BIOTECHNOLOGICAL AND PHARMACEUTICAL POTENTIAL OF MANGROVE ENDOPHYTES FROM THE SUNDARBANS, BANGLADESH: A REVIEW

Bioresearch Communications
Volume 12, Issue 1, January 2026

DOI:
doi.org/10.3329/brc.v12i1.86780

Sunzida Akter Eva#, Sadia Sultana#, Md. Alomgir Hossain# and Mohammad Nazir Hossain*

Department of Genetic Engineering and Marine Biotechnology, Bangladesh Maritime University, Dhaka-1216, Bangladesh

#Contributed equally

ABSTRACT

Mangrove endophytes have significant potential across medicine, agriculture, and industry due to their ability to adapt to extreme conditions, resulting in the production of unique compounds, including secondary metabolites, enzymes, and phytohormones. They show promise as sources of new drugs for various diseases, including cancer and infections, as well as agents for agricultural use, such as biocontrol and plant growth promotion, and can also produce valuable industrial enzymes. Mangrove Endophytes are Unique because they are adapted to harsh conditions, including high salinity and waterlogged, anoxic soil. This adaptation drives them to produce unique metabolites and enzymes to survive and compete in their challenging environment. The Sundarbans in Bangladesh is the world's largest contiguous mangrove forest, an expansive delta region formed by the confluence of the Ganges, Brahmaputra, and Meghna rivers. This unique and dynamic ecosystem is a UNESCO World Heritage site and a biosphere reserve, renowned for its incredible biodiversity. The Sundarbans is a significant source of endophytes, especially fungal endophytes, because its harsh, unique ecosystem pressures symbiotic microorganisms to produce a wide range of potent bioactive compounds. Research on Sundarbans endophytes is an area of growing interest, particularly for discovering new antimicrobial agents and exploring their potential in agriculture. Despite the significant potential, research into mangrove endophytes of the Sunderbans is still in its early stages. Many species remain unexplored, and further investigation is needed to fully understand their ecological roles and harness their full potential. The use of advanced molecular techniques and innovative cultivation methods, such as epigenetic modification and co-cultivation, is expected to reveal even more valuable metabolites for future applications. The biotechnological and medicinal potential of mangrove endophytes from Bangladesh's Sundarbans is discussed in this review. These endophytes can be used to create powerful new medications, enzymes, biodiesel, biopesticides, and many other products.

KEYWORDS: Sunderbans, Mangrove, Endophytes, Bacteria, Fungi

RECEIVED: 10 September 2025, ACCEPTED: 18 November 2025

TYPE: Review Article

***CORRESPONDING AUTHOR: Mohammad Nazir Hossain, Department of Genetic Engineering and Marine Biotechnology, Bangladesh Maritime University, Dhaka-1216, Bangladesh.**
Email: nazir.geb@bmu.edu.bd

Introduction

The Sundarbans are one of the world's largest mangrove forests. It is listed as a world heritage site by UNESCO (UNECSO, 2024). Bangladesh and India are the two countries that divide the Sundarbans mangrove forest. It covers around 10,000 square kilometers; about 60% of it is in Bangladesh, and the rest is in India. Situated at the delta of the Ganges, Brahmaputra, and Meghna rivers, forming a dynamic river ecosystem that is rich in biodiversity.(Giri et al., 2007).The Sundarbans is rich in biodiversity, with over 334 plant species and a diverse range of animals, including 291 aquatic species and over 375 wildlife species.(Haque & Islam, n.d.)but its microbial diversity remains underexplored, especially endophytes (Iftekhar & Saenger, 2008).

Endophytes are microorganisms that live inside plant tissues without harming them. They are primarily bacteria and fungi(Strobel & Daisy, 2003). They may be isolated from any tissue section of the host plant, including the root, stem, leaf, lower buds, and more (Debbab et al., 2012).They and their host plants frequently develop symbiotic partnerships in challenging environments. (Strobel & Daisy, 2003) which includes changing salinity, pH, temperature, tidal changes, water currents and winds, and less oxygen-rich soil (Debbab et al., 2012). The endophytes that are most commonly observed are fungi. Endophytes are considered a significant source of genetic variation and produce useful bioactive compounds.(Strobel & Daisy, 2003). Bioactive compounds are secondary metabolites, including alkaloids, phenolic acids, quinones, steroids, saponins, tannins, and terpenoids etc (Gouda et al., 2016a).

Potential candidates with antibacterial, anti-insect, anticancer, and other bioactive qualities are produced by endophytes. Additionally, these endophytic microorganisms are a valuable source for drug developmen.(Gouda et al., 2016a). This includes the creation of other useful goods, such as enzymes, nutraceuticals, and cosmetics (Imhoff et al., 2011).Several studies show that Mangrove endophytic microbes have a great deal of medicinal potential because they produce bioactive compounds that have antimicrobial, cytotoxic, antioxidant, and anticancer effects.(Zhou et al., 2022)(Izzati et al., 2020a)10(Article et al., 2012)(Sandrawati et al., 2023).The potential of endophytic fungal secondary metabolites as anticancer drugs has been shown by their significant cytotoxic activity against cancer cell lines, including skin (A431), breast (MCF-7), cervical (HeLa), and lung (A549)(Kamat et al., 2020).This review is to investigate the biotechnological and pharmaceutical potential of endophytic microbes associated with mangrove ecosystems, with particular focus on the Sundarbans region of Bangladesh.

The Ecosystem of Sundarbans

The physical environment

The Sundarbans are located in the tropical region (Figure 1). The four main seasons in the Sunderbans are pre-monsoon, monsoon, post-monsoon, and dry winter. The mean annual rainfall inside the forest ranges from around 2000 mm in the east to 1600 mm in the west, with the amount of rainfall increasing from west to east. At Shatkhira in the west Sundarbans, the average annual maximum temperature has been measured at 31.30 °C. Between Shatkhira and Patuakhali, the mean annual relative humidity ranges from 70% to 80%. The pH of the soil ranges from 6.5 to 8, making it slightly alkaline to neutral(Choudhury et al., 2001).

Figure 1. Map of Sundarbans Source: Wikimedia.org

Wetlands of the Sundarbans

There are over 450 rivers in the Bangladesh Sundarbans Mangrove Forest (BSMF), including estuaries, creeks, and canals (Figure 2). The total area of these waterbodies is approximately 12,000 km² of waterways, with seasonal variations between 1757 (Volume, 2010) and 1864 km². (Khan, 2011)The majority of freshwater sources in Bangladesh come from stream flow through the Ganges, Bahmaputra, and Surma-Kushiara Rivers, which originate in the Himalayas(Parkinson, n.d16.However, upstream water diversion at the Farakka Barrage has significantly decreased freshwater inflow. As a result, the structure and health of the wetland ecosystem have changed due to increasing salinity, changes in sedimentation, and a decrease in water volume during the dry season (Khan, 1983). The wetlands of the Sundarbans are also distinguished by tidal activity. With typical tidal heights between 1.56 and 2.86 meters, the area sees semidiurnal tides, which peak during the monsoon season (Aziz & Paul, 2015).

Figure 2. Wetlands of Sundarbans Source: Photo taken by the author(s)

Mangroves of the Sundarbans

The total area of the Sundarbans mangrove forest is 6,017 km ^{2} (Aziz & Paul, 2015).Sundarbans has a rich biodiversity of 334 plant species(Iftekhar & Saenger, 2008)4 (Chaffey, et al., 1985)listed 230 (Siddiqui, 2009) species, and out of the 70 mangrove species found worldwide, 28 are found in Bangladesh. It was found that eight major plants in the Bangladesh Sundarbans mangrove forest produce the various forest types: Heritiera fomes, Bruguiera gymnorhiza, Sonneratia apetala, Xylocarpus mekongensis, X. granatum, and Excoecaria agalocha (Chaffey, et al., 1985).Table 1 shows the list of plants in Sunderbans.

