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Biocontrol Potential of Indigenous Root-Associated Fungi against Fusarium Wilt (*Fusarium oxysporum* f. sp. *cubense*) in Banana (*Musa* sp.)

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Abstract

Fusarium oxysporum f. sp. cubense (Foc) is a soil-borne pathogen causing Fusarium wilt in banana and is widely distributed in Indonesia. Biological control using antagonistic fungi is a promising strategy for managing this disease. This study aimed to evaluate the effectiveness of indigenous root-associated fungi in controlling Fusarium wilt in banana cv. Barangan Merah**.** The indigenous fungal isolates and Foc were obtained from the isolate collection of the Research Center for Horticulture, BRIN, Indonesia. The experiment was arranged in a randomized block design comprising six treatments (Control, *Fusarium* sp. 1, *Fusarium* sp. 2, *Fusarium* sp. 3, *Trichoderma* sp., unidentified fungus), four replicates, and five plants per replicate**.** Two-month-old banana plantlets derived from tissue culture were treated by placing 15 mL of fungal propagules per plant in the soil around the roots. The study showed that the application of *Fusarium* sp. 2 delayed the incubation period of Fusarium wilt in banana cv. Barangan Merah to 47.33 days, compared with 30.44 days in the untreated control. *Fusarium* sp. 2 resulted in the lowest disease intensity (33.65%)**.** The application of indigenous fungi did not significantly affect plant height, stem circumference, or leaf number under the experimental conditions. *Fusarium* sp. 2 is a promising indigenous biocontrol candidate against Fusarium wilt in banana; however, further molecular identification, pathogenicity, safety confirmation, inoculum standardization, and field validation are required before practical recommendation.

Keywords: Antagonistic isolates, Barangan Merah, disease severity, *Fusarium* sp. 2, Tropical Race 4.

Introduction

Fusarium wilt is one of the most serious constraints to banana production worldwide. The disease is mainly caused by the soil-borne fungus *Fusarium oxysporum* f. sp. cubense (Foc). Foc has traditionally been classified into races 1, 2, 3, and 4 based on the banana cultivars that it infects. More recently, tropical race 4 (TR4), which is widely distributed in tropical regions, has been reported as a distinct species, Fusarium odoratissimum (Maryani, 2018). Banana plants infected by this pathogen initially show yellowing from the leaf margins toward the midrib, followed by wilting. Internally, the pseudostem shows reddish-brown vascular discoloration (Maryani, 2018; Dita et al., 2018). The pathogen can disrupt plant defense mechanisms and ultimately cause tissue death (Maryani et al., 2023).

In Indonesia, Foc was first reported in 1997. Severe outbreaks were recorded in Halmahera, covering approximately 3,000 ha,

followed by 1,700 ha in Lampung and 300 ha in Riau. The disease then spread to other areas, causing damage to banana plantations in West Sumatra, North Sumatra, and Jambi (Nasir and Jumjunidang, 2003; Nasir et al., 2005). Hermanto et al. (2011) reported the occurrence of Fusarium wilt in various banana cultivars across 15 provinces in Indonesia, ranging from Aceh to Papua. More recently, Rahayuniati et al. (2024) reported the widespread distribution of Fusarium wilt in the lowland areas of Banyumas Regency.

The management of Fusarium wilt remains challenging because *Foc* is a soil-borne pathogen that can persist in soil for long periods and is difficult to control once it has established in banana fields. Synthetic fungicides have been used in some disease management practices; however, intensive and continuous fungicide application may cause residue accumulation, environmental contamination, reduced crop sustainability, toxicity risks to humans and animals, and the development of fungal resistance (Suwastini et al., 2020; Purnama et al., 2025). Therefore, environmentally safer and biologically based control strategies are needed.

