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Biocontrol efficacy of endophytic bacteria from *Mimosa pudica* L. against *Fusarium oxysporum* in *kepok* banana (*Musa acuminata* × *balbisiana*) in vitro

Efikasi pengendalian hayati bakteri endofit dari *Mimosa pudica* L. terhadap *Fusarium oxysporum* pada pisang kepok (*Musa acuminata* × *balbisiana*) secara *in vitro*

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ABSTRACT
Fusarium oxysporum f. sp. *cubense* (Foc) is a major fungal pathogen responsible for Fusarium wilt disease in banana plants, significantly reducing productivity and leading to substantial economic losses. This study aimed to evaluate the biocontrol potential of endophytic bacteria isolated from *Mimosa pudica* L. against *Foc* through an *in vitro* assay. A completely randomized design (CRD) with four treatments was employed, including a negative control (CP0), a positive control (CPF0), and two endophytic bacterial isolates from *Mimosa pudica* L. (BEP8 and BEP15), each with four replications. The antagonistic activity of these isolates was assessed using the dual culture method. The results demonstrated that BEP8 and BEP15 significantly inhibited *Foc* growth from 1 to 5 days after inoculation (DAI), with maximum inhibition rates observed on day 4, reaching 36.60% and 37.52%, respectively. These findings suggest that endophytic bacteria from *Mimosa pudica* possess potential as biocontrol agents against *Foc*. However, further molecular identification and greenhouse trials are necessary to confirm their efficacy in real-world applications.

ABSTRAK
Fusarium oxysporum f. sp. *cubense* (Foc) merupakan patogen utama penyebab penyakit layu Fusarium pada tanaman pisang, yang menyebabkan penurunan produktivitas serta kerugian ekonomi yang signifikan. Penelitian ini bertujuan untuk mengevaluasi potensi bakteri endofit yang diisolasi dari *Mimosa pudica* L. sebagai agen pengendali hayati terhadap *Foc* melalui uji *in vitro*. Rancangan acak lengkap (RAL) dengan empat perlakuan diterapkan, terdiri dari kontrol negatif (CP0), kontrol positif (CPF0), serta dua isolat bakteri endofit dari *Mimosa pudica* L. (BEP8 dan BEP15) dengan empat ulangan. Aktivitas antagonis isolat diuji menggunakan metode *dual culture*. Hasil penelitian menunjukkan bahwa BEP8 dan BEP15 secara signifikan menghambat pertumbuhan *Foc* pada 1 hingga 5 hari setelah inokulasi (HSI), dengan persentase penghambatan tertinggi pada hari ke-4, masing-masing sebesar 36.60% dan 37.52%. Hasil ini mengindikasikan bahwa bakteri endofit dari *Mimosa pudica* berpotensi sebagai agen pengendali hayati terhadap *Foc*. Namun, diperlukan identifikasi molekuler lebih lanjut serta uji efikasi di rumah kaca untuk memastikan efektivitasnya dalam aplikasi lapangan.

INTRODUCTION

Banana (*Musa spp.*) is one of the most important fruit crops in tropical and subtropical regions, serving as a staple food and a significant economic commodity. Among its cultivars, *kepok banana* (*Musa acuminata* × *balbisiana*) is widely consumed due to its nutritional value and versatility in processed food products such as banana chips and traditional desserts (Dwivany et al., 2021). However, banana production faces a serious challenge due to Fusarium wilt disease,

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caused by *Fusarium oxysporum* f. sp. *cubense* (*Foc*), a soil-borne fungal pathogen that severely affects plant health by blocking vascular tissues, leading to leaf chlorosis, wilting, and ultimately plant death (Maryani et al., 2023). The impact of Fusarium wilt is particularly alarming in Indonesia, where the disease significantly reduces banana yields. In Banten Province, for instance, the per capita consumption of *kepok banana* has declined from 92 grams per week in 2021 to 84 grams in 2023, partially due to reduced availability caused by disease outbreaks (Badan Pusat Statistik [BPS], 2023).

Conventional control strategies for Fusarium wilt primarily rely on chemical fungicides, which, while effective, pose serious environmental and health concerns. Prolonged fungicide application can lead to the development of fungicide-resistant pathogen strains and negatively impact soil microbiota, making alternative eco-friendly disease management approaches increasingly essential (Emiliawati et al., 2022; Nurhasanah & Sulhaswardi, 2021; Purnama et al., 2024; Purnama et al., 2025). Among these alternatives, biological control using beneficial microorganisms, particularly endophytic bacteria, has gained attention due to its potential to suppress plant pathogens through mechanisms such as antibiotic production, nutrient competition, and the induction of plant resistance (Muslim, 2019). Endophytic bacteria colonize plant tissues without causing harm and have been widely explored for their antagonistic properties against various plant diseases (Selangga & Listihani, 2021).