(a)

(b)

Figure 3. (a)Aerial Root (Source: Image capture by the author(s) during sample collection in Sundarbans, Bangladesh) and (b) Stilt Root of Sundarbans, Bangladesh (Source: flickr.com)

Table 1. Plant list of Sundarbans in Bangladesh (Siddiqui, 2019)

Sl. No.	**Scientific Name**	**Family**	**Vernacular Name**	**Type of Plant**
1.	*Acacia nilotika* Willd.	Leguminosae	Babla	Tree
2.	*Acalypha godseffiana* Linn.	Euphorbiaceae	Muktajhuri	Small shrub
3.	*Acalypha indica* Linn.	Euphorbiaceae	Muktajhuri	Small herb
4.	*Acanthus ilicifolius* Linn.	Acanthaceae	Hargoza	Scrambling, thorny herb
5.	*Achyranthes aspara* Linn.	Amaranthaceae	Upang	Rough chaff shrub
6.	*Acrostichum aureum* Linn.	Polypodiaceae	Hodo, Tiger fern	Gregarious fern
7.	*Aegialitis rotundifolia* Roxb.	Plumbaginaceae	Dhalchaka	Small tree
8.	*Aegiceras corniculatum* Bl.	Myrsinaceae	Khalisha, khalshi	Shrub or small tree
9.	*Aeschynomene aspara Linn.*	Leguminosae	Joloz Shola	Grass
10.	*Aeschynomene indica* Linn.	Leguminosae	Joloz Shola	Grass
11.	*Albizia lebbeck* Benth.	Leguminosae	Kala koroy	Tree
12.	*Albizia procera* Benth.	Leguminosae	Sada koroy	Tree
13.	*Albizia richardiana* King & Prain	Leguminosae	Raj koroy	Tree
14.	*Amaranthus spinosus* Linn.	Amaranthaceae	Kantanote	Small spinus shrub
15.	*Amoora cucullata* Roxb.	Meliaceae	Amur	Small tree
16.	*Aponogeton natans* Engl.	Apongotonaceae	Swampy herb	Swampy herb
17.	*Argemone mexicana* Linn.	Papaveraceae	Shialkanta	Thorny weed
18.	*Argemone mexicana* Linn.	Papaveraceae	Shialkata	Thorny herb
19.	*Asparagus racemosus* Linn.	Lilliaceae	Satamuli	Climber
20.	*Avicennia officinalis* Linn.	Avicenniaceae	Baen	Tree
21.	*Avicennia alba* Bl.	Avicenniaceae	Morcha baen	Small tree
22.	*Avicennia marina* Vierh.	Avicenniaceae	Sada baen	Small tree
23.	*Barringtonia acutangula*	Barringtoniaceae	Hijal	Small tree

	Gaertl.			
24.	*Barringtonia racemosa* Spreng.	Barringtoniaceae	Kumba, kumbi	Small tree
25.	*Blumea lacera* Burm.	Compositae	Bon gash	Aromatic herb
26.	*Boerhaavia diffusa* Linn.	Nyctaginaceae	Punarnava	Small herb
27.	*Borassus flabellifer* Linn.	Palmae	Tal	Palm tree
28.	*Bouea burmanica* Griff.	Anacardiaceae	Muriam	Small tree
29.	*Brownlowia tersa* Benth.	Tiliaceae	Sundri lata	Scandent shrub
30.	*Bruguiera gymnorrhiza Lamk.*	Rhizophoraceae	Kankra	Tree
31.	*Bruguiera parviflora* W. \& A.	Rhizophoraceae	Kankra	Tree
32.	*Bruguiera sexangula* Lam.	Rhizophoraceae	Kankra	Medium tree
33.	*Buettneria herbacea* Roxb.	Sterculiaceae	Kamraj	Climber
34.	*Buettneria pilosa* Roxb.	Sterculiaceae	Harjora	Climber
35.	*Caesalpina crista* Linn.	Leguminosae	Kutum katta	Scandent, armed shrub
36.	*Caesalpina sappan* Linn.	Caesalpinoidae	Gulmo	Scandent, armed shrub
37.	*Calamus tenuis* Roxb.	Palmae	Bet	Climber
38.	*Calophyllum inophyllum* Linn.	Guttiferae	Puinal	Small tree
39.	*Calotropis procera* Br.	Asclepiadaceae	Akanda	Shrub with coppices
40.	*Cassia alata* Linn.	Leguminosae	Dadmordon	Shrub
41.	*Cassia fistula* Linn.	Leguminosae	Sonalu	Medium tree
42.	*Cassia occidentalis* Linn.	Leguminosae	Kalkasunda	Shrub
43.	*Cassia sophera* Linn.	Leguminosae	Kalkisinde	Shrub
44.	*Casuarina littorea* Linn.	Casuarinaceae	Jhau	Tree
45.	*Cayratia padata* Linn.	Vitaceae	Gulialata	Climber
46.	*Cayratia trifoliate* Linn.	Vitaceae	Amal lata	Climber
47.	*Celosia argentea* Linn.	Amaranthaceae	Swampy weed	Weed
48.	*Celosia cristata* Linn.	Amaranthaceae	Swampy weed	Herb
49.	*Centala asiatica Linn.*	Unbellifera	Thakuni	Small creeper
50.	*Cerbera manghas* Gaertn.	Apocynaceae	Dagor	Small tree
51.	*Ceriops decandra* Griff.	Rhizophoraceae	Goran	Small tree with coppices
52.	*Ceriops tagal* Robins.	Rhizophoraceae	Moth goran	Small tree with coppices
53.	*Cissus quadrangularis* Linn.	Vitaceae	Harvhanga lata	Climber
54.	*Cissus Repens* Lam.	Vitaceae	Marmaria lata	Climber
55.	*Clerodendrum viscosum* Vent.	Verbenaceae	Ghetu	Herb
56.	*Clerodendrum inerme* Gaertn.	Verbenaceae	Sitka, sitki	Scandent shrub
57.	*Coccinia cordifolia* Cogn.	Cucurbitaceae	Telakuchha	Climber
58.	*Coix lachrymajobi* Linn.	Gramineae	Kunce	Weed
59.	*Colocasia nymphaeifolia* Kunt.	Araceae	Jongli Kachu	Herb
60.	*Crotolaria saltiana* Andr.	Papilionoideae	Jhunjana	Shrub
61.	*Croton bonplandianum*	Euphorbiaceae	Putri	Weed
62.	*Curcuma zedoira* Rose.	Zingiberceae	Sothi	Tuber-like herb
63.	*Cuscuta reflexa* Roxb.	Convolvulaceae	Swarnolata	Parasite
64.	*Cymbopogon martini* Roxb.	Graminae	Gandhabena	Herb
65.	*Cynodon dactylon* Linn.	Graminae	Durba grass	Grass

66.	*Cynometra ramiflora* Linn.	Leguminosae	Shingra	Shrub
67.	*Cyperus corymbosus* Roxb.	Cyperaceae	Bon Mathi	Grass-like herb (sedge)
68.	*Cyperus difformis* Linn.	Cyperaceae	Behua	Fodder grass
69.	*Cyperus iria* Linn.	Cyperaceae	Motha grass	Grass
70.	*Dalbergia candenatensis* Prain.	Leguminosae	Chanda lota	Scrambling climber
71.	*Dalbergia spinosa* Roxb.	Leguminosae	Kalilota	Scandent, armed shrub
72.	*Datura fastuosa* Linn.	Solanaceae	Dhutra	Shrub
73.	*Datura innoxia* Mill.	Solanaceae	Dhutra	Shrub
74.	*Delima sarmentosa* Linn.	Dilleniaceae	Salia lata	Climber
75.	*Dendrophthoe falcate* Ett.	Loranthaceae	Porgassa	Woody parasite in tree crown
76.	*Derris sinuata* Benth.	Leguminosae	Mahajonilata	Climber
77.	*Derris scandens* Benth.	Leguminosae	Pan lota	Climber
78.	*Derris trifoliata* Lour.	Leguminosae	Gila lota	Climber
79.	*Diospyros peregrina* Gur.	Ebenaceae	Gub	Tree
80.	*Doemia extensa* Linn.	Asclepiadaceae	Dodhi lata	Climber
81.	*Drypetes roxburghii* Hur.	Euphorbiaceae	Achet	Scandent shrub
82.	*Echinochloa colonum* Link.	Graminae	Grass	Herb
83.	*Eclipta alba* Hassk.	Compositae	Keshraj	Herb
84.	*Eichornia crassipes* Solms.	Lemnaceae	Kachuripana	Floating species
85.	*Eleocharis* sp.		Jol Ghash	Basket making grass
86.	*Emilia sonchifolia* DC.	Compositae	Sadhimodi	Herb
87.	*Entada phaseoloides* Merr.	Leguminosae	Gila lata	Climber
88.	*Equisetum arvense* Roxb.	Equisitaceae	Calamophyta	Horse tail fern
89.	*Equisetum debile* Roxb.	Equisitaceae	Calamophyta	Horse tail fern
90.	*Eriochloa procera* Hubb.	Graminae	Nol gash	Grass
91.	*Erythrina variegate* Linn.	Leguminosae	Bonmander	Soft thorny tree
92.	*Eugenia fruticosa* Roxb.	Myrtaceae	Ban jam	Small tree
93.	*Eugenia lanceafoiia* Roxb.	Myrtaceae	Pania jam	Medium tree
94.	*Eugenia operculata* Roxb.	Myrtaceae	Tepa jam	Medium tree
95.	*Eupatorium odoratum* Linn.	Compositae	Asamlota	Climber
96.	*Euphorbia antiquorum* Linn.	Euphorbiaceae	Dudhia	Herb
97.	*Euphorbia nivulia* Ham.	Euphorbiaceae	sij	Shrub
98.	*Excoecaria agallocha* Linn.	Euphorbiaceae	Gewa	Tree
99.	*Excoecaria indica* Muell.	Euphorbiaceae	Batla, batul	Small tree
100.	*Ficus bengalensis* Linn.	Moraceae	Bot	Tree
101.	*Ficus hispida* L.F.	Moraceae	kakdumur	Tree
102.	*Ficus microcarpa* La.	Moraceae	Jir	Tree with aerial roots
103.	*Ficus racemosa* Linn.	Moraceae	Jogdumur	Tree
104	*Flagellaria indica*	Flagellariaceae	Abetaa	Climber
105	*Flueggea mycocarpa* Bl.	Euphorbiaceae	Sitka, sitki	Scandent shrub
106	*Girardiana heterophylla* Decene.	Urticaceae	Gulmo	Shrub
107	*Hedyotis corymbosa* Linn.	Rubiaceae	Khetpapra	Grass
108	*Heritiera fomes* Buch.-Ham.	Sterculiaceae	Sundri	Tree
109	*Hibiscus tiliaceus* Linn.	Malvaceae	Bhola	Shrub
110	*Holarrhena antidysenterica* Wall.	Apocynaceae	Kuriz	Shrub