One widely used approach to suppress plant diseases is the use of biopesticides based on antagonistic fungi. Natural biocontrol products can reduce dependence on synthetic chemicals (Woo et al., 2023). Several microorganisms, including *Trichoderma* spp., *Burkholderia* sp., *Pseudomonad fluorescens* and *Pantoea* sp., have been reported to show antagonistic activity against plant pathogens (Sulyanti et al., 2018; Riska et al., 2026; Duchateau et al., 2024). However, improving the efficacy and field performance of antagonistic microorganisms remains an important research priority. Indigenous microorganisms, which originate from the host plant or its surrounding environment, are promising candidates because they are already adapted to the plant-associated habitat. Indigenous fungi may occur in the rhizosphere or as endophytes inside plant tissues. In addition to their adaptive ability, these fungi may suppress plant pathogens through secondary metabolite production and may contribute directly or indirectly to plant growth and soil fertility (Lannur et al., 2021; Ali et al., 2022; Fite et al., 2023).

Previous studies have largely emphasized *Trichoderma* spp., *Bacillus* spp., and *Pseudomonas* spp. for Foc control (Tran et al., 2026). However, interactions among antagonistic microorganisms, pathogens, and host plants are often strain- and host-specific, and many studies on Foc control in banana remain limited to in vitro screening (Solórzano et al., 2025). Information on the use of indigenous *Fusarium* sp. isolates associated with banana roots for suppressing Fusarium wilt is still limited. Therefore, this study aimed to evaluate the effectiveness of indigenous banana root-associated fungi, particularly indigenous Fusarium isolates, in suppressing Fusarium wilt in banana.

Methods

The study was conducted from September to December 2024 at the laboratory and joint experimental field of the Research Center for Horticulture, National Research and Innovation Agency (BRIN), Green Hill Arya Residential Complex, Lubuk Sikarah District, Solok City, West Sumatra, Indonesia.

Research Design

The experiment was arranged in a randomized block design (RBD) consisting of six treatments: A = without indigenous fungi (control), B = *Fusarium* sp. 1 (isolated from the pith of Kepok Tanjung banana), C = *Fusarium* sp. 2 (isolated from the cortex of Kepok Tanjung banana), D = *Fusarium* sp. 3 (isolated

from the pith of Kepok Tanjung banana), E = *Trichoderma* sp. (isolated from the pith of Kepok Tanjung banana), and F = unidentified fungus (isolated from the cortex of Kepok Tanjung banana). Each treatment was replicated four times, and each experimental unit consisted of five plants. A healthy non-*Foc*-inoculated control was not included in this experiment. Since all plants were challenged with *Foc*, the growth parameters should be interpreted under disease-pressure conditions.

Fungal Isolate Collection

The five indigenous fungal isolates and one Foc TR4 isolate used in this study were obtained from the collection of the Research Center for Horticulture, National Research and Innovation Agency (BRIN), Indonesia, and were maintained on filter paper. The five indigenous fungal isolates were originally collected from healthy roots of Kepok Tanjung banana plants grown by farmers in Nagari Aripan, X Koto Singkarak District, Solok, West Sumatra. Morphological characterization based on Barnett and Hunter (1998) indicated three indigenous isolates belonged to the genus *Fusarium*, whereas one was classified as a non-*Fusarium* fungus. The non-*Fusarium* isolate was characterized by a purple colony, a fine cottony surface, and a dense colony margin. Microscopically, it had septate and hyaline hyphae, with abundant round conidia observed on PDA medium. The Foc TR4 isolate used in this study was isolate 01010208, originally isolated from banana cv. Barangan. It had previously been identified as VCG 01213/16 by Jumjunidang et al. (2012) based on vegetative compatibility group testing, and its pathogenicity had been evaluated under the ACIAR Hort/2007/34 research project. The same isolate was later used by Arifandi et al. (2025).

Preparation of Potato Dextrose Agar Medium

Potato dextrose agar (PDA) medium was prepared by dissolving 39 g of instant PDA in 1 L of distilled water in an Erlenmeyer flask. The medium was heated until boiling and sterilized in an autoclave at 121 °C and 15 psi for 20 min.

Preparation of Growth Substrate for Antagonistic Fungi and Foc

Millet was used as the growth substrate for fungal inoculum production, following the method developed by Warman and Aitken (2018). A total of 3.2 kg of millet was cleaned and soaked in clean water for 24 h to ensure optimal water absorption. After soaking, the millet was drained, placed into 1 kg polyethylene bags at 150 g per bag, and tied with rubber bands. The millet substrate was sterilized twice in an autoclave at 121 °C for 20 min to eliminate unwanted microorganisms.

