strong
11-20 mm	Strong
6-10 mm	Moderate
≤ 5 mm	Weak

Observation of Mycelium of Pathogenic Fungus After Antagonist Test

Observation of fungal mycelium is done in two ways, namely visually and microscopically. Visual observation is done by looking at the growth zone of the fungal mycelium. Microscopic observations were made by observing the tip of the fungal mycelium in the inhibition zone. The surface of the SDA media containing the tip of the mycelium of *Ganoderma* sp. fungus inhibited by phosphate solubilizing bacteria was cut 1x1 cm, then placed on a glass object and covered with a cover glass (Suryanto *et al*., 2012). Hyphae were observed under a light microscope with a magnification of 400× and examined for the presence or absence of abnormal morphology of the fungus mycelium, such as bending of the tip of the mycelium, broken mycelium, split mycelium, branched mycelium, lysed mycelium or stunted mycelium growth (Lorito *et al*., 1993). According to Halo *et al*., (2019) hyphae with abnormal morphology can be bent hyphae, hook-like hyphal ends, narrowed hyphae, lysed hyphae, swollen hyphae and hyphae with protrusions.

Data Analysis

Data analysis using one-way analysis of variance (ANOVA) at the 95% confidence level, if it shows a significant effect, then the Duncan Multiple Range test will be carried out at the 5% level using SPSS 26.0 software (Dendang, 2015).

RESULTS

Antagonistic Test of Phosphate-Solubilizing Bacterial Isolates *Bacillus cereus* against *Ganoderma* sp.

The results of the antagonistic test observed on the sixth day after incubation between phosphate-solubilizing bacterial isolates (*B. cereus* PS1.1*, B. cereus* PS1.2, *B. cereus* PS1.4) against *Ganoderma* sp. BP1 fungal isolates on SDA media showed inhibition in the treatment (Figure 2).

Based on the measurement of the diameter of the inhibition of PSB isolates (*B. cereus* PS1.1, *B. cereus* PS1.2*, B. cereus* PS1.4) against the fungus *Ganoderma* sp. BP1, the highest inhibition diameter with a very strong inhibition category in treatment P2 (positive control), namely using 1% hexaconazole fungicide by 24.50 mm, strong inhibition category in treatment P5 (*B. cereus* PS1.4 vs. *Ganoderma* sp. BP1) by 11.01 mm, and the moderate inhibition category in the P3 treatment (*B. cereus* PS1.1 vs *Ganoderma* sp. BP1) at 9.43 mm and P4 (*B. cereus* PS1.2 vs *Ganoderma* sp. BP1) at 9.45 mm (Table 2). The results of ANOVA analysis showed that each treatment had a significant difference in inhibition diameter ($P < 0.05$), meaning that there was a significant effect on the average inhibition diameter. Based on the results of the Duncan Multiple Range test at the 95% confidence level, it is known that treatment P1 (negative control) is significantly different from P2 (positive control), P3 (*B. cereus* PS1.1 vs *Ganoderma* sp. BP1), P4 (*B. cereus* PS1.2 vs *Ganoderma* sp. BP1) and P5 (*B. cereus* PS1.4 vs *Ganoderma* sp. BP1). Treatment P2 (positive control) was significantly different from treatment P1 (negative control), P3 (*B. cereus* PS1.1 vs *Ganoderma* sp. BP1), P4 (*B. cereus* PS1.2 vs *Ganoderma* sp. BP1) and P5 (*B. cereus* PS1.4 vs *Ganoderma* sp. BP1). Treatment P3 was not significantly different from treatment P4 (*B. cereus* PS1.2 vs *Ganoderma* sp. BP1) but significantly different from P1 (negative control), P2 (positive control) and P5 (*B. cereus* PS1.4 vs *Ganoderma* sp. BP1).

