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Diversity and Morphological Characterization of Fungi in the Mangrove Forest of Belawan, North Sumatra

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Abstract: This study aimed to isolate and morphologically characterize fungi from the mangrove area of Belawan, North Sumatra, to better understand their diversity and potential roles within the ecosystem. Mangrove forests are vital coastal ecosystems that support diverse microbial communities, including fungi, which play essential roles in nutrient cycling and ecosystem stability. This study aimed to isolate and characterize fungal diversity from the Belawan mangrove area, North Sumatra. Sampling was conducted on water and soil, followed by fungal isolation on Potato Dextrose Agar containing 1% NaCl. A total of 15 fungal isolates were obtained—nine from water and six from soil samples. Morphological characterization revealed considerable diversity in colony shape (circular, irregular, filamentous), texture (granular, cottony, velvety), margin (undulate, filiform, entire), and color (green, white, pink, grayish white, black, dark brown). Microscopic examination showed various conidial morphologies, including round conidia that burst open like fans, crescent-shaped conidia, needle-shaped conidia with branched conidiophores, and conidia arranged in chains on phialides. The dominant genus identified was Aspergillus, exhibiting typical macroscopic and microscopic traits. Physical-chemical parameters of the sampling sites indicated stable environmental conditions suitable for mangrove fungi. This study highlights the rich fungal diversity in the Belawan mangrove ecosystem and underscores the ecological importance of fungi in maintaining mangrove health. The results provide a foundation for further molecular identification and exploration of the biotechnological potential of mangrove-associated fungi.
Keywords: Mangrove fungi; morphological characterization; belawan mangrove; soil and water isolates

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INTRODUCTION

Mangrove forests are coastal ecosystems that thrive in intertidal zones, estuaries, and brackish waters across tropical and subtropical regions (Alongi, 2020). In North Sumatra, they cover approximately 15,000,000 hectares and play vital ecological and economic roles. These ecosystems provide essential habitats for diverse flora and fauna, offering spawning, sheltering, and feeding areas (Lee et al., 2014; Nagelkerken et al., 2008). Mangroves also protect coastlines from erosion, storms, and tsunamis, while supporting local communities through the provision of food, fuelwood, and medicinal resources (Alongi, 2014; Akram et al., 2023). Their multifunctional roles make mangroves crucial for biodiversity conservation, coastal resilience, and sustainable livelihoods, highlighting the importance of research on their condition and management (Brown & Djamaluddin, 2017; Hadika & Karuniasa, 2020).

The microbial community within mangrove ecosystems, including bacteria, archaea, fungi, and protists, plays a fundamental role in sustaining primary productivity, facilitating nutrient cycling, and maintaining vegetation health. These microorganisms decompose organic matter into inorganic nutrients, which are then utilized by other organisms in the ecosystem, thereby supporting interconnected food webs. Their presence is indispensable for the stability and productivity of mangrove forests (Bai et al., 2013).

Beyond their ecological functions, the productivity of mangrove ecosystems is strongly supported by microbial communities. Among these, mangrove-associated fungi are particularly significant due to their richness in enzymes and secondary metabolites with diverse applications. Species such as Aspergillus niger, Halocyphina villosa, and Lignicola longirostris have been reported to produce protease and cellulase enzymes, which are valuable in industrial and medical applications (Immaculatejeyasanta et al., 2011). Similarly, fungi isolated from the roots of Avicennia marina, including Acremonium sp., Alternaria chlamydospora, Alternaria sp., Aspergillus sp., Fusarium sp., and Pestalotiopsis sp., were found to produce proteases, highlighting their biotechnological potential (Maria & Sridhar, 2002). Furthermore, fungi from mangrove sediments along the Red Sea coast of Saudi Arabia, such as Alternaria alternata, Aspergillus terreus, Cladosporium sphaerospermum, Eupenicillium hirayamae, and Paecilomyces variotii, were shown to utilize petroleum as the sole carbon source, produce extracellular enzymes, and release significant amounts of CO_2, demonstrating their potential for bioremediation (Ameen et al., 2016).