Propagation of indigenous antagonistic fungi and Foc inoculum

The antagonistic fungi and Foc inoculum used in the experiment were prepared as propagules on sterilized millet following the method of Warman and Aitken (2018), with minor adjustments. Three fungal colony discs (5 mm in diameter) were transferred into sterilized millet and mixed evenly under a laminar airflow cabinet to minimize contamination. The inoculated millet was incubated at 25–30 °C for 7–14 days and gently mixed daily to ensure uniform colonization. Inoculum density, including conidial concentration, CFU g^{-1}, propagule density, or viability percentage, was not quantified in the present study. Instead, inoculum preparation was standardized based on the number of colony discs, millet weight, incubation period, and amount of colonized millet applied to each experimental unit. Thus, procedural reproducibility was supported by standardized preparation and application steps.

Planting Medium and Test Plants

The planting medium consisted of black Andosol soil collected from a vegetable-growing area without banana cultivation in Alahan Panjang, West Sumatra, mixed with cattle manure at a ratio of 3:1. The soil was sieved using a 50-mm wire sieve to remove roots and coarse materials and to obtain a uniform texture. The medium was placed in 4-kg polybags and left for three days before use. The test plants were two-month-old banana cv. Barangan Merah plantlets derived from tissue culture after acclimatization, with approximately five leaves and a height approximately 10 cm. The plantlets were obtained from PT Hijau Surya Biotechindo, Asahan Regency, North Sumatra. Before the experiment, plantlets were selected based on freshness, healthy roots, and uniform size.

Application of Indigenous Fungi

One day before treatment, the planting medium was watered to field capacity. Two-week-old fungal propagules grown on millet were homogenized by mixing. A total of 15 mL of antagonistic fungal propagules was placed into a hole at the center of the planting medium at a depth of approximately 10 cm. Banana cv. Barangan Merah plantlets were then planted above the fungal inoculum, covered with soil up to the collar region, and gently compacted. The plants were not watered for three days to allow better colonization of the banana roots by the antagonistic fungi according to Warman and Aitken (2018) with slight modification.

***Foc* Inoculation**

Foc TR4 inoculation was performed four weeks after banana planting. One day before *Foc* application, the plants were watered to field capacity. Three holes, each approximately 3 cm in depth and located 3–5 cm from the plant base, were prepared. *Foc* propagules were placed into each hole at 15 mL per hole and then covered with soil, following Warman and Aitken (2018).

Observed Parameters

Incubation period

The incubation period was recorded from one day after *Foc* inoculation until the first appearance of disease symptoms, indicated by yellowing at the margins of older leaves followed by symptoms on younger leaves.

Disease incidence

Disease intensity was assessed on 10 occasions after Foc inoculation. The numbers of wilted or yellowing leaves and total leaves were recorded, and disease intensity was calculated using the following formula:

$$Id = \frac{D}{T}\ x\ 100 \quad \text{..... (1)}$$

Id = Disease incidence (%), D = number of diseased plants, T = Total number of observed plants

Disease intensity

Disease intensity was calculated based on the number of wilted or yellowing leaves. The number of wilted/yellowing leaves was recorded on 10 observations until the end of the observation period. Disease intensity was calculated using the following formula:

$$It = \frac{W}{T}\ x\ 100 \quad \text{..... (2)}$$

It = Disease intensity (%), W = number of wilted/yellowing leaves, T = Total number of observed leaves

The severity categories were determined based on the percentage of wilted/yellowing leaves (Table 1, Figure 1).

Table 1. Disease intensity categories based on wilted leaves (Riska et al., 2012; Jumjunidang et al. 2025)

Wilted leaves (%)	Disease intensity
0	No disease
>0–25	Mild disease
>25–50	Moderate disease
>50-100	Severe disease



Figure 1. Performance of banana cv. Barangan Merah plants showing Fusarium wilt severity categories: A = no disease, B = mild disease, C = moderate disease, and D = severe disease

Plant height

Plant height was measured from 1 cm above the soil surface at the plant base to the intersection point of the two youngest leaves using a ruler. A marker stake was installed to ensure consistent measurement.