Table 2. Mean diameter of inhibition against *Ganoderma* sp. BP1 on the sixth day after incubation

Treatments	Mean diameter of inhibition on day six ± SD (mm)	Category David dan Stout (1971)
P1 (*Ganoderma* sp.)	0,00±0,00[a]	No Inhibition
P2 (Fungisida Heksakonazol 1% vs *Ganoderma* sp. BP1)	24,50±0,31[b]	Very Strong
P3 (*B. cereus* PS1.1 vs *Ganoderma* sp. BP1)	9,43±0,58[c]	Moderate
P4 (*B. cereus* PS1.2 vs *Ganoderma* sp. BP1)	9,45±0,81[c]	Moderate
P5 (*B. cereus* PS1.4 vs *Ganoderma* sp. BP1)	11,01±1,17[d]	Strong

Notes: Mean numbers followed by the same letter in the same column indicate results that are not significantly different in the Duncan test at the 95% confidence level

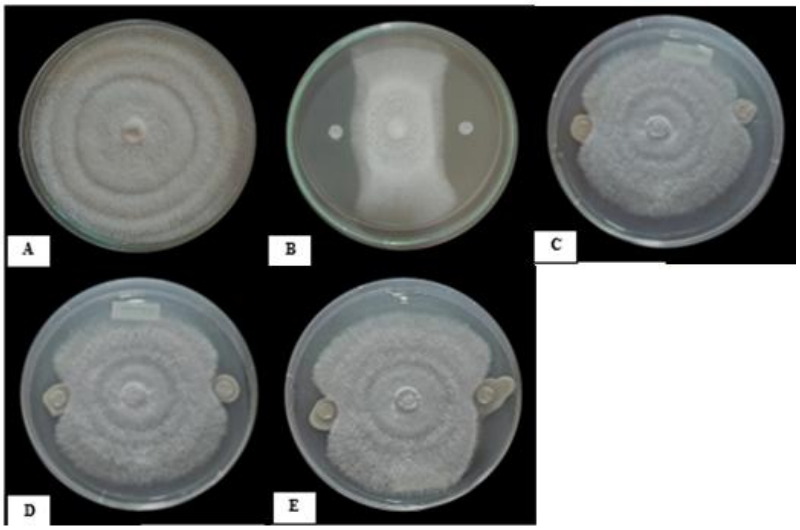

Figure 2. Antagonistic test results of phosphate-solubilizing bacteria (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) against *Ganoderma* sp. BP1 on the sixth day after incubation. (a). Negative control, (b). Positive control, (c). *B. cereus* PS1.1 vs *Ganoderma* sp. BP1, (d). *B. cereus* PS1.2 vs *Ganoderma* sp. BP1, (e). *B. cereus* PS1.4 vs *Ganoderma* sp. BP1