Mimosa pudica L., a leguminous plant commonly known as "sensitive plant" or *putri malu*, has been identified as a rich source of endophytic bacteria with biocontrol potential. Previous studies have reported that endophytic bacteria isolated from *Mimosa pudica* exhibit strong antimicrobial properties. Amaniyah et al. (2017) successfully isolated *Pseudomonas sp.* from *Mimosa pudica*, which showed high antagonistic activity against *Xanthomonas axonopodis*, the causative agent of bacterial pustule disease in soybean. Similarly, Sánchez-Cruz et al. (2019) identified *Enterobacter sp.* from *Mimosa pudica* roots that demonstrated antifungal properties against *Phytophthora capsici*, *Alternaria solani*, and *Fusarium* species in chili plants.

Furthermore, Williams et al. (2020) found that *Serratia sp.* isolated from *Mimosa pudica* nodules exhibited nematicidal effects against *Nacobbus aberrans*, a root-knot nematode affecting potato crops. Despite these promising findings, studies specifically investigating the antagonistic potential of *Mimosa pudica*-derived endophytic bacteria against *Foc* remain limited. Existing research has mainly focused on bacterial pathogens (e.g., *Xanthomonas* and *Pseudomonas* spp.) or general fungal suppression, while direct application against *Foc* in banana plants remains largely unexplored. Moreover, while some studies highlight antibiotic production as a suppression mechanism, the specific inhibitory capacity of these bacteria against Fusarium wilt requires further validation. Addressing this gap is crucial for developing effective and sustainable biocontrol strategies for banana disease management.

This study aims to evaluate the biocontrol efficacy of endophytic bacteria isolated from *Mimosa pudica* L. against *Foc* through an *in vitro* dual culture assay. Specifically, the study seeks to assess the antagonistic activity of selected endophytic bacterial isolates (BEP8 and BEP15) in inhibiting *Foc* growth over time. The findings of this research are expected to contribute to the development of eco-friendly biocontrol strategies for Fusarium wilt in banana cultivation while expanding the scientific understanding of endophyte-mediated pathogen suppression for sustainable agricultural practices.

MATERIALS & METHODS

Study site and duration

This study was conducted at the Soil and Agroclimate Laboratory, Department of Agroecotechnology, Faculty of Agriculture, Sultan Ageng Tirtayasa University, Serang, Banten, Indonesia. The research was carried out from September to December 2024 under controlled laboratory conditions. The room temperature was maintained at 20–25°C, and the pH of the working environment was set at 7.2 using a pH meter (Hanna Instruments HI2211, Romania).

Materials

The biological materials used in this study included roots of *Mimosa pudica* L. collected from a cultivated area in Serang, Banten, Indonesia, and *Fusarium oxysporum* f. sp. *cubense* (*Foc*) strain obtained from the Soil and Agroclimate Laboratory culture collection. The bacterial culture media consisted of Nutrient Agar (NA) (Oxoid, Thermo Fisher Scientific, UK) and Potato Dextrose Agar (PDA) (Merck KGaA, Darmstadt, Germany). Sterilization processes were carried out using 70% ethanol (Merck KGaA, Darmstadt, Germany) and 2.5% sodium hypochlorite (Sigma-Aldrich, USA), while microbial suspensions were prepared using 0.85% NaCl solution (Sigma-Aldrich, USA).

Experimental design and treatments

The study was designed using a completely randomized design (CRD) with a non-factorial arrangement, consisting of four treatments: CP0 (negative control) where *Foc* was grown on PDA without fungicide, CPF0 (positive control) where *Foc* was grown on PDA supplemented with a commercial fungicide containing active ingredient mancozeb (Dithane M-45, Dow AgroSciences, USA), BEP8 treatment where *Foc* was co-cultured with endophytic bacterial isolate BEP8 from *Mimosa pudica*, and BEP15 treatment where *Foc* was co-cultured with endophytic bacterial isolate BEP15 from *Mimosa pudica*. Each treatment was replicated four times, resulting in a total of 16 experimental units.

Isolation of endophytic bacteria from Mimosa pudica L.

Endophytic bacteria were isolated from 10 g of *Mimosa pudica* root samples, which were cut into 2 cm segments and subjected to surface sterilization following the protocol of Muslim (2019). The roots were first rinsed with sterile distilled water, then immersed in 70% ethanol (Merck KGaA, Germany) for 1 min, followed by 2.5% sodium hypochlorite (Sigma-Aldrich, USA) for 5 min, and finally rinsed three times with sterile distilled water for 1 min each. The surface-sterilized root segments were then macerated and serially diluted up to 10^{-8} in 0.85% NaCl solution (Sigma-Aldrich, USA). The diluted samples were spread on Nutrient Agar (NA) (Oxoid, Thermo Fisher Scientific, UK) and incubated at 28°C for 48 h. Bacterial colonies with distinct morphology were selected and purified through repeated streaking. The isolates were maintained at 4°C in NA slants for further analysis.