Stem circumference

Stem circumference was measured at 1 cm above the soil surface, parallel to the marker stake, using a measuring tape.

Data Analysis

The data were analyzed using analysis of variance (ANOVA), and when significant differences were detected, treatment means were separated using Tukey's test at the 5% significance level. Statistical analysis was performed using Minitab 20.0. All data are presented as means ± standard deviation (SD).

Results

The indigenous antagonistic fungi showed variation in their ability to suppress Fusarium wilt up to seven weeks after *Foc* inoculation. This variation was found in disease incubation period and disease incidence. The longest incubation period occurred in plants treated with *Fusarium* sp. 2, which delayed disease symptom appearance up to 47.33 days after inoculation. Plants treated with *Fusarium* sp. 1 and *Fusarium* sp. 3 showed incubation periods of 32.58 and 38.92 days, respectively, which were slightly longer than the untreated control. The shortest incubation period occurred in *Trichoderma* sp., the unidentified fungus, and *Fusarium* sp. 1, which delayed disease appearance only up to 30.58, 30.92, and 32.58 days, respectively. The indigenous fungi did not significantly reduce the proportion of diseased plants in banana cv. Barangan Merah. Disease incidence reached 100% in most treatments. *Fusarium* sp. 2 showed the lowest numerical disease incidence, 83.33%, but this value was not significantly different from other treatments (Table 2).

Although disease incidence did not differ significantly among treatments, disease intensity differed among the tested indigenous fungi. The lowest disease intensity was observed in plants treated with *Fusarium* sp. 2, with a value of 33.65%, which was not significantly different from *Fusarium* sp. 3, but it was significantly lower than other treatments. The lower disease intensity observed in *Fusarium* sp. 2 and *Fusarium* sp. 3 treatments, where the virulence category of *Foc* pathogen after application of both treatments showed moderate (Table 4), but the underlying mechanism was not directly tested in this study (Table 3).

Table 2. Incubation period and disease incidence of Fusarium wilt in banana cv. Barangan Merah treated with indigenous root-associated fungi at seven weeks after *Foc* inoculation.

Treatment	Incubation period (days)	Disease incidence (%)
A (untreated control)	30.44 ± 4.93 c	100.00 ± 0.00 a
B (*Fusarium* sp. 1)	32.58 ± 4.01 bc	100.00 ± 0.00 a
C (*Fusarium* sp. 2)	47.33 ± 5.01 a	83.33 ± 30.91 a
D (*Fusarium* sp. 3)	38.92 ± 7.48 b	100.00 ± 0.00 a
E (*Trichoderma* sp.)	30.58 ± 4.62 c	100.00 ± 0.00 a
F (Unidentified fungus)	30.92 ± 5.68 c	100.00 ± 0.00 a

Values followed by the same letter in the same column are not significantly different according to Tukey's test at 5%. Data are presented as mean ± SD from four replicates

Table 3. Disease intensity and disease severity category of Fusarium wilt in banana cv. Barangan Merah treated with indigenous root-associated fungi at seven weeks after Foc inoculation.

Treatment	Disease intensity (%)	Category
A (untreated control)	79.05 ± 19.60 a	Severe
B (*Fusarium* sp. 1)	69.07 ± 25.00 ab	Severe
C (*Fusarium* sp. 2)	33.65 ± 13.99 c	Moderate
D (*Fusarium* sp. 3)	48.95 ± 9.39 bc	Moderate
E (*Trichoderma* sp.)	83.66 ± 20.98 a	Severe
F (Unidentified fungus)	79.83 ± 24.33 a	Severe

Values followed by the same letter in the same column are not significantly different according to Tukey's test at 5%. Data are presented as mean ± SD from four replicates

The indigenous root-associated fungi tested in this study did not negatively affect banana plant growth under the experimental conditions. Plant height, stem circumference, and leaf number increase did not differ significantly among treatments at seven weeks after *Foc* inoculation. All treatments showed comparable vegetative growth. The plant height increase ranged from 17.96 to 23.38 cm. Stem circumference increase ranged from 7.28 to 9.93 cm, while leaf number increase ranged from 9.42 to 10.67 leaves (Table 4).