Mangrove ecosystems harbor a diverse array of fungi with significant biotechnological potential. Endophytic fungi from Avicennia marina in West Java, Indonesia, including Cladosporium anthropophilum, Penicillium chrysogenum, and Fusarium verticillioides, demonstrated strong antibacterial activity against Staphylococcus aureus and Vibrio harveyi (Mulyani et al., 2023). Filamentous fungi isolated from mangrove sediments, such as Aspergillus, Penicillium, and Trichoderma, showed the ability to degrade low-density polyethylene microplastics, with Aspergillus sp. (AQ3A) reducing 47% of polymer mass (Aguiar et al., 2024). Additionally, Trichoderma sp. (MG-07) from decaying mangrove wood in East Kalimantan effectively degraded 20%–80% of aliphatic compounds in crude oil under saline conditions, highlighting its potential for marine bioremediation (Sitompul *et al*., 2024). Collectively, these studies underscore the rich fungal diversity in mangroves and their versatile applications in biotechnology, including antimicrobial production and environmental remediation.

Despite numerous studies worldwide, data on fungal diversity in Indonesian mangroves, particularly in Belawan, North Sumatra, remain limited. This study aims to isolate and characterize fungi from the Belawan mangrove forest to provide baseline information on their diversity and ecological roles.

METHOD

This study was conducted from June 2024 to March 2025 in the Microbiology Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Medan. Sample collection was carried out in the Belawan mangrove area, North Sumatra, as shown in Figure 1.

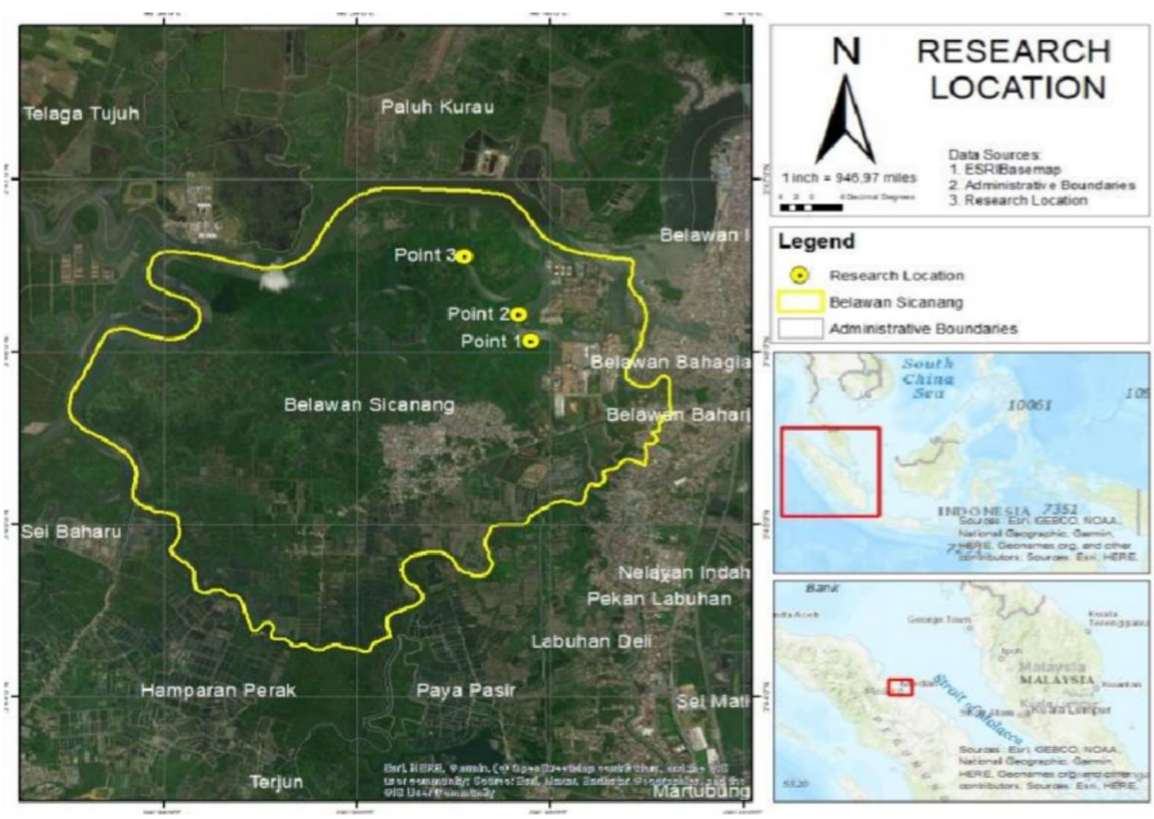


Figure 1. Map of the research location in the Belawan area, North Sumatra.