Screening for antagonistic activity

The antagonistic activity of the isolated bacteria against *Foc* was evaluated using the dual culture assay following the method described by Asran-Amal et al. (2005) and modified by Sanjaya et al. (2019). A 5-mm agar plug of actively growing *Foc* mycelium was placed at the center of a PDA plate, while a bacterial streak was made 2 cm away from the fungal inoculum. The plates were incubated at 28°C for 7 days, and the inhibition zone was measured daily. The antifungal activity was quantified based on the inhibition zone formation using the equation:

$$\text{Inhibition (\%)} = \frac{R_1 - R_2}{R_1} \times 100\% \quad (1)$$

where R_1 represents the radial growth of *Foc* in the control plate (mm), and R_2 represents the radial growth of *Foc* in the presence of the endophytic bacterial isolate (mm). Observations were made daily for 7 days to assess the inhibitory potential of the bacterial isolates.

Pathogenicity and morphological characterization

The pathogenicity of *Foc* was confirmed using a 48-h pathogenicity assay based on the method of Hantoko & Cahyani (2023). Endophytic bacterial isolates were subjected to macroscopic morphological characterization, including colony shape, color, texture, and edge formation, following the taxonomic guidelines of Bergey's Manual of Systematic Bacteriology. Additionally, a potato tuber assay was conducted to assess the pathogenic potential of the isolates. A 5-mm bacterial suspension (10^6 CFU/mL) was injected into freshly cut potato tubers (*Solanum tuberosum* cv. Granola, local supplier, Indonesia), which were then incubated at 28°C for 48 h. The formation of soft rot and discoloration was recorded as an indicator of pathogenicity.

Data transformation and statistical analysis

Quantitative data, including inhibition zone diameter and percentage of fungal inhibition, were transformed before statistical analysis. The clear zone diameter data were transformed using the equation $\sqrt{(x + 0.5)}$, while the fungal inhibition percentage data were subjected to arcsine transformation, following the recommendations of Nugroho (2008). Statistical analysis was performed using analysis of variance (ANOVA) at a 5% significance level, and when significant differences were detected (*F*-value > *F*-table), Duncan's Multiple Range Test (DMRT) at 5% was conducted using DSAASTAT software (Onofri, University of Perugia, Italy).

RESULTS & DISCUSSIONS

Clear zone diameter of endophytic bacteria

In the initial screening phase (*Screening I*), 30 endophytic bacterial isolates were tested for their antagonistic activity against *Foc*. Among them, 14 isolates were capable of producing a clear zone, indicating antifungal activity. Three isolates, i.e. BEP5, BEP8, and BEP15, exhibited the highest inhibition zone diameters, exceeding 1 cm, with measurements of 1.4, 1.7, and 2.2 cm, respectively. These three isolates were subsequently subjected to a pathogenicity test using potato tubers to determine their safety as biocontrol agents. The results indicated that two bacterial isolates (BEP8 and BEP15) showed no signs of rot (negative reaction), whereas one isolate (BEP5) caused soft rot (positive reaction). Consequently, BEP8 and BEP15 were selected for further evaluation in the dual culture assay to assess their inhibitory potential against *Foc*. The results of the screening phase are summarized in Table 1.

Table 1. Preliminary screening of endophytic bacterial isolates from *Mimosa pudica* roots

Biosecurity Testing	Endophytic bacteria screening Total isolates
Antagonistic Reaction Test	30
Pathogenicity Test	3

The preliminary screening aimed to identify antibiotic activity in endophytic bacteria based on the formation of clear zones. The presence of a clear zone suggests the production of secondary metabolites such as antibiotics, which inhibit fungal growth. According to Muslim (2019), antibiotics are one of the key mechanisms through which antagonistic agents interact directly with plant pathogens, suppressing their growth and reducing infection intensity. The production of secondary metabolites by endophytic bacteria can create inhibitory effects on fungal pathogens, thereby contributing to their biocontrol potential.

Table 2. Average clear zone diameter of endophytic bacteria (cm)

Treatment	1 DAI	2 DAI	3 DAI	4 DAI	5 DAI	6 DAI	7 DAI
CP0 (Negative Control)	0.707^{a}	0.707^{a}	0.707^{a}	0.707^{ns}	0.707^{ns}	0.707^{ns}	0.707^{ns}
CPF0 (Positive Control)	0.707^{a}	0.707^{a}	0.707^{a}	0.707^{ns}	0.707^{ns}	0.707^{ns}	0.707^{ns}
BEP5	1.946^{b}	1.454^{b}	0.968^{b}	0.707^{ns}	0.707^{ns}	0.707^{ns}	0.707^{ns}
BEP8	1.961^{b}	1.354^{b}	0.950^{b}	0.724^{ns}	0.707^{ns}	0.707^{ns}	0.707^{ns}
BEP15	1.903^{b}	1.248^{b}	0.834^{ab}	0.707^{ns}	0.707^{ns}	0.707^{ns}	0.707^{ns}

Note. Values followed by the same letter in the same column are not significantly different according to Duncan's Multiple Range Test (DMRT) at α = 5%. Data on clear zone diameter were transformed using $\sqrt{(x + 0.5)}$. CP0 = negative control (*Foc* only), CPF0 = positive control (*Foc* + antibiotic + fungicide), BEP5 = endophytic bacterium 5, BEP8 = endophytic bacterium 8, BEP15 = endophytic bacterium 15. ns = not significant.