111	*Hoya parasitica* Wall.	Asclepiadaceae	Pargacha	Epiphyte
112	*Hydrilla* sp.		Joloz plant	Fern
113	*Hydrocotyle sibthorpioides* Lam.	Umbellifera	Thankuni	Herb
114	*Hygroryza aristata* Nees.	Gramineae	Uridhan	Grass
115	*Imperata arundinaceae* Linn.	Gramineae	Songash	Grass
116	*Imperata cylindrica* Beauv.	Gramineae	Dhanshi/ ulu	Grass
117	*Intsia bijuga* Kunt.	Leguminosae	Bhaela, bharal	Small tree
118	*Intsia retusa* Kunt.	Leguminosae	Hinge	Small tree
119	*Ipomoea alba* Linn.	Convolvulaceae	Dudhkalm	Succulent, herb
120	*Ipomoea aquatica* Forsk.	Convolvulaceae	Kalmisak	Swamp creeper
121	*Ipomoea fistulosa* Mart.ex	Convolvulaceae	Dholkalmi	Succulent, herb
122	*Ipomoea hedracea* Jack.	Convolvulaceae	Dudh kalmi	Succulent, creeper
123	*Ipomoea pescaprae* Linn.	Convolvulaceae	Sagolkuri	Succulent, herb
124	*Ipomoea quamoclit* Linn.	Convolvulaceae	Tarulata	Cupid's flower, creeper
125.	*Ixora arborea* Roxb.	Rubiaceae	Bon bakul	Small tree
126.	*Jatropha curcas* Linn.	Euphorbiaceae	Bonveranda	Shrub
127.	*Kaempferia rotunda* Linn.	Zingiberaceae	Bhui chapa	Tuber
128.	*Kandelia candel* W. and A.	Rhizophoraceae	Gura, gurae, gural	Small tree
129.	*Lagerstroemia speciosa* Linn.	Lythraceae	Jarul	Tree
130.	*Lannea coromandelica* Merr.	Anacardiaceae	Jiga	Small deciduous tree
131.	*Lantana camara* Linn.	Verbenaceae	Chotra	Lantana herb
132.	*Leea aequata* DC.	Vitaceae	Kagjanga	Shrub
133.	*Leersia hexandra* Swartz.	Leguminosae	Arali	Herb
134.	*Lemna paucicostata* Hegelm.	Lemnaceae	Khudipana	Duck weed
135.	*Lepisanthes rubiginosa* Lee.	Sapindaceae	Bon lichu	Tree
136.	*Ludwigia adscendens* Hara.	Onagraceae	Keshordam	Floating herb
137.	*Lumnitzera racemosa Willd.*	Combretaceae	Kirpa, kripa	Small tree
138.	*Lycopodium clavatum*	Lycopodiaceae	Club moss	Herb-like fern
139.	*Macrosolen cochinchinensis*	Loranthaceae	Porgassa	Woody parasite on crowns
140.	*Macuna gigantea*	Leguminosae	Doyal	Climber
141.	*Mangifera indica* Linn.	Anacardiaceae	Aam	Tree
142.	*Mallotus repandus* Muell.Arg.	Euphorbiaceae	Bon notoy	Scandent shrub
143.	*Marsilea pilularia*	Marsiliaceae	Joloz fern	Swampy soft plant
144.	*Marsilea quadrifolia*	Marsiliaceae	Joloz plant	Swampy soft plant
145.	*Melochia corchorifolia* Linn.	Sterculiaceae	Tikiokra	Herb
146.	*Mikania cordata* Roxb.	Compositae	Asamlata	Climbing hemp weed
147.	*Mikania scandens* Cl.	Compositae	Tara lata	Climbing hemp weed
148.	*Mimusa pudica* Linn.	Leguminosae	Lazzabati	Shrub
149.	*Monochoria hastate* Linn.	Pontederiaceae	Swampy weed	Swampy grass
150.	*Mucuna pruriens* DC.	Leguminosae	Bilaiasra	Climber
151.	*Myriostachya wightiana*	Gramineae	Dhanshi	Grass, on new

	Hook.f.			accretions
152.	*Nelumbo nucifera* Gaertn.	Nymphaeaceae	Paddo	Floating flower
153.	*Nymphaea nouchalli* Burm. f.	Nymphaeaceae	Sada sapla	Water lily
154.	*Nymphaea stellata* Willd.	Nymphaeaceae	Shaluk	Water vegetation
155.	*Nypa fruticans* Wurmb.	Palmae	Golpata	Palm, underground stem
156.	*Ocimum americanum* Linn.	Labiatae	Bon tulshi	Herb
157.	*Ocimum basilicum* Linn.	Labiatae	Vui tulshi	Shrubby basil
158.	*Operculina terpethum* Silva.Manso.	Convolvulaceae	Dudh kalmi	Climber, grass
159.	*Oryza coarctata* Roxb.	Gramineae	Uridhan/dhanshi	Grass
160.	*Paederia foetida* Linn.	Rubiaceae	Ganda vadali	Grass
161.	*Pandanus foetidus* Roxb.	Pandanaceae	Kewa katta	Prickly succulent pine
162.	*Paramignya citrifolia* Hk.f.	Rubiaceae	Bonlebu	Shrub
163.	*Pergularia daemia* Chiov.	Asclepiadaceae	Dudhialata	Creeper
164.	*Petunga roxburghii* DC.	Rubiaceae	Narikili	Small tree
165.	*Phoenix paludosa* Roxb.	Palmae	Hantal	Thorny palm
166.	*Phoenix sylvestris Roxb.*	Palmae	Khejur	Date palm
167.	*Phragmites karka Rtz.*	Gramineae	Nol kagra	Grass
168.	*Pistia stratiotes* Linn.	Araceae	Topapana	Water lettuce
169.	*Polygonum hydropiper* Linn.	Polygonaceae	Panimoris	Herb
170.	*Polygonum lanigerum* Br.	Polygonaceae	Sadakukri	Herb
171.	*Polygonum orientale* Linn.	Polygonaceae	Bishkhathali	Herb
172.	*Polygonum plebejum* Br.var.	Polygonaceae	Chemti sag	Herb
173.	*Polypodium cuculatum*	Polypodiaceae	Polypodium	Fern
174.	*Polypodium parasiticum*	Polypodiaceae	Polypodium	Fern
175.	*Pongamia pinnata* Pierre.	Leguminosae	Karanj, karanja	Small tree
176.	*Potresia* sp.	Leguminosae	Bunodhan	Herb
177.	*Premna corymbosa* Linn.	Verbenaceae	Serpoli, setpoli	Shrub or small tree
178.	*Psilotum nudum*	Psilotaceae	Pteridophyte	Rootless parasite
179.	*Pteris longifoliata*	Polipodiaceae	Sun fern	Sub aerial fern
180.	*Rhinacanthus communis* Nees.	Acanthaceae	Juipana	Floating pana
181.	*Rhizophora apiculata* Bl.	Rhizophoraceae	Jhana	Tree with stilt roots
182.	*Rhizophora mucronata* Lamk.	Rhizophoraceae	Garjan	Tree with stilt roots
183.	*Sacchararum bengalense* Linn.	Gramineae	Jhati/Munda grass	Grass
184.	*Sacchararum officinalis* Linn.	Gramineae	Son	Grass
185.	*Sacchararum spontaneum* Linn.	Gramineae	Kash	Grass
186.	*Sagittaria sagittifolia* Linn.	Alismataceae	Choto kut	Tuber
187.	*Salacia chinensis*	Celastraceae	Choyt barai	Small tree
188.	*Salvi plebej* Br.	Labiatae	Bhui Tulshi	Herb
189.	*Sarcobolus globosus* Wall.	Asclepiadaceae	Bowali lota	Climber
190.	*Sargassum nereocystis*	Sargassaceae	Brown shaibal	Shaibal
191.	*Selaginella rupestris*	Selaginellaceae	Club moss	Perennial moss