The equipment used in this study included a GPS, thermometer, pH meter, refractometer, autoclave, oven, biosafety hazard cabinet, fungal incubator, spectrophotometer, centrifuge, cork borer (6 cm), and microscope. The materials used consisted of 1% NaCl, Potato Dextrose Agar (PDA) medium, chloramphenicol, lactophenol blue, microscope slides, and cover slips.

Collection of Samples

The physical and chemical parameters of the waters that were tested included water pH, soil pH, salinity, water temperature, soil temperature, and turbidity. The measurement of physicochemical factors was carried out in situ. Water and soil samples were immediately transported to the laboratory and stored at 4°C until further analysis. All samples were used for fungal isolation.

Isolation and Purification of Fungal from The Mangrove Area of Belawan

Collections water and soil sampling is conducted in the Mangrove forest area of Belawan total of 100 ml of water is collected using sterile bottles, while 100 grams of soil are taken and placed into sterile clip bags. The water and soil samples are placed in a cool box and brought to the laboratory. The water and soil samples are diluted up to 10-5, 0.1 ml sample of the diluted water and soil is inoculated Potato Dextrose Agar medium (PDA) containing 1% NaCl using the spread plate method. The culture is incubated at 27°C for 3–5 days. Once fungal colonies appeared, they were purified on PDA medium.

Characterization of Fungal Isolates from The Mangrove Area of Belawan

Fungal isolate characterization was carried out both macroscopically and microscopically. Macroscopic observations included colony shape, texture, elevation, margin, and colour. Microscopic examination was performed using the fungal block square method. A square block of PDA medium was placed on a glass slide, a small amount of fungal culture was inoculated onto the medium, then covered with a sterile cover glass and incubated for 48 hours. After incubation, the cover glass was transferred to a new slide containing a drop of lactophenol blue and observed under a microscope at 40x magnification.

RESULTS AND DISCUSSION

Physical and Chemical Analysis of Water and Soil in Belawan

Summarizes the physical and chemical characteristics of soil and water samples collected from three different stations within the Belawan mangrove area.

Table 1. Physical–chemical data of soil and water samples in the belawan mangrove area at three sampling points

Parameter	Unit	Stastion 1	Stastion 2	Stastion 3
Water pH	-	6,8	6,8	7,0
Salinity	%	1,4	1,5	1,0
Water Temperature	ºC	28,6	28,7	29,5
Turbidity	NTU	1,54	1,57	2
Soil pH	-	6.7	6.7	6.8
Soil Temperature	ºC	24.4	24.6	25.3