The analysis of variance (ANOVA) revealed that the endophytic bacterial treatments significantly influenced the formation of clear zones against *Foc* during the first three days after inoculation (1–3 DAI). As shown in Table 2, the largest clear zone diameter on Day 1 was observed in BEP8 (1.961 cm), while BEP5 exhibited the highest inhibition on Day 2 (1.454 cm) and Day 3 (0.968 cm). As observed in Table 2, the clear zone diameter decreased progressively over time. From 5 to 7 DAI, there were no significant differences between the endophytic bacterial treatments and the negative (CP0) and positive (CPF0) controls, suggesting that the bacterial isolates may have ceased producing secondary metabolites with antifungal properties. The decline in inhibition could be attributed to the stationary phase of bacterial growth, during which secondary metabolite production typically declines, as reported by Selangga & Listihani (2021).

The formation of clear zones serves as a key indicator of secondary metabolite activity. According to Ariyanti et al. (2021), the larger the clear zone, the greater the production of antibiotic compounds by endophytic bacteria, leading to stronger inhibition of pathogenic fungal growth. Conversely, when bacterial metabolism slows, secondary metabolite production decreases, which may explain the eventual reduction in inhibition observed in later days. These findings suggest that BEP8 and BEP15 have strong early-stage antifungal activity against *Foc*, but their inhibitory effects diminish over time. Further research is needed to explore ways to sustain bacterial metabolite production, such as optimizing nutrient availability or applying bacterial inoculants at different growth phases. Additionally, molecular identification and metabolite profiling should be conducted to determine the specific bioactive compounds responsible for fungal inhibition.

Macroscopic morphology of endophytic bacteria

Observation of bacterial colonies was performed on BEP5, BEP8, and BEP15 isolates, which exhibited the highest inhibition zone diameters during the initial screening phase. The macroscopic morphological characterization of bacterial colonies aimed to determine key features such as colony shape, color, margin, and elevation. According to Yuanita et al. (2019), macroscopic morphological observations are essential for facilitating the purification process and distinguishing bacterial isolates from one another.

Table 3. Macroscopic morphological characteristics of endophytic bacteria from *Mimosa pudica* roots

Bacterial isolate	Shape	Color	Margin	Elevation
BEP5	Circular	Milky white	Undulate	Flat
BEP8	Circular	Milky white	Serrate	Flat
BEP15	Circular	White	Undulate	Raised

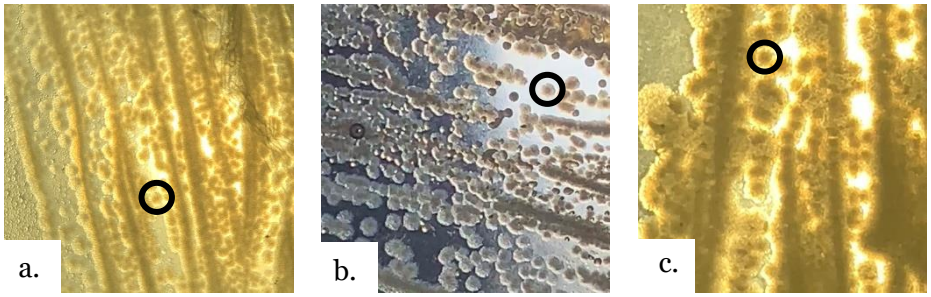

Figure 1. Macroscopic morphology of single colonies of endophytic bacteria from *Mimosa pudica* roots: (a) single colony of BEP5 (circled area); (b) single colony of BEP8 (circled area); (c) single colony of BEP15 (circled area).

Based on Table 3, the macroscopic morphological characteristics of the endophytic bacterial isolates were relatively similar. All isolates exhibited a circular colony shape, with colors ranging from milky white to white. The colony margins were classified as undulate (wavy) and serrate (serrated), while colony elevations varied between flat and raised. According to Petersen & McLaughlin (2016), bacterial colony morphology can be categorized into circular, irregular, and rhizoid (root-like) structures. Colony pigmentation is also classified into pigmented and non-pigmented types, with pigmented colonies typically appearing yellow, brown, or red, whereas non-pigmented colonies are generally white, milky white, or transparent. The macroscopic morphology of the endophytic bacterial isolates is visually represented in Figure 1, which illustrates 24-h-old single bacterial colonies from *Mimosa pudica* root isolates.

Pathogenicity test on potato tubers

The pathogenicity test using potato tubers was conducted to evaluate the potential pathogenic properties of endophytic bacterial isolates. If the potato exhibited a positive reaction, characterized by visible rot symptoms, the tested bacterial isolate was considered highly pathogenic and potentially harmful to plants. Conversely, a negative reaction, in which the potato remained intact without signs of rot, indicated that the bacterial isolate was non-pathogenic and could be considered a potential biocontrol agent. According to Hantoko & Cahyani (2023), bacterial isolates that successfully infect potato tubers during pathogenicity testing possess a significant level of pathogenicity, making them capable of spreading disease in agricultural fields.