192.	*Sesbania sesban* Merr.	Leguminosae	Katshola	Common sesban
193.	*Sida acuta* Burm.	Malvaceae	Kureta/Ban methi	Herb
194.	*Smilax zeylanica* Linn.	Liliaceae	Kumari lata	Creeper
195.	*Solanum indicum* Linn.	Solanaceae	Bon begun	Shrub
196.	*Sonneratia apetala* Ham.	Sonneratiaceae	Keora	Tree
197.	*Sonneratia caseolaris* Engl.	Sonneratiaceae	Choyla	Tree
198.	*Stenochlaena paludosa*	Blechnaceae	Dheki lata	Climber
199.	*Stenochlaena palustris*	Blechnaceae	Deki lota	Climbing fern
200.	*Syzygium cumini* Skeels.	Myrtaceae	Jam	Medium tree
201.	*Syzygium operculata* Roxb.	Myrtaceae	Butijam	Medium tree
202.	*Tamarindus indica* Linn.	Leguminosae	Tentul	Tree
203.	*Tamarix gallica* Linn.	Tamaricaceae	Jhao, nonajhao	Small tree
204.	*Teris longifoliata*	Polipodiaceae	Common fern	Sub aerial fern
205.	*Tetrastigma bracteslatum*	Vitidaceae	Golgoti lota	Climber
206.	*Thumbergia* sp.	Thumbergiaceae	Jermani lota	Climber
207.	*Tinospora cordifolia* Miers.	Menispermaceae	Guluncha	Creeper
208.	*Tragia involucrata* Linn.	Euphorbiaceae	Bisuti	Perennial hairy twinner
209.	*Trapa bispinosa* Roxb.	Trapaceae	Paniphal	Floating plant
210.	Trewia polycarpa Benth.	Euphorbiaceae	Pithali	Small tree
211.	*Trichosanthes cucumerina*	Cucurbitaceae	Banchichinga	Herbaceous climber
212.	*Typha elephantiana* Roxb.	Typhaceae	Hogla	Grass used mat making
213.	*Typhonium trilobatum* Schott.	Araceae	Ghet kachu	Tuber
214.	*Urena lobota* Linn.	Malvaceae	Banokra	Small shrub
215.	*Utricularia aurea* Laur.	Utriculariaceae	Swampy weed	Herb
216.	*Vallisueria spirilis* Linn.	Hydrocharitaceae	Bicha	Climber
217.	*Vanda roxburghii* Br.	Orchidaceae	Rashna	Parasite
218.	*Vangueria spinosa* Roxb.	Rubiaceae	Maina	Small grass
219.	*Vetiveria zizanioides* Hash.	Gramineae	Bena	Grass
220.	*Vicia hirsuta* Coch.	Leguminosae	Bon lota	Climber
221.	*Vigna radiata* (L.) Wilizek.	Leguminosae	Arohi lata	Climber
222.	*Viscum album* Linn.	Loranthaceae	Banda lota	Woody parasite in tree crowns
223.	*Viscum orientale* Willd.	Loranthaceae	Shamu lota	Woody parasite in tree crowns
224.	*Vitex negundo* Linn.	Verbenaceae	Nishanda	Small shrub
225.	*Vitis lanceolaria* Laws.	Vitaceae	Harinia lata	Climber
226.	*Vitis quadrangularis* Wall.	Vitaceae	Harjora	Climber
227.	*Vitis trifoliate* Linn.	Vitaceae	Anal lata	Climber
228.	*Wolffia arrhiza*	Lemnaceae	Shuzi pana	Floating duck weed
229.	*Xylocarpus granatum* Koen.	Meliaceae	Dhundul	Small tree
230.	*Xylocarpus mekongensis* Pierre	Meliaceae	Passur	Tree

Methodology

A literature search was conducted using the keywords "Endophytes," "Bangladeshi Mangrove," "Mangrove Forest," "Sundarbans," "Mangrove plant," "Drug development from endophytes," "endophytic bacteria," "endophytic fungi," and "Pharmacological activities of endophytes" on electronic databases (Website, PubMed, Scopus, Science Direct, Google scholar, Springer Link, and ResearchGate).

Inside plants: What's an ENDOPHYTE?

Endophytes are the most mysterious organisms on earth. They simply reside inside the host plant to survive without causing any harm – how amazing is that! The relationship between host and endophytes reflects the harmony of nature as they contribute to each other's lives. A large number of plant species pertake in this host-endophyte relationship. There is certainly more to this organism than meets the eye. In 1809, German botanist Johann Heinrich Friedrich Link first described "Endophytae" suggesting parasitic fungi. In the 19th century, influential scientists like Louis Pasteur and Auguste Fernbach believed that "healthy plants were microbe-free". In 1887**,** M. Victor Galippe proposed that both fungi and bacteria could enter plants from soil and might even benefit the host, which created quite a controversy and was dismissed by most, although Jorissen and Marcano supported the theory. The concept of beneficial microorganism colonizing the plant tissue was recognized in the late 20th century, especially when researchers started to realize the fact that endophytes could live in plants without causing disease, and might even aid in plant growth or produce compounds that are valuable (Rutkowska et al., 2023).

German Botanist Heinrich Anton de Bary first introduced the word "Endophytes" in 1866 to describe the organism that lives inside the plant tissue.(Dutta et al., 2014)

The term "Endophytes" is derived from two Greek words: "Endon" means "within" and "Phyton" means "plant". Hence, the word can be deciphered as "in the plant". A widely recognized definition of "endophyte" was provided by Jeffrey K. Stone, Charles W. Bacon, and James F. White Jr. in their seminal chapter titled *An Overview of Endophytic Microbes: Endophytism Defined*. This work is part of the book *Microbial Endophytes*, edited by Bacon and White, and published by Marcel Dekker in 2000. In this chapter, the authors defined "Endophytes" as - Microorganisms (primarily fungi and bacteria) that colonize internal plant tissues without causing apparent disease symptoms. Some definitions consider "Endophytes" as organisms causing no apparent harm and existing without causing any visible symptoms within the host. Endophytes can colonize inside the host tissue and infect without causing any visible symptoms. Microorganisms, such as latent pathogens, saprobes, mutualists, and commensals, are considered the common endophytic classes. Mostly fungi and bacteria as well as some species of archaea and protists colonize plant tissues intercellularly and intracellularly, often systemically without triggering host defense responses. But mycorrhizal fungi are not considered as endophytes because of their distinct symbiotic mechanisms. Bacterial endophytes often inhabit vascular tissues for effective distribution. Endophytes often show continuity between mutualism and parasitism as they tend to become pathogenic in case the host defense system is debilitated. The characteristics of endophytes can appear mostly similar to pathogens and symbionts, which is why they can be difficult to categorize properly. Typical habitats of endophytes are the plants that appear healthy, but despite co-existing harmlessly, their role can alter under certain environmental and biological conditions, such as environmental changes, nutrient fluctuation or alterations in the plant's physical state. The ability of any microorganism to live as an endophyte is addressed as "Endophytism." Endophytism can evolve independently in different microbial lineages to adapt to similar environments or ecological niches. Endophytism allows efficient nutrient consumption and helps to maintain a tolerable environment for endophytes inside the host plant. Endophytism also incorporates a mutualistic relationship between the host and the microbe, which benefits both by increasing their survival and dispersal. In addition to being a treasured biological resource, endophytes play diverse indispensable functions in nature by giving protection to the host plant against pathogens, herbivores and biotic as well as abiotic stress conditions such as pests, drought, salinity, heavy metals etc. They also help the host plant to obtain nutrients in extreme environments and also promote plant growth and development by producing phytohormones.(Schulz & Boyle, 2006; White, 2020).

Endophytes form a holobiont with the host, which allows them to intervene in their mechanism and activity. There are possibilities of endophytes being vertically transmitted by host plant seeds, which may influence the heredity of the host.(Hardoim et al., 2015)

As endophytes are an established microbe that is beneficial for their host organism, they also have potential uses for humans. The perspective of using endophytes begins from biotechnology, including agriculture (biocontrol, biofertilizers) and even pharmaceuticals (natural products, secondary metabolites).