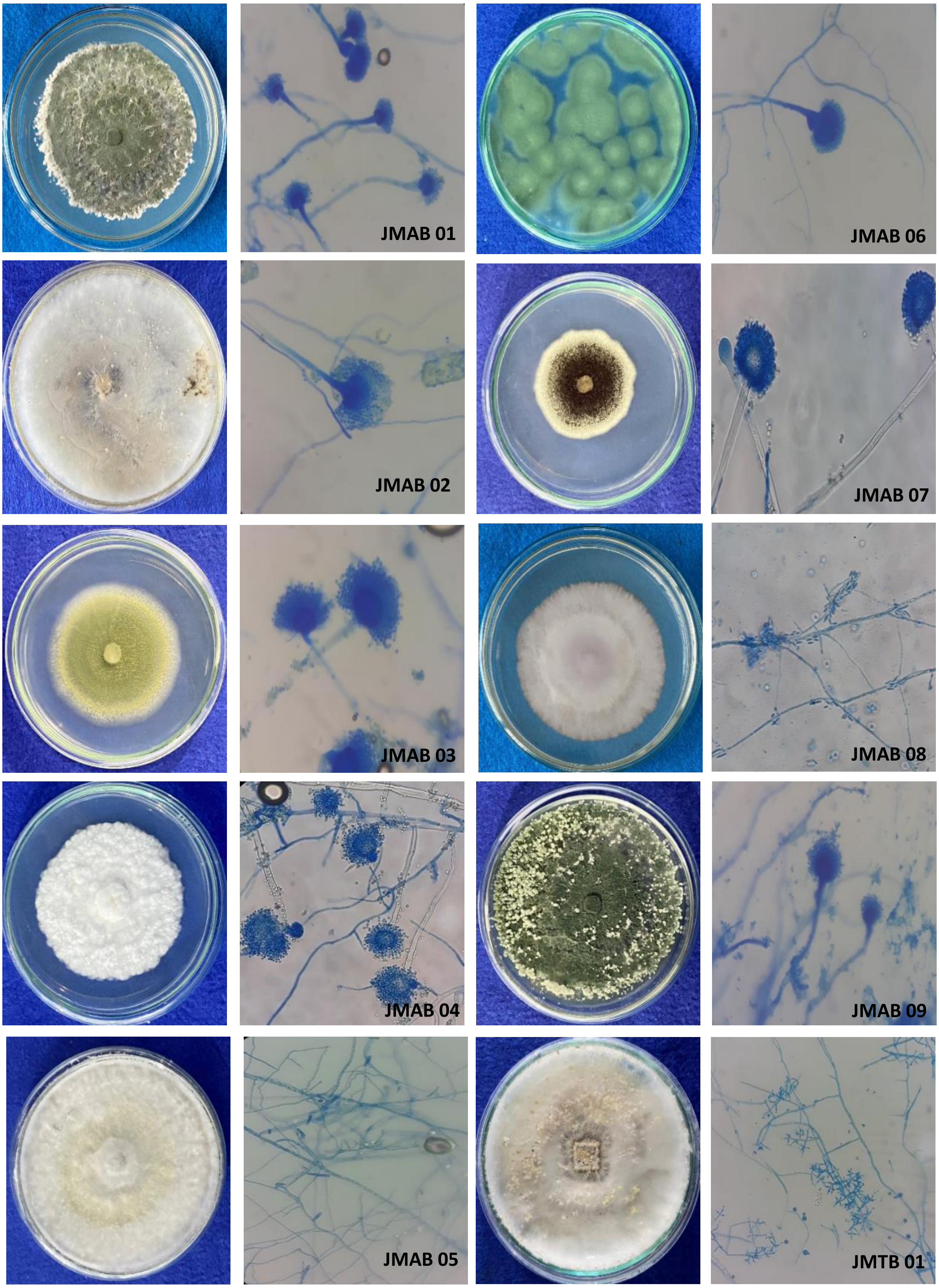
The results show that water and soil conditions in the Belawan mangrove area are generally stable. Water pH (6.8–7.0), salinity (1.0–1.5%), and temperature (28.6–29.5°C) fall within normal ranges for brackish mangrove environments. Low turbidity indicates minimal sediment disturbance. Soil pH (6.7–6.8) and temperature (24.4–25.3°C) are also consistent with typical mangrove soil and water. Overall, all parameters suggest that the area remains ecologically suitable for mangrove growth with only slight variations between stations.

Rahmawati et al. (2023) Environmental factors such as temperature, season, salinity, pH, and oxygen influence fungal abundance in mangrove soils. Temperature strongly affects fungal diversity by regulating microbial metabolism, growth, and reproduction. Warmer conditions increase ecosystem productivity and provide more organic substrates, resulting in higher microbial diversity. Higher temperatures also speed up decomposition and nutrient availability.

Rousk & Baath (2011), Soil pH strongly influences fungal presence in mangrove sediments, as each species has a different tolerance range. Mangrove soils typically range from slightly acidic (6–7) to alkaline (7–10). Most molds grow well between pH 4.5–8.5, with optimal growth near pH 4.5, and their growth decreases below this level. Compared to bacteria, molds tolerate lower pH because phospholipid fatty acids (PLFAs) help maintain membrane stability and support adaptation in harsh conditions.