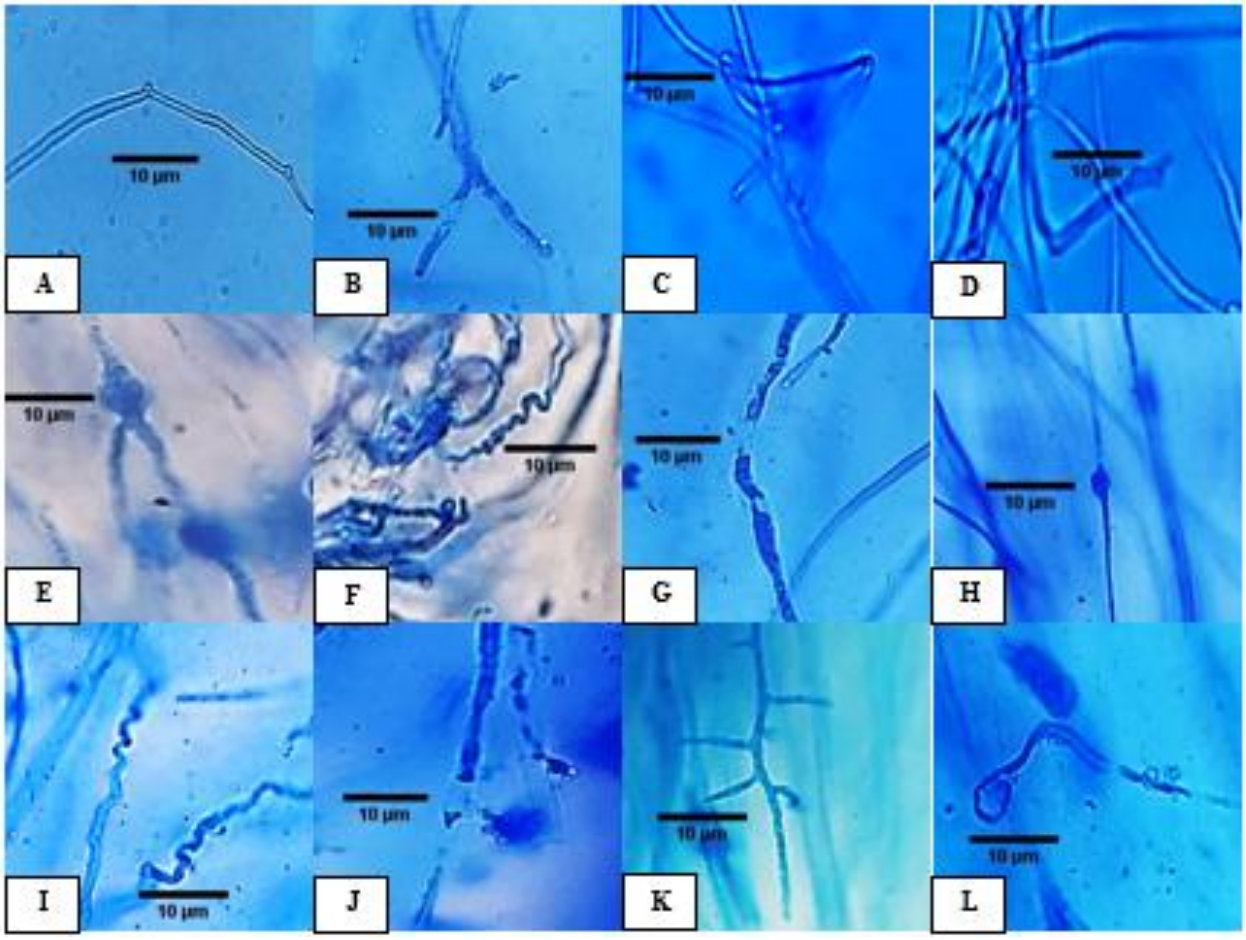

Figure 3. Abnormal hyphae shape on *Ganoderma* sp. BP1 after antagonistic test. (a). Normal hyphae (negative control); 1% hexaconazole effect (positive control): (b). Lysed hyphae, (c). Twisted Hyphae, (d). Hook-like hyphae tip; effect of isolate PS1.1: (e). Round-shaped Hyphae, (f). Curly hyphae; effect of isolate PS1.2: (g). Lysed hyphae, (h). Round- shaped hyphae, (i). Curly hyphae; effect of isolate PS1.4: (j). Lysed hyphae, (k). Branched hyphae, (l). Tip of hyphae bent. Scale = 10µm, magnification = 400×

Treatment P5 (*B. cereus* PS1.4 vs *Ganoderma* sp. BP1) was significantly different from treatments P1 (negative control), P2 (positive control), P3 (*B. cereus* PS1.1 vs *Ganoderma* sp. BP1) and P4 (*B. cereus* PS1.2 vs *Ganoderma* sp. BP1) (Table 2).

Microscopic Hyphae of *Ganoderma* sp. after Antagonist Test

Microscopic observations to see the abnormal hyphal morphology of *Ganoderma* sp. BP1 were made on the seventh day. Due to the antagonistic activity of phosphate solubilizing bacteria (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4), the hyphae of *Ganoderma* sp. BP1 experienced abnormal growth. Treatment P1 (negative control) had normal *Ganoderma* sp. BP1 hyphae. Treatment P2 (positive control) caused lysed hyphae, twisted hyphae, and hook-like hyphal tips. Treatment P3 (*B. cereus* PS1.1 vs *Ganoderma* sp. BP1) caused round hyphae, and curly hyphae. Treatment P4 (*B. cereus* PS1.2 vs *Ganoderma* sp. BP1) caused lysed hyphae, round hyphae, and curly hyphae. Treatment P5 (*B. cereus* PS1.4 vs *Ganoderma* sp. BP1) caused lysed hyphae, branched hyphae and bent hyphae tips (Figure 3).