Endophytes are a rich source of biologically active compounds such as antimicrobial, antifungal, antibiotics, antioxidants and plant hormones such as auxin. Some endophytes can directly parasitize plant pathogens or outcompete them in niche occupancy for habitat and food or produce enzymes such as chitinase, glucanase etc. that participate in the disease control mechanism of mangrove plants. Some endophytes show insecticidal activity by producing substances like naphthalene or show nematicidal activity by suppressing root-knot nematodes. Endophytes also have the ability to trigger systemic acquired resistance (SAR) and induce systemic resistance (ISR) by expressing pathogenesis-related (PR) proteins and ethylene and jasmonic acid signalling in plants.(Dutta et al., 2014)

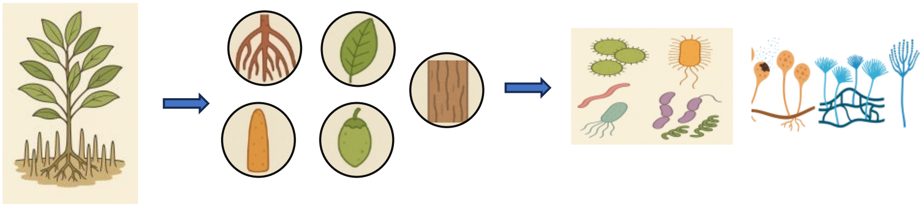

Figure 4. Isolation of endophytic bacteria and fungi from the root, leaf, bark, pneumatophore, and fruit tissues of a mangrove plant; Source: Figure constructed by the author(s)

Novel endophytic species are already the talk of the town because of their promising aspects. Several impactful discoveries suggest that some endophytic species can produce taxol and emit hydrocarbon, thus named “mycodiesel”, which is a breakthrough in the sustainable fuel industry. Certain endophytes can also produce volatile organic compounds that are similar to gasoline and diesel, and can also produce straight-chain hydrocarbons and esters, which can be potentially used as renewable fuels. Some unique environments, such as tropical rainforests, harbour endophytes that produce antimicrobial volatile compounds that are EPA-approved for agricultural use. Discovery of compounds such as pestacin (a powerful antioxidant), ambuic acid (anti-quorum-sensing agent), torreyanic acid (cytotoxic compound with anticancer potential), colutellin A (immunosuppressant peptide), and cryptocin (antifungal compound that is active against plant pathogens) shows the immense potential held by the endophytic species.(Strobel, 2018)

Despite the numerous potentials, endophytic species are still underutilized. There are several reasons which could possibly influence the utilization of this wonder microbe. The intricate interactions between endophytes and their host tissues, as well as the microbiological role and mechanism of their response behaviors, remain unclear to researchers despite a plethora of investigations. The driving forces behind microbial community assemblages in different hosts and the environmental, as well as genetic and phenological factors that influence the composition of endophytic microbial communities are still obscure to some extent. A crucial matter in endophytic research is that it is totally dependent on gnotobiotic (sterile) conditions, which leads to biased or improper results, as the imitation of a real environment cannot be maintained. Most importantly, we need to conduct more experiment-based studies to understand the endophytes and to utilise them for betterment.(Compant et al., 2016)

Endophytic Diversity in Mangroves

Mangroves are a specific kind of densely wooded plant that grows in subtropical and tropical latitudes where the sea meets the land. Severe environmental circumstances like high salinity, tides, strong winds, anaerobic muddy soils, and high temperatures are all particularly adapted to them. Mangrove vegetation becomes a great source of endophytic microbes due to its fast structural and physiological modification(Paul et al., 2023). The majority of these endophytic microorganisms are bacteria and fungi that coexist naturally with the tissues of their host mangroves, including the leaves, roots, stems, bark, and pneumatophores(Sopalun et al., 2021). They protect their host plant from infections and improve its capacity to withstand environmental stresses, which results in the evolution of new metabolic processes (Chatterjee & Abraham, 2020).

Chemical analysis of mangrove endophytes found bioactive secondary metabolites such as alkaloids, terpenoids, flavonoids, coumarins, chromones, polyketides, and peptides with a variety of structural characteristics. While endophytic microorganisms found in land plants have been extensively explored for their antibacterial, antifungal, anticancer, antimalarial, antiviral, antioxidant, and antidiabetic properties, isolates associated with mangroves have shown similar bioactivity (Das et al., 2018).The main endophyte species that have been isolated from mangrove vegetation are as follows:

A) Endophytic Bacteria: The endophytes have been associated with around 200 taxa from 16 bacterial phyla. The majority of the species comprises *Actinobacteria, Proteobacteria, and Firmicutes* phyla. Endophytic bacteria include both gram-positive and gram-negative strains, including *Achromobacter, Acinetobacter, Agrobacterium, Bacillus, Brevibacterium, Microbacterium, Pseudomonas, Xanthomonas*, etc (Gouda et al., 2016b. These bacterial endophytes produce secondary metabolites that are both medicinally effective and structurally diverse (Dat et al., 2019) . They are known to boost yields, enhance endurance to biotic and abiotic stresses, strengthen plant defense against pests, increase plant immunity, and serve a vital role in green agriculture (Ghorpade et al., 2023). Additionally, mangrove bacterial endophytes are employed in the synthesis of biofuel, environmental biodegradation, and engineering of bionanomaterials for advanced ecological inventions(Nag et al., 202433-34; Vaish & Pathak, 2023)

B) Endophytic Fungi: Endophytic fungi are classified under *Ascomycota, Basidiomycota, and Zygomycota* species based on their evolutionary tree. First identified by Cribb, these fungi are known to be an important natural substrate for the identification of potential bioactive compounds with applications in pharmacology, ecological control, and agriculture (Cadamuro et al., 2021). Fungal endophytes synthesize a variety of biologically active metabolites, such as pestalotiopsones A–F, talaperoxides A–D, steperoxide B, xylacinic acids A–B, cytochalasin D, isosclerone, nectriacids A–C, and 12-epicitreoisocoumarinol(Rahaman et al., 2020a). As to the study, *Penicillium, Rhizopus nigricans, Alternaria alternata, Aspergillus species, Colletotrichum, Phomopsis, Phyllosticta, and Sporormiella* are the most abundant endophytic fungal genera. These fungi are vital to mangrove ecosystems as they degrade organic material and produce protein-rich debris that sustains aquatic food networks (Paul et al., 2023). Furthermore, these new compounds have prospects in pathogen control associated with the health of humans, animals, and the environment(Cadamuro et al., 2021). Additionally, they are used as biofertilizers and biocontrol agents for rice farming(Muthu Narayanan et al., 2024).

Pharmaceutical potential of mangrove endophytes

A) Bioactive properties of secondary metabolites synthesized by fungal endophytes

Mangrove ecosystems host a diverse and unique environment that fosters endophytic fungi capable of producing chemically diverse metabolites. Endophytic fungi are prolific producers of bioactive compounds. Endophyte research started to get limelight only after the discovery of the anticancer agent Taxol, found in an endophytic fungus. After that, more natural products such as podophyllotoxin, lovastatin, alkaloids, terpenoids, isocoumarins, polyketides were found. There are also reports of finding compounds like -ascosalipyrrolidinones, citrinin, asperamide A, pestalotheol C that have potential activity against *Plasmodium*, *Candida albicans*, *HIV*, *H1N1*, and *Herpes virus*.(Jeewon et al., 2019) .

The biotic stress produced by the dominant ecosystem supports the production of natural products with insecticidal, antimicrobial, antiviral, anti-inflammatory, antidiabetic activities. Some notable discoveries suggest the production of xyloketals with neuroprotective effects from an endophytic species found in a mangrove plant called *Xylaria*. There are also some endophytic species of *Penicillium* and *Aspergillus* that produce novel azaphilons, terpenoids, and xanthone compounds with antidiabetic, anticancer, and AChE-inhibiting activity, respectively.(El-Bondkly et al., 2021)

Corynespora cassiicola fungus synthesizes a secondary metabolite that targets protein kinases like PIM1 and VEGFR2. Mangrove environments host fungi that have α-glucosidase and acetylcholinesterase inhibition ability, which makes them potential candidates for diabetes or brain-related disease such as Alzheimer's disease and other neurodegenerative diseases. Some compounds supposedly help to modulate ion channels by blocking calcium or potassium channels, which is relevant for cardiovascular and neural therapies.(Debbab et al., 2013)

The mangrove forest in the Sundarbans of Bangladesh is a vast source of fungal endophytes with significant pharmaceutical potential that is yet to be explored. To date, only 80 fungal isolates from 9 mangrove species have been documented, which shows the extent of underutilization of the resource! Almost every endophytic fungal strain found in the Sundarbans showed significant antimicrobial, antioxidant, cytotoxic (Anti-Cancer), α-Glucosidase Inhibition (Antidiabetic) activity, which offer promising leads for novel antibiotics, plant-based antioxidants, anticancer, and antidiabetic therapeutic treatment (Rahaman et al., 2020b) (Figure 5).

In order to effectively explore and utilise the fungal endophytic resource from mangrove plants of the Sundarbans, we need to focus more on phylogenetic studies and biological activities. We need to expand the exploration by conducting large-scale surveys as well as adding seasonal and geographical variation to the collection to study the entire microbial diversity. There is also a need to establish research centers with proper facilities near Sundarbans, fully dedicated to endophytic study and also focus on industrial application, along with engaging industries in pilot-scale production and bioactivity validation, in addition to conducting international collaboration. The biological activity of the fungus and bacteria endophytes found in the Sundarbans, Bangladesh, has been listed in Tables 2 and 3.