Fungi isolated from mangrove

A total of nine fungal isolates were obtained from water samples and six isolates from soil samples collected from the Belawan mangrove area. The colony morphology was predominantly circular and irregular in shape. The dominant colony textures were cottony and velvety, with undulate margins being the most commonly observed among the isolates. Colony colors varied widely, including green, white, pink, grayish white, and black.


JMAB 01
JMAB 06
JMAB 02
JMAB 07
JMAB 03
JMAB 08
JMAB 04
JMAB 09
JMAB 05
JMTB 01

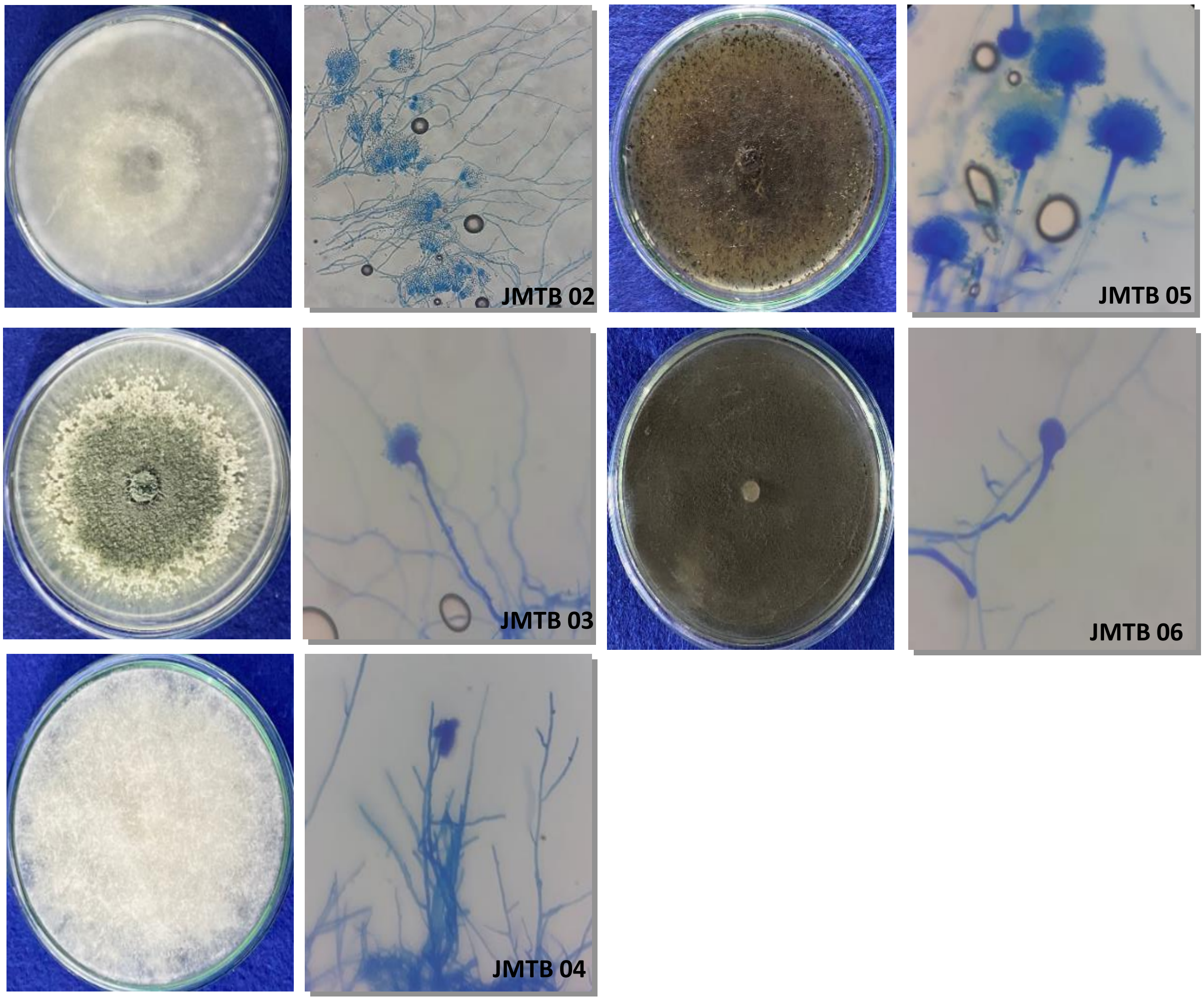


Figure 2. Microscopic and Macroscopic Features of Fungal Isolates from the Mangrove Area of Belawan

Fungal isolation on PDA medium from the Belawan mangrove area 15 fungal isolates. The fungal isolates exhibited diversity in colony shape, texture, margin, colour, and conidia morphology (Table 2).