The results of the pathogenicity test, conducted over a 48-h incubation period, revealed that isolate BEP5 (Figure 2a) exhibited pathogenic properties, as it produced a positive reaction, causing the potato surface to become soft when touched with an inoculating needle. Consequently, BEP5 was deemed unsuitable as a biocontrol agent due to its potential to cause plant disease. In contrast, isolates BEP8 (Figure 2b) and BEP15 (Figure 2c) exhibited a negative reaction, indicating no rot symptoms, with the potato surface remaining firm when probed with an inoculating needle.

According to Aisyah et al. (2022), the early symptoms of potato tuber decay caused by pathogens include surface discoloration and the presence of slime when the tuber is cut open. In this study, the observed rot symptoms included softened tissue, dark brown to black discoloration, a thin layer of slime, and a slightly unpleasant odor. These findings align with the results of Maghfiroh et al. (2022), who reported that pathogenic bacteria induce changes in potato surface texture and color, produce cream-colored slime, and emit an unpleasant odor. The results of the potato pathogenicity test are presented in Figure 2.

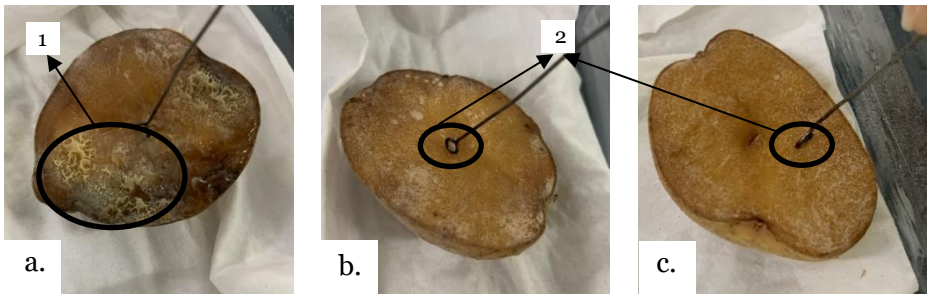

Figure 2. Pathogenicity test results on potato tubers after 48 h of incubation at room temperature: (a) Potato tuber inoculated with BEP5; (b) Potato tuber inoculated with BEP8; (c) Potato tuber inoculated with BEP15; (1) Symptoms of rot; (2) Firm surface when touched with an inoculating needle.

Inhibition percentage of endophytic bacteria in dual culture assay

The dual culture assay was conducted over a 7-day observation period to evaluate the antagonistic potential of endophytic bacteria against *Foc* based on their inhibition percentage. The results indicated that the tested endophytic

bacteria effectively inhibited *Foc* growth. According to Istikorini & Budiman (2023), the inhibition of pathogenic fungal growth due to secondary metabolite production is the primary mechanism in testing the antagonistic properties of endophytic bacteria.

The ANOVA results (Table 4) indicated that endophytic bacterial treatments significantly differed from both the negative control (CP0) and the positive control (CPF0) at 1–5 DAI. The highest inhibition percentages for endophytic bacteria were observed at 4 DAI, with BEP8 reaching 36.601% and BEP15 reaching 37.522%. However, in comparison to CPF0 (positive control containing fungicide and antibiotic), the inhibition percentage of the endophytic bacteria was relatively lower.

Table 4. Average inhibition percentage of endophytic bacteria against *Foc*

Treatment	1 DAI	2 DAI	3 DAI	4 DAI	5 DAI	6 DAI	7 DAI
CP0 (Negative Control)	11.617^{a}	11.617^{a}	11.617^{a}	11.617^{a}	11.617^{a}	11.617^{a}	11.617^{a}
CPF0 (Positive Control)	41.952^{c}	43.248^{c}	42.989^{c}	43.287^{c}	42.968^{b}	42.369^{b}	33.938^{b}
BEP8	27.016^{b}	31.615^{b}	31.181^{b}	36.601^{b}	29.376^{b}	21.327^{a}	18.695^{a}
BEP15	21.731^{b}	28.995^{b}	32.087^{b}	37.522^{b}	29.399^{b}	20.604^{a}	18.858^{a}

Note. Values followed by the same letter in the same column indicate no significant difference based on Duncan's Multiple Range Test (DMRT) at α 5%. All data underwent double arcsine transformation. CP0 = negative control (fungus only), CPF0 = positive control (fungus + antibiotic + fungicide), BEP8 = endophytic bacterium 8, BEP15 = endophytic bacterium 15.