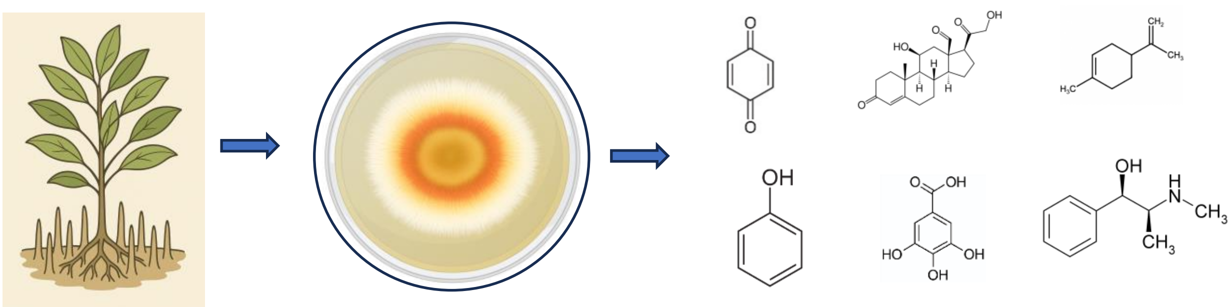

Figure 5. Isolation and bioactive compound screening of endophytic fungi from mangrove plant parts; Source: Figure constructed by the author(s)

Table 2. Fungal endophytes identified in mangrove plant species native to the Sundarbans, Bangladesh and their biological activity:

Local name	Scientific name	Fungi Species	Bioactive compound	Activity/function	Reference
Goran	*Ceriops decandra*	*Fusarium oxysporum*, *Clonostachys* spp. and *Fusarium solani*	Anthocyanin	Anoxident, antimicrobial, cytotoxic	(Munshi et al., 2021)
		Aspergillus sp, *Penicillium* sp, *Aspergillus fumigatus*	Fumigaclavine C, Azaspirofuran B, Fraxetin	Antibacterial (*S. aureus*, *P. aeruginosa*, *E. coli*), anti-inflammatory, cytotoxic, antitumor, antiseizure, antifungal, antioxidant, anticancer, hepatoprotective	(Neamul Kabir Zihad et al., 2022)
		Talaromyces sp.	Not tested	Strong α-glucosidase inhibition, antioxidant	(Rahaman et al.,

				activity	2020b)
Keora	*Sonneratia apetala*	*Cladosporium cladosporioides, Cladosporium perangustum, Cladosporium tenuissimum, Fusarium equiseti, Alternaria tenuissima, Alternaria brassicicola, Alternaria arborescens, Epicoccum nigrum, Colletotrichum glosporides, Neopestalotiopsis chrysea, Xenoacremonium recifei, Aspergillus niger*	Not tested	Antimicrobial (The ethyl acetate and methanolic extracts of these fungi were tested against five human pathogens Bacteria**:** *Escherichia coli*, *Staphylococcus aureus*, *Micrococcus luteus*, *Pseudomonas aeruginosa* Fungus**:** *Candida albicans*	(T. R. Nurunnabi et al., 2020)
		Colletotrichum gloeosporioides	Kojic acid	Activity of kojic acid against *Micrococcus luteus*.The crude extract was highly potent against *Pseudomonas aeruginosa*	(T. Nurunnabi et al., 2018)
Sundari	*Heritiera fomes*	*Pestalotia* sp.	Xylitol**,** Oxysporone **(**NMR, MS, and HPLC)	Antimicrobial, Anti-MRSA	(T. R. Nurunnabi et al., 2018)
		Trichoderma harzianum	Not tested	Bactericidal activity, cytotoxic (MCF-7, SK-LU-1)	(Rahaman et al., 2020b)
		Talaromyces sp.	Not Tested	Strong α-glucosidase inhibition, antioxidant activity	
Bara Bean, Kala Bean	*Avicennia officinalis*	*Aspergillus* sp.	Not tested	Not tested	(Neamul Kabir Zihad et al., 2022)
Maricha Bean, Sada Bean	*Avicennia alba*	*Penicillium citrinum*	Not tested	Antibacterial, α-glucosidase inhibition, antioxidant	(Rahaman et al., 2020b)
Kanak Bean, Sada Bean	*Avicennia marina*	*Aspergillus fumigatus*	Not tested	Antibacterial (*K. rhizophila*, *E. coli*), antifungal (*A. brasiliensis*), α-	

				glucosidase inhibition, antioxidan	
Kakra	*Bruguiera sexangula*	*Aspergillus oryzae*	Not tested	High polyphenol content, selective ABTS antioxidant activity, cytotoxic on MCF-7 cells	
		Aspergillus sp.	Not tested	Not tested	
		Aspergillus terreus	Not tested	Antibacterial (*S. aureus, B. subtilis*), α-glucosidase inhibition, antioxidant	
Lata Sundri	*Brownlowia tersa*	*Talaromyces sp.*	Not tested	Strong α-glucosidase inhibition, antioxidant activity	
Kalilata	*Derris trifoliata*	*Penicillium chrysogenum*	Not tested	Highest antioxidant activity (DPPH, ABTS, FRAP), cytotoxic against SK-LU-1	
Dhundal	*Xylocarpus granatum*	*Talaromyces* sp.	Not tested	Strong α-glucosidase inhibition, antioxidant activity	
		Aspergillus terreus	Not tested	Antibacterial (S. aureus, B. subtilis), α-glucosidase inhibition, antioxidant	
Passur	*Xylocarpus moluccensis*	*Talaromyces* sp.	Not tested	Antifungal (*C. albicans*), α-glucosidase inhibition, cytotoxic (MCF-7), high FRAP	
		Penicillium verruculosum	Not tested	Antibacterial (K. rhizophila), high antioxidant activity	
		Aspergillus fumigatus	Not tested	Antibacterial (*K. rhizophila, E. coli*), antifungal (*A. brasiliensis*), α-glucosidase inhibition, antioxidant	

B) Bioactivity of the Secondary Metabolites Synthesized from Bacterial Endophytes:

Bioactive secondary metabolites with substantial pharmacological potential have been found to be abundant in mangrove endophytes. Polyketides, alkaloids, terpenes, chromones, coumarins, and peptides are among the identified molecules that are produced from mangrove endophytes. these substances have a wide range of biological characteristics, like cytotoxicity, antioxidant, antifungal, antibacterial, antidiabetic, α-glucosidase, acetylcholinesterase, and antiviral (Dat et al., 2019; Dat & Phung Thi Thuy, 2021) . Therefore, natural substances have been demonstrated as an effective resource for drug development, with over 80% of marketed drugs originating from these origins (Gouda et al., 2016b) . The Sundarbans of Bangladesh region, being the biggest mangrove forest in the world, is considered to have a vast endophytic variety, with little focus on isolating endophytic bacteria and their capacity to generate secondary metabolites for pharmaceutical applications (Zihad et al., 2022). In order to address the prevalent issue of drug resistance to different pathogens, the finding of bioactive compounds and their secondary metabolites from mangrove endophytic bacteria will provide an effective solution (Gouda et al., 2016b) .

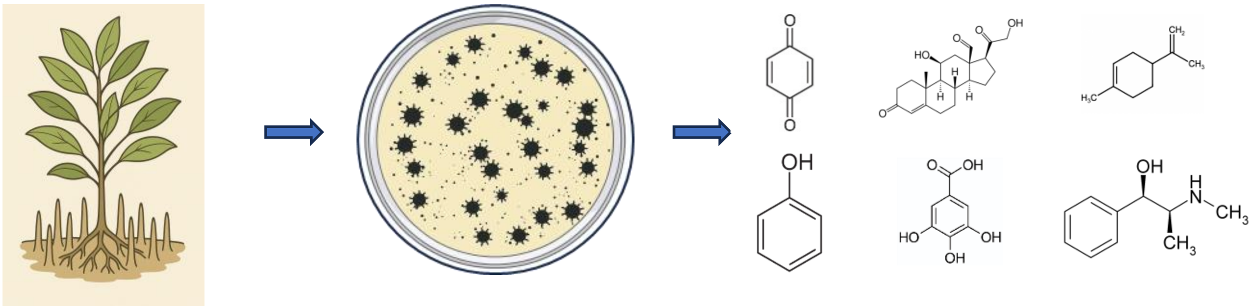

Figure 6. Isolation and bioactive compound screening of endophytic bacteria from mangrove plant parts; Source: Figure constructed by the author(s)

Table 3. The list of isolated bacterial endophytes with potential pharmaceutical activity from different countries of mangrove origin are given as follows:

Mangrove Plant	Used Segment	Location	Isolated Endophytic Bacteria	Activity	References
Rhizophora apiculata	Root	Vietnam	*Streptomyces*, *Bacillus*, *Pseudovibrio*, *Microbacterium*, *Rossellomorea*, *Brevibacterium*, *Microbulbifer*, *Micrococcus*, and *Paracoccus*	antimicrobial, antioxidant, α-amylase and α-glucosidase inhibitory, xanthine oxidase inhibitory, and cytotoxic activities	(Dat et al., 2021)
Avicennia marina and Xylocarpus granatum	leaves, branches, fruits and roots	Serang, Banten Province	3 bacterial strains	Antioxidant	(Rahmawati et al., 2019)
Aegiceras corniculatum (L.) Blanco, *Sonneratia alba Sm. and Avicennia alba Blume.*	leaves, stems, fruits, and roots,	Indonesia.	Bacteria (didn't identified)	antioxidant and cytotoxic activity	(Izzati et al., 2020)
Rhizophora mucronata Lam.	Roots, Stems, Leaves and Fruits	Lombok Island (Gili Sulat)	18 bacteria isolates	Antibacterial	(Maulani et al., 2019)
Rhizophora stylosa	Leaves	Canh Duong, Phu Loc, Thua Thien Hue.	Bacillus, Streptomyces, Pseudovibrio and Pseudomonas	antimicrobial and antioxidant agents	(Dat et al., 2020)