Table 2. Macroscopic and microscopic characteristics of fungi from mangroves, Belawan

No	Isolates	Morphological Characteristics of The Fungal Isolate					
		Macroscopic				Microscopic	Genus
		Shapes	Textures	Margins	Surface colours		
1.	JMAB 01	Circular	granular	Filiform	Dark green	Round conidia then burst open like fans	*Aspergillus*
2.	JMAB 02	Irregular	Cottony	Undulate	Grayish white	Round conidia then burst open like fans	*Aspergillus*
3.	JMAB 03	Filamentous	Granular	Filiform	Green	Round conidia then burst open like fans	*Aspergillus*
4.	JMAB 04	Irregular	Granular	Entire	White	Round conidia then split open like a fan	*Aspergillus*

No	Isolates	Morphological Characteristics of The Fungal Isolate					
		Macroscopic				Microscopic	Genus
		Shapes	Textures	Margins	Surface colours		
5.	JMAB 05	Circular	Cottony	Undulate	Grayish white	Conidia are crescent-shaped	*Fusarium*
6.	JMAB 06	Irregular	Granular	Undulate	Dark green	Round conidia then split open like a fan	*Aspergillus*
7.	JMAB 07	Circular	Velvety	Entire	Black	Round conidia then split open like a fan	*Aspergillus*
8.	JMAB 08	Irregular	Cottony	Undulate	Pink	Conidia are crescent-shaped	*Fusarium*
9.	JMAB 09	Irregular	granular	Undulate	Dark green	Round conidia then split open like a fan	*Aspergillus*
10.	JMTB 01	Irregular	Granular	Filiform	Greenish white	Conidia are needle-shaped, and the conidiophores are branched	*Trichoderma*
11.	JMTB 02	Circular	Granular	Undulate	White	Conidia are arranged in chains on phialides, conidiophores are branched	*Clonostachys*
12.	JMTB 03	Irregular	Granular	Undulate	Greenish white	Round conidia then split open like a fan	*Aspergillus*
13.	JMTB 04	Filamentous	Cottony	Undulate	White	Conidiophores are branched	-
14.	JMTB 05	Circular	Velvety	Undulate	Dark brown	Round conidia then split open like a fan	*Aspergillus*
15.	JMTB 06	Irregular	Granular	Undulate	Green	Round conidia then burst open like fans	*Aspergillus*

The morphological characterization of fungal isolates from the mangrove ecosystem in Belawan revealed significant diversity in both macroscopic and microscopic features. Macroscopically, the isolates exhibited various colony shapes such as circular, irregular, and filamentous, accompanied by different textures including granular, cottony, and velvety. The colony margins ranged from filiform and undulate to entire, while surface colors varied widely, with dark green, grayish white, green, white, black, pink, greenish white, and dark brown among the observed hues. These variations reflect the heterogeneous fungal community adapted to the mangrove environment. Microscopically, the majority of isolates produced round conidia that often appeared to burst open like fans, a trait typical of certain fungal genera such as Aspergillus. Some isolates displayed crescent-shaped conidia characteristic of Fusarium, while others exhibited needle-shaped conidia with branched conidiophores or conidia arranged in chains on phialides, features commonly associated with Clonostachys. This morphological diversity not only confirms the presence of multiple fungal species but also underscores the ecological complexity within mangrove habitats. Such diversity is crucial for ecosystem functioning, as fungi contribute to organic matter decomposition and nutrient cycling. Furthermore, the distinct morphological traits suggest potential for biotechnological applications, consistent with previous studies highlighting mangrove fungi as sources of valuable enzymes and metabolites. This morphological assessment lays the groundwork for further molecular analyses to accurately identify the fungal species and explore their functional roles in mangrove ecosystems.