Table 4. Plant height, stem circumference, and leaf number increase in banana cv. Barangan Merah treated with indigenous root-associated fungi at seven weeks after *Foc* inoculation.

Treatment	Plant height increase (cm)	Stem circumference increase (cm)	Leaf number increase (leaves)
A (untreated control)	17.96 ± 6.96 a	7.81 ± 2.40 a	9.91 ± 1.16 a
B (*Fusarium* sp. 1)	22.75 ± 6.52 a	9.04 ± 2.18 a	9.75 ± 1.42 a
C (*Fusarium* sp. 2)	22.25 ± 6.73 a	7.28 ± 1.85 a	9.42 ± 1.93 a
D (*Fusarium* sp. 3)	19.75 ± 8.89 a	7.40 ± 2.35 a	9.75 ± 1.28 a
E (*Trichoderma* sp.)	18.33 ± 7.12 a	9.68 ± 2.56 a	9.75 ± 1.42 a
F (Unidentified fungus)	23.38 ± 7.93 a	9.93 ± 2.86 a	10.67 ± 1.23 a

Values followed by the same letter in the same column are not significantly different according to Tukey's test at 5%. Data are presented as mean ± SD from four replicates.

Consistent with the other disease parameters, plants treated with *Fusarium* sp. 2 showed slower disease development and lower disease intensity than the other treatments. Wilt symptoms appeared more than four weeks after *Foc* inoculation, and disease development remained below 40% up to seven weeks after inoculation. In contrast, the other indigenous fungal treatments delayed symptom appearance only until approximately the fourth week, after which disease development increased sharply (Figure 2).