Avicennia officinalis	Pneumat-ophore	Poover, eastern coast of Kerala, India	Pseudomonas medocina, Bacillus pumilus, Sphingomonas spiritivorum and Pseudomnas stutzeri .	Probiotics potential & disease resistance	(Jakhi, 2014)
Avicennia marina	Leaves	Yanbu region	10 bacterial strains, molecular identification of,Mixta and Cytobacillus species	antimicrobial	(Abdellatif & Arafat, 2024)
Bruguiera gymnorrhiza (Lam .)	Stems	Kollam district of Kerala, India.	*B. subtilis*	Antibacterial activity, antagonistic	(Gayathri et al., 20251)
Rhizophora stylosa	Roots	Gio Linh district, Quang Tri province.	73 bacterial strains, (molecular identification of Bacillus, Streptomyces, and Pseudovibrio)	antioxidant and antidiabetic agents	(Dat & Phung Thi Thuy, 2021)
R. mucronata	Roots, Stems, and Leaves	Wana Tirta ecotourism area, Kulon Progo, Yogyakarta	f 54 isolates of endophytic bacteria	L-asparaginase,to treat acute lymphoblastic leukemia and other malignant cancers	(NAFISA TURRAHMAH et al., 2023)55
Rhizophora apiculata	Roots	Thua Thien Hue province, Viet Nam	*Bacillus sp.*	Cytotoxic and antimicrobial activity	(Dat et al., 2022)
Avicennia marina	Explant pigment		*Micrococcus luteus*	antioxidant and anticancer activity.	(Kandasamy & Kathirvel, 2024)
Avicennia marina	Leaves, Stems, and Roots	vietnam	*Actinimycetes (Streptomyces cacaoi, Streptomyces californicus, Streptomyces enissocaesillis, Streptomyces coelicoflavus, and Streptomyces variabilis)*	antibacterial, anticancer, and antioxidant agents.	(Quach et al., 2022)

Conclusions

Mangrove-associated endophytes constitute a promising yet underexplored source of bioactive natural products with potential pharmaceutical applications. These symbiotic microorganisms have the capacity to produce secondary metabolites, including antimicrobial, antioxidant, enzymatic, and cytotoxic compounds. In regions such as Bangladesh, home to the Sundarbans, one of the largest mangrove forests globally, these endophytes offer a unique opportunity for bioprospecting. Bangladesh is currently dependent on imported raw materials for pharmaceutical production, and with the increasing constraints imposed by international intellectual property agreements, the discovery and utilization of native microbial resources could play a pivotal role in supporting local drug development. Systematic isolation, characterization, and optimization of mangrove-derived endophytes are essential steps toward realizing their therapeutic potential. The conservation of mangrove ecosystems is critical, as the loss of host plant species directly threatens the associated microbial biodiversity. Integrating microbial research with biodiversity preservation and ethical bioprospecting practices is vital to ensure sustainable exploitation of these resources. The targeted exploration of mangrove endophytes presents a strategic opportunity for advancing pharmaceutical innovation in Bangladesh. A coordinated approach involving scientific research, conservation policy, and biotechnology development is necessary to harness these microbial communities for national health and economic benefit.

- **Difficult isolation and cultivation**: A significant number of endophytic strains are unculturable using standard laboratory methods. Many endophytes are slow-growing and may not sporulate easily on artificial media, making isolation, morphological characterization, and identification difficult.
- **Limited knowledge of ecology**: There is a lack of in-depth knowledge about the symbiotic relationships between mangrove endophytes and their host plants. Endophytes usually colonize the host plant promoting nutrient uptake and shielding it from pest, biotic and abiotic stresses in order to maintain stable symbiosis. A better understanding of how these microorganisms interact with their hosts in their natural habitat is needed to fully comprehend their metabolic functions.
- **Reproducibility of metabolite production**: When removed from their natural environment, some endophytes decrease or cease the production of key secondary metabolites. Factors such as genetic silencing in the absence of host signals can cause low yields of target compounds during large-scale fermentation.
- **Redundancy and re-isolation**: Traditional screening methods often lead to the re-isolation of already-known substances. Discovering novel compounds requires innovative strategies to activate silent biosynthetic gene clusters.
- **Limited research**: Compared to other ecosystems, the endophytes of mangrove plants remain poorly explored, with only a small fraction of known mangrove species being pharmacologically validated.
- **Access and preservation**: Sampling and monitoring mangrove ecosystems are difficult and expensive due to geographical inaccessibility and ecological sensitivity. The degradation and loss of mangrove habitats due to climate change and human activity further threaten this unique and valuable source of biodiversity

Funding

This work was supported by a University Grants Commission (UGC) research grant from Bangladesh Maritime University (BMU), Dhaka, Bangladesh (2024-2025).

Acknowledgments

The authors thank the Marine Biotechnology Laboratory at Bangladesh Maritime University, Bangladesh, for providing all the technical and laboratory support necessary to conduct this research.

Conflict of interest

The authors declare that they have no conflict of interest.

References

1. Chaffey, D., Millar, F. & Sandom, J., 1985. *A Forest Inventory of the Sundarbans, Bangladesh: Main Report,* London: Overseas Development Administration.
2. Department, F., 2010. *Integrated Resources Management Plans for the Sundarbans.* Dhaka : Ministry of Environment and Forests.
3. Jakhi, P. S. J. K. &. K. S., 2014. *Perspectives on Biodiversity of India: Volume I.* s.l., Center for Inovation in Science and Action (CISSA), pp. pp:531-538.
4. Khan, E. U. H., 2011. *The Bangladesh Sundarbans.* Dhaka, Bangladesh: Wildlife Trust of Bangladesh (WTB).
5. Khan, H., 1983. *Irrigation water requirements in Bangladesh.* Dublin, United Kingdom: Tycooly International Publishing Ltd..
6. Siddiqui, A. H., 2009. *Sundarbans and Visit to the Sundarbans.* Dhaka: Angikar Prokashoni.
7. UNECSO, 2024. *The Sundarbans.* [Online] Available at: https://whc.unesco.org/en/list/798/
8. Abdellatif, M. M., & Arafat, H. H. (2024). Endophytic Microbial Diversity, Heavy Metal Accumulation, and Antimicrobial Properties of Avicennia marina from Saudi Arabia. *Journal of Pure and Applied Microbiology*, *18*(2), 995–1003. https://doi.org/10.22207/JPAM.18.2.14
9. Article, R., Lycias Joel, E., Bhimba, V., Article ELSA LYCIAS JOEL, R., & Bhimba, B. (2012). *FUNGI FROM MANGROVE PLANTS: THEIR ANTIMICROBIAL AND ANTICANCER POTENTIALS*. http://www.ncbi.nlm.nih.gov/nuccore/HQ823763
10. Aziz, A., & Paul, A. R. (2015). Bangladesh Sundarbans: Present status of the Environment and Biota. In *Diversity* (Vol. 7, Issue 3, pp. 242–269). MDPI AG. https://doi.org/10.3390/d7030242
11. Cadamuro, R. D., da Silveira Bastos, I. M. A., Silva, I. T., da Cruz, A. C. C., Robl, D., Sandjo, L. P., Alves, S., Lorenzo, J. M., Rodríguez-Lázaro, D., Treichel, H., Steindel, M., & Fongaro, G. (2021). Bioactive Compounds from Mangrove Endophytic Fungus and Their Uses for Microorganism Control. *Journal of Fungi*, *7*(6), 455. https://doi.org/10.3390/jof7060455
12. Chatterjee, A., & Abraham, J. (2020). Mangrove endophytes: a rich source of bioactive substances. In *Biotechnological*

Utilization of Mangrove Resources (pp. 27–47). Elsevier. https://doi.org/10.1016/B978-0-12-819532-1.00002-0