Khalil et al. (2013) reported the presence of fungi belonging to the genera Absidia, Alternaria, Aspergillus, Cladosporium, Paecilomyces, Penicillium, and Trichoderma. Among these, the genus Aspergillus was the most prevalent, with A. flavus occurring at a frequency of 100%, followed by A. niger at 95.8% and A. fumigatus at 58.3%. This predominance of Aspergillus species underscores their ecological importance and their ability to thrive in mangrove and other coastal habitats.

Rahmawati et al. (2023) Fungal identification is carried out through morphological characterization, including macroscopic and microscopic observations, physiological profiling, and molecular analysis. A total of 102 fungal species belonging to 33 different genera have been successfully isolated from mangrove soils, including Acrophialophora, Absidia, Acremonium, Alternaria, Aspergillus, Botrytis, Chaetomium, Chrysonilia, Cephalosporium, Cladosporium, Coelomycetes, Curvularia, Dendrophion, Drechslera, Eupenicillium, Fusarium, Gliocladiopsis, Graphium, Monilia, Mucor, Paecilomyces, Penicillium, Phoma, Rhizopus, Sporothrix, Scopulariopsis, Stachybotrys, Synchepalastrum, Thamnidium, Trichoderma, Trophyton, Ulocladium, and Verticillium. The majority of fungi isolated from mangrove soils belong to the Ascomycota phylum, likely due to the ability of their spores to adapt to the unique conditions of the mangrove substrate.

The dominant fungal isolates identified as Aspergillus from mangrove soils exhibit diverse macroscopic and microscopic characteristics. Macroscopically, their colony shapes range from circular to irregular and filamentous, with textures varying from granular, cottony, to velvety. Colony margins are mostly undulate or filiform, and surface colors include dark green, grayish-white, green, white, black, pink, and dark brown. Microscopically, Aspergillus isolates are characterized by round conidia that typically burst open like fans or split open resembling a fan, with some conidia appearing crescent-shaped or needle-shaped. Conidiophores often exhibit branching, and phialides are present, with conidia arranged in chains along these structures. These morphological features are consistent with known characteristics of the Aspergillus genus.

The genus Aspergillus was identified based on observed macroscopic and microscopic morphological characteristics. Colony colors of the isolates ranged from gray, green, brown, white, black, to brownish-gray on PDA medium at 27°C. The colonies exhibited rapid growth, appearing by the third day, and had a powdery texture. Members of the genus Aspergillus are distinguished by common features of asexual reproductive structures, including the formation of vesicles and septate hyphae. Phialides are flask-shaped and cover the surface of the vesicles, while conidia are produced in radial chains on top of the phialides (Makhubela et al., 2017).

CONCLUSION

Based on the research findings, a total of 15 fungal isolates were obtained from the Belawan mangrove area, comprising nine isolates from water samples and six isolates from soil samples. These isolates exhibited considerable morphological diversity in colony shape, texture, margin, and color, reflecting the complexity of the fungal community in the mangrove ecosystem. Colony shapes were predominantly circular and irregular, with cottony and velvety textures and mostly undulate margins, while colony colors varied widely, including green, white, pink, grayish white, black, and dark brown. Microscopically, the isolates displayed diverse conidial morphologies such as round conidia bursting open like fans, crescent-shaped conidia, needle- shaped conidia with branched conidiophores, and conidia arranged in chains on phialides. Among these isolates, the dominant genus was Aspergillus, characterized by typical macroscopic and microscopic features consistent with its identification. This morphological diversity indicates a well-adapted and ecologically important fungal community in the mangrove environment, which warrants further molecular studies to accurately identify the species and assess their ecological and biotechnological roles.

RECOMMENDATION

It is recommended to perform molecular identification of the fungal isolates to confirm species, investigate their ecological roles and enzymatic activities, and explore their biotechnological potential. Long-term monitoring of fungal diversity and mangrove environmental conditions is also suggested to support conservation and sustainable use of the Belawan mangrove ecosystem.

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