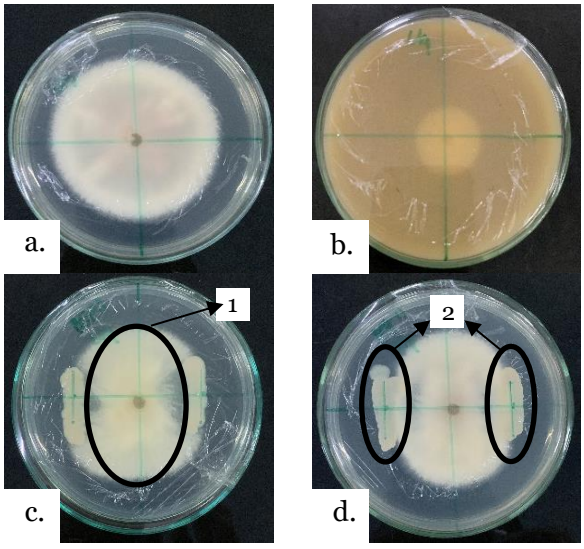

Figure 3. Dual culture assay results at 4 DAI: (a) CP0 (negative control, *Foc*); (b) CPF0 (positive control, *Foc* + antibiotic + fungicide); (c) Endophytic Bacterium 8 (BEP8); (d) Endophytic Bacterium 15 (BEP15); (1) *Foc* growth; (2) endophytic bacterial streak.

The lower inhibition percentages of endophytic bacteria could be attributed to environmental factors, particularly their ability to compete for nutrients. Selangga & Listihani (2021) reported that bacterial inhibition capacity is influenced by competition for nutrients in the same growth medium. Additionally, Pasalo et al. (2022) found that the effectiveness of endophytic bacteria in inhibiting fungal growth is more dependent on the quantity of antibiotic compounds they produce, which directly influences nutrient competition. Overall, the CPF0 treatment exhibited the highest inhibition percentage throughout 1–7 DAI, ranging from 41–43%, except at 7 DAI, where it decreased to 33%. Based on Prastya et al. (2014), inhibition percentages are classified as strong (>40%), moderate (30–40%), and weak (<30%). In contrast, the lowest inhibition percentages were recorded in BEP15 at 1, 2, 6, and 7 DAI, whereas BEP8 showed the lowest inhibition at 3–5 DAI.

The strong inhibition observed in CPF0 is likely due to the presence of a fungicide containing 70% propineb, which effectively inhibits *Foc* growth. According to Tefa et al. (2016), propineb 70% is a contact fungicide commonly applied directly to infected plants for disease control. Nurhasanah & Sulhaswardi (2021) further noted that propineb-based fungicides have a low risk of developing resistance, as they act non-selectively against pathogenic fungi. The dual culture assay results after 4 DAI (Figure 3) demonstrated that the fungal hyphal diameter in the CPF0 treatment was smaller compared to CP0, BEP8, and BEP15, which exhibited larger hyphal diameters. This suggests that the fungicide in CPF0 was more effective in inhibiting *Foc* than endophytic bacteria, as confirmed by the inhibition percentages in Table 4.

The differences in inhibition percentages between BEP8 and BEP15 were attributed to differences in bacterial species and the types of secondary metabolites produced. Jahuddin et al. (2021) stated that variation in inhibition percentages among endophytic bacteria is indicative of differences in the quantity and activity of antibiotics produced. The decreasing inhibition percentages after 4 DAI indicate that secondary metabolite production by endophytic bacteria declined, as noted by Foeh et al. (2019), who reported that endophytic bacterial antibiotics degrade over time, reducing their inhibitory effectiveness against fungal pathogens.

Mahmuda et al. (2024) added that inhibition decline is not only due to decreasing antibiotic production but also to pathogen adaptation to endophytic bacterial antibiotics, allowing them to survive. The inhibition zone measurements, calculated using a modified method from Andries et al. (2014), revealed that the best inhibition zones from 1–4 DAI were recorded in BEP8, with diameters of 8.93 cm, 8.48 cm, 8.00 cm, and 7.36 cm, respectively. The lower inhibition percentages of endophytic bacteria could be influenced not only by environmental factors and antibiotic concentrations but also by the higher sensitivity of *Foc* to fungal-derived antibiotics than to bacterial-derived antibiotics. According to Muslim (2019), pathogenic fungi such as *Fusarium sp.* and *Pythium sp.* are more sensitive to fungal-derived antibiotics than bacterial-derived antibiotics.

CONCLUSIONS

This study confirms the biocontrol potential of endophytic bacteria from *Mimosa pudica* against *Fusarium oxysporum* f. sp. *cubense* (*Foc*), the causative agent of Fusarium wilt in *kepok* banana. The dual culture assay showed that BEP8 and BEP15 effectively inhibited *Foc* growth, with BEP15 achieving the highest inhibition (37.522% at 4 DAI). However, their inhibition was lower than the positive control (CPF0), which contained fungicide. Pathogenicity testing confirmed that BEP8 and BEP15 were non-pathogenic, while BEP5 induced soft rot and was unsuitable for biocontrol. Although inhibition declined after 4 DAI, likely due to reduced metabolite production or fungal adaptation, these findings suggest that *Mimosa pudica*-derived endophytic bacteria have promising potential as eco-friendly biocontrol agents. Further studies on formulation optimization, greenhouse trials, and molecular characterization are needed to enhance their efficacy for sustainable Fusarium wilt management in banana cultivation.