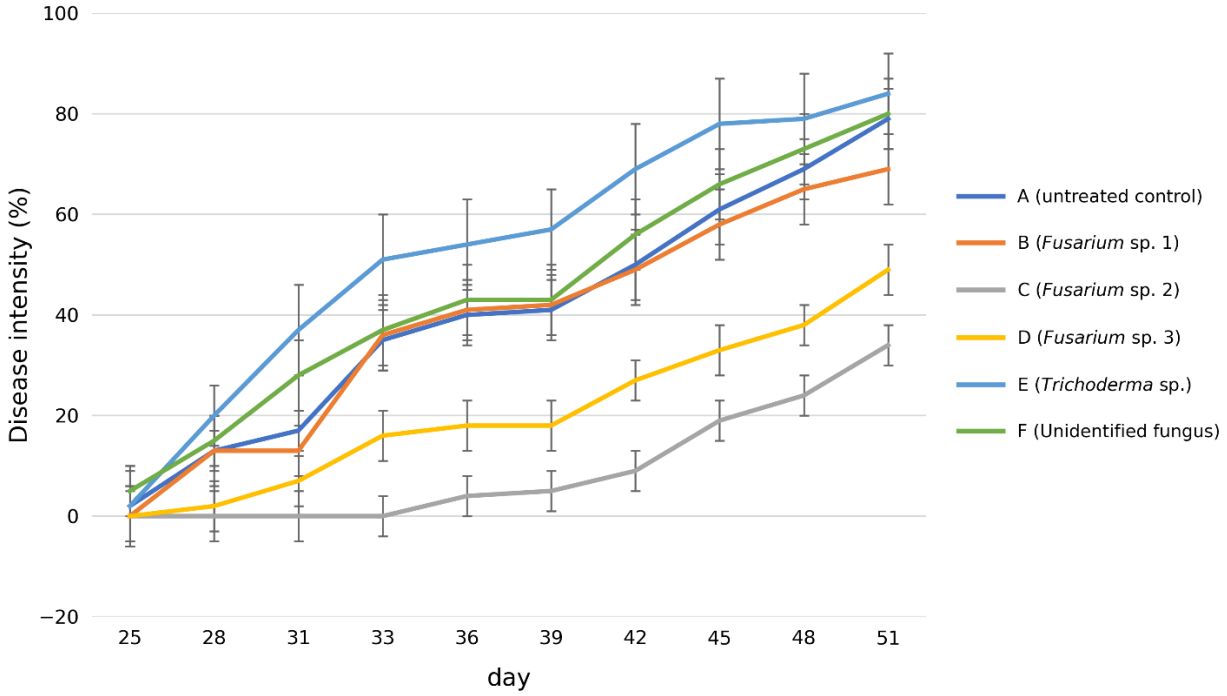


Figure 2. Development of Fusarium wilt in banana cv. Barangan Merah treated with indigenous root-associated fungi up to 51 days after after *Foc* inoculation. Data are presented as mean ± SD from four replicates.

Discussion

In this study, *Fusarium* sp. 2 produced the longest incubation period of Fusarium wilt, delaying symptom appearance to 47.33 days after Foc inoculation. However, disease incidence did not differ significantly among treatments; *Fusarium* sp. 2 showed the lowest numerical disease incidence at 83.33%, while the other treatments reached 100% (Table 2). The distinction is important because disease incidence reflects the proportion of infected plants, whereas the incubation period reflects the time over which symptom expression can be delayed after pathogen inoculation. Thus, Fusarium sp. 2 mainly suppressed early disease development rather than completely preventing infection.

The ability of *Fusarium* sp. 2 to delay symptom onset is relevant to the concept of biological control using microorganisms naturally associated with the host plant's habitat. Endophytic and rhizosphere fungi live in close association with host plants and may exhibit antagonistic activity through secondary metabolite production, antibiotic production, mycoparasitism, competition for nutrients and space, and induction of host resistance (De Lamo and Takken, 2020). Foc is one of the most damaging pathogens of banana, and its management remains difficult due to its persistence in soil and its ability to

infect susceptible cultivars. Recent studies have emphasized that microbial biocontrol remains a promising yet highly context-dependent strategy for managing banana Fusarium wilt, as antagonist performance may vary with microbial identity, host cultivar, pathogen pressure, and environmental conditions (Solórzano et al., 2025; Tran et al., 2026). This finding indicates that selected indigenous root-associated fungi may help slow disease establishment, although the specific mechanism was not directly examined in this study.

Fusarium sp. 2 not only delayed symptom appearance but also reduced final disease severity. In this study, *Fusarium* sp. 2 also showed the lowest disease intensity, at 33.65%. Based on disease severity, *Fusarium* sp. 2 and *Fusarium* sp. 3 were categorized as moderate, whereas *Fusarium* sp. 1, *Trichoderma* sp., and the unidentified fungus were categorized as severe (Table 3). The reduction in disease intensity is biologically important because symptom severity reflects the extent of plant tissue affected by Fusarium wilt. In practical terms, an isolate that reduces disease intensity may help maintain plant condition for a longer period, even when infection still occurs.

Some nonpathogenic Fusarium isolates have been reported to contribute to disease suppression, although their effects are likely to be strain-, host-, and pathogen-specific. Khamidi et al. (2022) reported that endophytic *Fusarium* sp. applied to shallot plants delayed the incubation period of basal rot disease by up to 23 days. In addition, *F. solani* and *F. subglutinans* have been reported to reduce gray mold disease, although the mechanisms involved are not fully understood and may be related to secondary metabolite production (Riska et al., 2026). The lower disease intensity observed in plants treated with *Fusarium* sp. 2 suggests that this isolate may have a disease-suppressive effect, but further confirmation is required to determine whether this effect is due to competition, antibiosis, induced resistance, or other mechanisms.

The disease progress curve showed that plants treated with *Fusarium* sp. 2 developed Fusarium wilt more slowly than plants in the other treatments. Wilt symptoms appeared more than four weeks after Foc inoculation, and disease development remained below 40% up to seven weeks after inoculation. In contrast, the other indigenous fungal treatments delayed symptom appearance only until approximately the fourth week, after which disease development increased sharply (Figure 2). This temporal pattern supports the results presented in Tables 2 and 3, showing that the beneficial effect of *Fusarium* sp. 2 was consistently expressed across three disease-related parameters: a longer incubation period, lower final disease intensity, and slower disease progression. Therefore, *Fusarium* sp. 2 can be considered a promising disease-suppressing agent rather than a complete infection-preventing agent.