DISCUSSION

PSB isolates (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) were tested against *Ganoderma* sp. BP1 fungus to see their inhibitory ability. The inhibition ability of each treatment began on the fourth day after the pathogenic fungus *Ganoderma* sp. BP1 was inoculated until the negative control *Ganoderma* sp. BP1 filled the petri dish on the sixth day. Treatment P1 (negative control) *Ganoderma* sp. BP1 colonies without treatment of PSB bacteria (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) grew well because there was no competition so that the nutrients were fulfilled. Based on the antagonist test, the three PSB isolates (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) and the positive control using hexaconazole 1% were able to suppress the growth of *Ganoderma* sp. BP1 (Figure 2) with varying diameters of inhibition (Table 2). This condition states that PSB isolates have the ability as antagonistic agents against the pathogenic fungus *Ganoderma* sp. BP1 through their ability to produce several growth inhibitory compounds. According to Loekas (2008), antagonistic bacteria release an inhibitory compound that can lyse the membranes of pathogenic fungi and disrupt their metabolic systems, so that the pathogenic fungi no longer have the ability to infect their host plants.

The results of measurements and observations showed that the treatment of PSB isolate P5 (*B. cereus* PS1.4 vs *Ganoderma* sp. BP1) had a strong inhibition category, and the treatments P3 (*B. cereus* PS1.1 vs *Ganoderma* sp. BP1) and P4 (*B. cereus* PS1.2 vs *Ganoderma* sp. BP1) had a moderate inhibition category (Table 2). The difference in the diameter of inhibition of each treatment of PSB isolates is thought to be because PSB isolates have different levels of ability to produce antimicrobial compounds. The size of the inhibition diameter produced is thought to be influenced by the sensitivity of the fungi and bacteria tested, the suspension of bacterial culture and the amount of antimicrobial compounds produced by bacteria. According to Cappucino & Sherman (2013), there are factors that affect the formation of inhibition zones, namely the speed of growth of the test microbes, the number of microbes tested, the level of microbial sensitivity to antimicrobial compounds, as well as the diffusion ability of antimicrobial compounds into the media and their interaction with the tested microbes. The ability of each bacterial isolate to inhibit the growth of *Ganoderma* sp. fungi is likely due to the antimicrobial compounds produced by each PSB isolate.

The results of measurements and observations of treatment P2 (1% hexaconazole vs *Ganoderma* sp. BP1) have a very strong inhibition category. Hexaconazole is a potential fungicide that is often used in oil palm plantations to control basal stem root (BSR) disease caused by *Ganoderma boninense* (Maznah *et al*., 2015). Hexaconazole is a systemic, protectant and eradicant fungicide of the triazole class (Kalam and Mukherjee, 2001). Systemic eradication power to all parts of the plant, namely through xylem vessels (Djojosumarto, 2008). The mechanism of action of triazole class fungicides is based on inhibition of ergosterol biosynthesis. Ergosterol is a compound derived from sterols and is a specific membrane constituent component in fungi that are not found in other microorganisms (Pratiwi, 2002). Triazole fungicides are known to have

broad-spectrum efficacy against *Ascomycetes*, *Basidiomycetes*, and *Deuteromycetes* fungi (Wahyuni *et al*., 2018).

Microscopic observations to see the abnormal hyphal morphology of *Ganoderma* sp. BP1 after the antagonist test were carried out on the seventh day. The antagonistic mechanism that occurs results in changes in the hyphal structure of the *Ganoderma* sp. BP1 fungus caused by PSB (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) and hexaconazole fungicide. Treatment P1 (negative control) of *Ganoderma* sp. BP1 hyphae looked normal (Figure 3a) due to the absence of competition with antagonistic bacteria. The P2 treatment (1% hexaconazole vs *Ganoderma* sp. BP1) caused hyphae lysis, hyphae twisting and hook-like hyphae tips (Figures 3b, c, d). The abnormal hyphae are thought to be due to the active ingredient compound of the fungicide hexaconazole causing changes in the hyphal structure by disrupting its shape and function. Situmorang *et al*. (2015) stated that fungicides that enter important parts of the fungus will indeed interfere with the function of these parts and work to change the shape and composition of the cell wall by limiting essential enzymes in the cell or changing the metabolic rate, but does not mean inhibiting all enzymes produced by the fungus. Hexaconazole which is a systemic fungicide can cause disruption of fungal cell wall synthesis, cell membrane synthesis and function, also affects energy generation in cells and metabolic intermediates, disrupts lipid synthesis and cell nucleus function (Sijpesteijn, 1970).