REFERENCES

Aisyah, R., Salsabila, A. M., Faiqah, J. A., Fadia, A. N., & Fitrah, G. (2022). Inventarisasi bakteri penyebab penyakit pada umbi kentang (*Solanum tuberosum* L.) dan cara penanggulangannya. *Prosiding Seminar Nasional Bio*, *2*(2), 44–53. https://doi.org/10.24036/prosemnasbio/vol2/420.

Amaniyah, F., Abadi, A. L., & Aini, L. Q. (2017). Eksplorasi bakteri endofit dari gulma putri malu (*Mimosa pudica* L.) yang berpotensi sebagai antagonis untuk mengendalikan penyakit pustul bakteri pada kedelai. *Jurnal HPT*, *5*(1), 1–7. https://jurnalhpt.ub.ac.id/index.php/jhpt/article/view/248/250.

Andries, J. R., Gunawan, P. N., & Supit, A. (2014). Uji efek anti bakteri ekstrak bunga cengkeh terhadap bakteri *Streptococcus mutans* secara *in vitro*. *Jurnal e-Gigi*, *2*(2), 1-8. https://doi.org/10.35790/eg.2.2.2014.5763.

Ariyanti, A. L., Suriani, & Wahab, S. S. (2021). Potensi mikroba antagonis *Bacillus cereus* dan *Trichoderma sp.* terhadap patogen penting tanaman jagung. *Tarjih Agriculture System Journal, 01*(1), 23-29. https://jurnal-

umsi.ac.id/index.php/agriculture/article/view/245.

Asran-Amal, A., Abd-Elsalam, K. A., Omar, M. R., & Aly, A. A. (2005). Antagonistic potential of *Trichoderma* spp. against *Rhizoctonia solani* and use of M13 microsatellite-primed PCR to evaluate the antagonist genetic variation. *Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz Journal*, *112*(6), 550–561. https://doi.org/10.1007/bf03356152.

Badan Pusat Statistik. (2023). *Produksi tanaman buah-buahan*. Badan Pusat Statistik. Jakarta.

Dwivany, F., Wikantika, K., Sutanto, A., Ghazali, F., Lim, C., & Kamalesha, G. (2021). Pisang indonesia (Issue September). ITB Press.

Emiliawati, Salamiah, & Fitriyani, D. (2022). Pengendalian penyakit moler (*Fusarium oxysporum*) pada bawang merah dengan serbuk kulit jengkol (*Pithecellobium jiringa*) di lahan gambut. *Jurnal Proteksi Tanaman, 5*(02), 499–505. https://doi.org/10.20527/jptt.v5i2.1255.

Foeh, S. C., Temaja, I. G. R. M., & Khalimi, K. (2019). Potensi bakteri endofit dalam menekan pertumbuhan *Phytophthora palmivora* (Butler) secara *in vitro*. *Jurnal Agroekoteknologi Tropika*, *8*(4), 388–398. https://ojs.unud.ac.id/index.php/JAT388.

Hantoko, D. A., & Cahyani, S. D. N. (2023). Perkembangan penyebab penyakit busuk lunak pada tanaman buah naga merah (*Hylocereus Polyrhizus*) di Kabupaten Banyuwangi. *Jurnal Berkala Ilmiah Pertanian, 6*(3), 122–128. https://doi.org/10.19184/bip.v6i3.35384.

Istikorini, Y. & Budiman, T. (2023). Uji Potensi mikrob rizosfer sebagai pengendali hayati penyebab penyakit tanaman. *Jurnal Silvikultur Tropika, 14*(03), 242–249. https://doi.org/10.29244/j-siltrop.14.03.242-249.

Jahuddin, R., Jamila, Awaluddin, & Suriani. (2021). *Exploration and screening for endophytic microbes of maize plant root against Fusarium Verticillioides*. *Jurnal HPT Tropika, 18*(1), 57-64. https://doi.org/10.23960/j.hptt.11857-64.

Maghfiroh, E. L., Munif, A., Nawangsih, A. A., & Akhdiya, A. (2022). Karakterisasi bakteri penyebab busuk lunak pada umbi porang (*Amorphophallus muelleri*) menggunakan primer pcr spesifik. *Jurnal Ilmu Pertanian Indonesia (JIPI), 27*(3), 463–471. https://doi.org/10.18343/jipi.27.3.463.

Mahmuda, I., Saylendra, A., Sulistyorini, E., & Isminingsih, S. (2024). Uji potensi isolat rhizobakteri menekan pertumbuhan jamur antraknosa cabai merah (*Capsicum nnum* L .) secara *in vitro. Jurnal Ilmiah Membangun Desa Pertanian dan Pertanian (JIMDP), 2748*(105). https://doi.org/10.37149/JIMDP.v9i6.1656.