The relatively better performance of *Fusarium* sp. 2 may be related to its origin from banana roots. This isolate was obtained from the cortex of Kepok Tanjung banana roots, while the test plant used in this study was banana cv. Barangan Merah. Gómez-Lama Cabanás et al. (2021) reported that Fusarium is among the fungal genera associated with banana roots. Because *Fusarium* sp. 2 originated from a banana root-associated environment, it may have been better adapted to the banana root niche and may have interacted more effectively with the host-associated microbiome. Indigenous fungi are often considered better adapted to their original habitats and may exhibit stronger antagonistic activity in similar environments. De Lamo and Takken (2020) explained that

endophytic Fusarium strains may temporarily induce host immune signaling and papilla formation, whereas pathogenic Fusarium strains may suppress some of these responses. However, root colonization, secondary metabolite production, induced resistance, and papilla formation were not directly measured in the present study. Therefore, these explanations should be interpreted as possible mechanisms or hypotheses that require further confirmation.

Based on Table 4, the application of indigenous root-associated fungi did not significantly affect banana vegetative growth. Plant height increase ranged from 17.96 to 23.38 cm, stem circumference increase ranged from 7.28 to 9.93 cm, and leaf number increase ranged from 9.42 to 10.67 leaves. None of the treatments showed significant differences at seven weeks after Foc inoculation (Table 4). However, the absence of negative effects on plant height, stem circumference, and leaf number indicates that these isolates did not impair early vegetative growth of banana cv. Barangan Merah under Foc-challenged conditions. This is important as a preliminary indication of plant-growth compatibility, particularly for *Fusarium* sp. 2, which showed disease-suppressive potential without reducing vegetative performance.

The lack of a significant growth response may be due to the short observation period, the age of the banana plantlets, disease pressure from Foc inoculation, or the possibility that the isolates primarily affected disease development rather than vegetative growth. Edwards et al. (2025) stated that some fungal endophytes require time to adapt to their environment, and not all applied indigenous fungi immediately influence plant growth. Environmental factors such as humidity, temperature, rainfall, and soil pH may also affect fungal colonization and performance. Ramatsitsi et al. (2023) further explained that unsuitable abiotic conditions can limit fungal development and reduce their ability to produce compounds associated with disease suppression.

Although *Fusarium* sp. 2 showed promising activity in delaying disease onset and reducing disease intensity, several limitations should be considered. Before *Fusarium* sp. 2 can be recommended as a biocontrol agent, further studies should include molecular identification, pathogenicity and safety confirmation, inoculum standardization, root colonization assessment, and field validation. These additional studies are essential because using Fusarium isolates as biocontrol agents requires careful confirmation of their nonpathogenicity, host safety, and stability under field conditions.

Conclusion

The study showed that the application of *Fusarium* sp. 2 delayed the incubation period of Fusarium wilt in banana cv. Barangan Merah to 47.33 days, compared with 30.44 days in the untreated control. *Fusarium* sp. 2 resulted in the lowest disease intensity (33.65%), compared with 79.05% in the untreated control**.** The application of indigenous fungi did not significantly affect plant height, stem circumference, or leaf number under the experimental conditions. *Fusarium* sp. 2 is a promising indigenous biocontrol candidate against Fusarium wilt in banana; however, further molecular identification, pathogenicity, safety confirmation, inoculum standardization, and field validation are required before practical recommendation.

Declaration

Author contribution

Firly Licardo drafted and prepared the manuscript. Riska supervised the study,

revised the manuscript, and handled correspondence. Chrisnawati contributed to methodology and manuscript revision. Aulia Meyuliana assisted with data collection and curation. Jumjunidang contributed to data analysis and validation. All authors read and approved the final manuscript.

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Competing interest

The authors declare that they have **n**o known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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