Treatment P3 (*B. cereus* PS1.1 vs *Ganoderma* sp. BP1) caused round hyphae and curly hyphae (Figures 3e, f). Treatment P4 (*B. cereus* PS1.2 vs *Ganoderma* sp. BP1) caused lysed hyphae, round hyphae and curly hyphae (Figures 3g, h, i). Treatment P5 (*B. cereus* PS1.4 vs *Ganoderma* sp. BP1) caused lysed hyphae, branched hyphae, and bent hyphal tips (Figures 3j, k, l). The abnormal hyphae that occurred were thought to be due to antifungal compounds produced by the PSB isolates and due to the defense mechanism of *Ganoderma* sp. BP1 against PSB. Lysis of hyphae indicates that PSB isolates are able to hydrolyze the cell wall of *Ganoderma* sp. Pathogenic fungal hyphae that experience swelling are thought to be a defense mechanism of the pathogen against isolate attack (Asril *et al*., 2022).

Ganoderma sp. BP1, which experienced abnormal hyphal growth after antagonistic testing, could be caused by secondary metabolite compounds and volatile compounds produced by PSB. Research by Hu *et al*. (2023) tested *Bacillus cereus* CF4-51 against *Sclerotinia sclerotiorum*, the results showed that the volatile compounds from *B. cereus* CF4-51 produced and the most influential were 1,2-*Benzenedicarboxylic acid* and *bis(2-methylpropyl)* ester which were able to cause damage to the cell membrane and cell wall of the fungus resulting in cytoplasmic leakage which could change the hyphal structure. These volatile compounds can also change the permeability of the fungal cell membrane so that these compounds can enter the cytoplasm of the pathogen which further damages the cell wall and changes its shape. *S. sclerotiorum* cells exposed to volatile compounds also form swollen rounded hyphae sections so that with this structure the pathogenic fungus fails to invade the plant (Hu *et al*., 2023).

The result of abnormal hyphae that undergo changes in shape such as branched hyphae, curly hyphae, and bent hyphal ends is also thought to be caused by compounds produced by PSB which result in changes in the gene expression of pathogenic fungi. According to Liu *et al*. (2018) and Takayama *et al*. (2010) that volatile compounds are able to affect the expression of genes (e.g., SsSac, Ss-Sl2, SsSOP1, and SsAMS2) associated with hyphal pole growth. Results suggest that such volatile compounds impact the expression of genes involved in hyphal pole integrity and budding. *Bacillus* also produces lipopeptides capable of binding to lipid membranes in cells, disrupting permeability and producing structural damage. Fengycin and iturin produced can open pores in the plasma membrane and can damage fungal hyphae. The activity of iturin is based on osmotic disruption while fengycin inhibits phospholipase (Aranda, 2005) as a result the structure of the fungal cell wall can undergo abnormal changes in shape.

Research by Surendran *et al*. (2017), stated that *G. boninense* hyphae exposed to phenolic compounds, namely 1 mM 2,6-*dimethoxy benzoic acid*, produced hyphae of *G. boninense* that branched a lot and inhibited hyphal growth. Research by Widiantini *et al*. (2018), stated that antagonistic endophytic bacteria affect the

morphology of *G. boninense* mycelia, namely mycelia curling, curling in reverse direction and thinning. Secondary metabolite compounds produced by endophytic bacterial isolates that affect the growth and morphology of *G. boninense* mycelia can allegedly be utilized to control basal stem rot disease in oil palm plants. Lytic enzymes such as chitinase and glucanase also play a role in the process of hyphal lysis. Bacteria that cause lysis activity in pathogens are one of the mechanisms that indicate disease biocontrol (Asril *et al*., 2022).

CONCLUSION

Three isolates of phosphate solubilizing bacteria (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) have the ability to inhibit the growth of the pathogenic fungus *Ganoderma* sp. BP1 isolated from the basal of oil palm with rot disease. Isolate PS1.4 is the isolate that has the highest inhibition diameter of 11.01 mm with a strong inhibition category, while isolates PS1.1 and PS1.2 are isolates that have inhibition diameter of 9.43 mm and 9.45 mm respectively with moderate category. Three isolates of phosphate solubilizing bacteria (*B. cereus* PS1.1, *B. cereus* PS1.2, *B. cereus* PS1.4) caused the hyphae of *Ganoderma* sp. BP1 to become abnormal, namely round hyphae, curly hyphae, lysed hyphae, branched hyphae and bent hyphal tips.

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