Maryani, N., Rayhan, E., Harahap, O., Khastini, R. O., & Ahmad, F. (2023). Deteksi penyakit layu fusarium pada pisang-pisang lokal di Pandeglang. *Jurnal Fitopatologi, 19*(25), 133-144. https://doi.org/10.14692/jfi.19.4.133.

Muslim, A. (2019). *Pengendalian hayati patogen tanaman dengan mikroorganisme antagonis.* Unsri Press. Palembang.

Nurhasanah & Sulhaswardi. (2021). Uji dosis fungisida berbahan aktif propineb dan waktu aplikasi terhadap pertumbuhan (*Fusarium oxsporum*) Secara *In Vitro*. *Jurnal Dinamika Pertanian*, *37*(2), 131-140. https://doi.org/10.25299/dp.2021.vol37(2).11856.

Nugroho, S. (2008). Rancangan percobaan dasar-dasar. UNIB Press.

Pasalo, N. M., Kandou, F. E. F., & Singkoh, M. F. O. (2022). Uji antagonisme jamur *Trichoderma* sp. terhadap patogen *Fusarium* sp. pada tanaman bawang merah *Allium cepa* isolat lokal tonsewer secara in vitro. *Jurnal Ilmu Alam Dan Lingkungan*, *13*(2), 1–7. https://doi.org/10.20956/jal.v13i2.22334.

Petersen, J., & Mclaughlin, S. (2016). *Laboratory exercises in microbiology : discovering the unseen world through hands-on investigation. City University of New York* (CUNY). New York.

Prastya, M. E., Suprihadi, A., Kusdiyantini, E., & Diponegoro, U. (2014). Eksplorasi rhizobakteri indigenous tanaman cabai rawit (*Capsicum frustescens* Linn.) dari pertanian semi organik Desa Batur Kabupaten Semarang sebagai agen hayati pengendali pertumbuhan jamur *Fusarium oxysporum* f.sp *capsici*. *Jurnal Biologi*, *3*(3), 18-31. https://ejournal3.undip.ac.id/index.php/biologi/article/view/19449.

Purnama, I., Swebocki, T., Ihsan, F., Mutamima, A., Boukherroub, R., Mechouche, M. S., & Fadilaturahmah, F. (2024). Evaluation of four indonesian leaf extracts for their antimicrobial activity against *Staphylococcus aureus* (MRSA) & *Escherichia coli* (K-12). In *E3S Web of Conferences* (Vol. 593, p. 05001). EDP Sciences. https://doi.org/10.1051/e3sconf/202459305001

Purnama, I., Malhat, F. M., Mutamima, A., Rusdiarso, B., & Noegrohati, S. (2025). Enhanced dissipation of azoxystrobin in loam soil under direct sunlight exposure. *International Journal of Environmental Science and Technology*, *22*(6):4521–4534. https://doi.org/10.1007/s13762-024-06152-z

Sánchez-cruz, R., Tpia, I., Batista-garcía, R. A., Méndez-santiago, E. W., Sánchez-carbente, R., Leija, A., & Folch-mallol, J. L. (2019). Isolation and characterization of endophytes from nodules of mimosa pudica with biotechnological potential. *Microbiological Research*, *218*, 76–86. https://doi.org/10.1016/j.micres.2018.09.008.

Sanjaya, I. G. N. P. W., Wirya, G. N. A. S., Phabiola, T. A., & Winantara, I. M. (2019). Isolasi dan seleksi bakteri antagonis sebagai alternatif pengendalian penyakit layu stroberi. *Jurnal Agroekoteknologi Tropika, 8*(2), 252–262. https://ojs.unud.ac.id/index.php/JAT.

Selangga, D. G. W., & Listihani. (2021). *Screening of endophytic bacteria isolated from mimosa pudica in bali island. SEAS (Sustainable Environment Agricultural Science), 05*(01), 50–57. http://dx.doi.org/10.22225/seas.5.1.3303.50-57.

Tefa, A., Widajati, E., Syukur, M., & Giyanto. (2016). Aplikasi bakteri probiotik untuk meningkatkan mutu fisiologi dan kesehatan bibit cabai (*Capsicum annuum* L.). *Jurnal Agron Indonesia, 44*(2), 176–182. https://doi.org/10.24831/jai.v44i2.13487.

Yuanita, M. M., Putri, E. A., & Rialita, A. (2019). Eksplorasi bakteri gram negatif endofit tanaman kunyit (*Curcuma longa* L.) yang memiliki kemampuan *quorum quenching*. *Jurnal Kedokteran Andalas, 42*(2), 80–90. https://doi.org/10.25077/mka.v42.i2.p80-90.2019.

Williams, E., Santiago, M., Gómez, O., Ricardo, R., Cruz, S., Luis, J., Mallol, F., Hernández, V. M., Edgar, V., Luna, V., Aguilar, L., Arnoldo, M., & Villarreal, W. (2020). *Serratia sp., an endophyte of mimosa pudica nodules with nematicidal, antifungal activity and growth-promoting characteristics*. *Journal Archive of Microbiology, 203, 549-559*. https://doi.org/10.1007/s00203-020-02051-2