13. Choudhury, Khasru., Waliuzzaman, Mir., Nishat, Ainun., & Ali Reza, A. H. M. . (2001). *The Bangladesh Sundarbans : a photoreal sojourn*. [IUCN Bangladesh Country Office, IUCN the World Conservation Union]: [Distributors, Mohiuddin & Son's].
14. Compant, S., Saikkonen, K., Mitter, B., Campisano, A., & Mercado-Blanco, J. (2016). Editorial special issue: soil, plants and endophytes. *Plant and Soil*, *405*(1–2), 1–11. https://doi.org/10.1007/s11104-016-2927-9
15. Das, S. K., Samantray, D., & Thatoi, H. N. (2018). Pharmacological Applications of Metabolites of Mangrove Endophytes: A Review. In *Microbial Biotechnology* (pp. 331–360). Springer Singapore. https://doi.org/10.1007/978-981-10-7140-9_16
16. Dat, T. T. H., Cuong, L. C. V., Ha, D. V., Oanh, P. T. T., Nhi, N. P. K., Anh, H. L. T., Quy, P. T., Bui, T. Q., Triet, N. T., & Nhung, N. T. A. (2022). The study on biological activity and molecular docking of secondary metabolites from Bacillus sp. isolated from the mangrove plant Rhizophora apiculata Blume. *Regional Studies in Marine Science*, *55*, 102583. https://doi.org/10.1016/j.rsma.2022.102583
17. Dat, T. T. H., Oanh, P. T. T., Cuong, L. C. V., Anh, L. T., Minh, L. T. H., Ha, H., Lam, L. T., Cuong, P. V., & Anh, H. L. T. (2021). Pharmacological Properties, Volatile Organic Compounds, and Genome Sequences of Bacterial Endophytes from the Mangrove Plant Rhizophora apiculata Blume. *Antibiotics*, *10*(12), 1491. https://doi.org/10.3390/antibiotics10121491
18. Dat, T. T. H., Oanh, P. T. T., Tam, V. T. T., & Anh, H. L. T. (2019). Antimicrobial and antioxidant activity of bacterial endophytes isolated from leaves of the mangrove plant <i>Rhizophora stylosa</i> *ACADEMIA JOURNAL OF BIOLOGY*, *41*(4). https://doi.org/10.15625/2615-9023/v41n4.14675
19. Dat, T. T. H., Oanh, P. T. T., Tam, V. T. T., & Anh, H. L. T. (2020). Antimicrobial and antioxidant activity of bacterial endophytes isolated from leaves of the mangrove plant <i>Rhizophora stylosa</i> *TAP CHI SINH HOC*, *41*(4). https://doi.org/10.15625/0866-7160/v41n4.14675
20. Dat, T. T. H., & Phung Thi Thuy, O. (2021). \(\textit{In vitro}\) antioxidant, α-amylase and α-glucosidase inhibitory activities of endophytic bacteria from the roots of the mangrove plant \(\textit{Rhizophora stylosa}\) Griffith. *Academia Journal of Biology*, *43*(3), 125–135. https://doi.org/10.15625/2615-9023/16143
21. Debbab, A., Aly, A. H., & Proksch, P. (2012). Endophytes and associated marine derived fungiecological and chemical perspectives. In *Fungal Diversity* (Vol. 57, Issue 1, pp. 45–83). https://doi.org/10.1007/s13225-012-0191-8
22. Debbab, A., Aly, A. H., & Proksch, P. (2013). *Mangrove derived fungal endophytes – a chemical and biological perception*. *Sridhar 2004*. https://doi.org/10.1007/s13225-013-0243-8
23. Dutta, D., Puzari, K. C., Gogoi, R., & Dutta, P. (2014). Endophytes: Exploitation as a tool in plant protection. *Brazilian Archives of Biology and Technology*, *57*(5), 621–629. https://doi.org/10.1590/S1516-8913201402043
24. El-Bondkly, E. A. M., El-Bondkly, A. A. M., & El-Bondkly, A. A. M. (2021). Marine endophytic fungal metabolites: A whole new world of pharmaceutical therapy exploration. *Heliyon*, *7*(3), e06362. https://doi.org/10.1016/j.heliyon.2021.e06362
25. Gayathri, R. S. R., Sheeba, M. S., Chandran, S. S., John, S., Chiseena, C. T., John, S., R.S., D., & J.S., G. (2025). Isolation, identification and bioprospecting potential of Bacillus subtilis, endophytic bacterium from Bruguiera gymnorrhiza (L.) Lam. ex Savigny. *Microbial Pathogenesis*, *203*, 107458. https://doi.org/10.1016/j.micpath.2025.107458
26. Ghorpade, S. M., Gorwadkar, V. R., & Kharmate, A. V. (2023). *Isolation of Endophytic Bacteria and Its Commercial Application as PGP for Sustainable Agriculture to Improve Crop Yield*. https://doi.org/10.21203/rs.3.rs-2356252/v1
27. Giri, C., Pengra, B., Zhu, Z., Singh, A., & Tieszen, L. L. (2007). Monitoring mangrove forest dynamics of the Sundarbans in Bangladesh and India using multi-temporal satellite data from 1973 to 2000. *Estuarine, Coastal and Shelf Science*, *73*(1–2), 91–100. https://doi.org/10.1016/j.ecss.2006.12.019
28. Gouda, S., Das, G., Sen, S. K., Shin, H. S., & Patra, J. K. (2016a). Endophytes: A treasure house of bioactive compounds of medicinal importance. In *Frontiers in Microbiology* (Vol. 7, Issue SEP). Frontiers Media S.A. https://doi.org/10.3389/fmicb.2016.01538
29. Gouda, S., Das, G., Sen, S. K., Shin, H.-S., & Patra, J. K. (2016b). Endophytes: A Treasure House of Bioactive Compounds of Medicinal Importance. *Frontiers in Microbiology*, *7*. https://doi.org/10.3389/fmicb.2016.01538
30. Haque, M. Z., & Islam, M. T. (n.d.). *Transboundary Issues in Forest and Biodiversity-Focusing on Sundarbans Forests and mitigating measures*. https://www.researchgate.net/publication/357172449
31. Hardoim, P. R., van Overbeek, L. S., Berg, G., Pirttilä, A. M., Compant, S., Campisano, A., Döring, M., & Sessitsch, A. (2015). The Hidden World within Plants: Ecological and Evolutionary Considerations for Defining Functioning of Microbial Endophytes. *Microbiology and Molecular Biology Reviews*, *79*(3), 293–320. https://doi.org/10.1128/mmbr.00050-14
32. Iftekhar, M. S., & Saenger, P. (2008). Vegetation dynamics in the Bangladesh Sundarbans mangroves: A review of forest inventories. In *Wetlands Ecology and Management* (Vol. 16, Issue 4, pp. 291–312). https://doi.org/10.1007/s11273-007-9063-5
33. Imhoff, J. F., Labes, A., & Wiese, J. (2011). Bio-mining the microbial treasures of the ocean: New natural products. In *Biotechnology Advances* (Vol. 29, Issue 5, pp. 468–482). https://doi.org/10.1016/j.biotechadv.2011.03.001
34. Izzati, F., Rahmawati, S. I., Hapsari, Y., Rachman, F., & Simanjuntak, P. (2020). Antioxidant and cytotoxic activity of endophytic bacteria isolated from mangrove species. *IOP Conference Series: Earth and Environmental Science*, *439*(1). https://doi.org/10.1088/1755-1315/439/1/012051
35. Jeewon, R., Luckhun, A. B., Bhoyroo, V., Sadeer, N. B., Mahomoodally, M. F., Rampadarath, S., Puchooa, D., Sarma, V. V., Sundara, S., Durairajan, K., & Hyde, K. D. (2019). *Pharmaceutical Potential of Marine Fungal Endophytes*.
36. Kamat, S., Kumari, M., Sajna, K. V., & Jayabaskaran, C. (2020). Endophytic fungus, Chaetomium globosum, associated with marine green alga, a new source of Chrysin. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-72497-3

37. Kandasamy, G. D., & Kathirvel, P. (2024). Production, characterization and in vitro biological activities of crude pigment from endophytic Micrococcus luteus associated with Avicennia marina. *Archives of Microbiology*, *206*(1), 26. https://doi.org/10.1007/s00203-023-03751-1
38. Maulani, B. I. G., Rasmi, D. A. C., & Zulkifli, L. (2019). Isolation and characterization of endophytic bacteria from mangrove Rhizophora mucronata Lam. and antibacterial activity test against some pathogenic bacteria. *Journal of Physics: Conference Series*, *1402*(3), 033038. https://doi.org/10.1088/1742-6596/1402/3/033038
39. Munshi, M., Sohrab, Md. H., Begum, Mst. N., Rony, S. R., Karim, Md. A., Afroz, F., & Hasan, Md. N. (2021). Evaluation of bioactivity and phytochemical screening of endophytic fungi isolated from Ceriops decandra (Griff.) W. Theob, a mangrove plant in Bangladesh. *Clinical Phytoscience*, *7*(1). https://doi.org/10.1186/s40816-021-00315-y
40. Muthu Narayanan, M., Metali, F., Shivanand, P., & Ahmad, N. (2024). Mangrove endophytic fungi: Biocontrol potential against Rhizoctonia solani and biofertilizers for fragrant rice cultivation. *Heliyon*, *10*(11), e32310. https://doi.org/10.1016/j.heliyon.2024.e32310
41. NAFISATURRAHMAH, A., SUSILOWATI, A., & PANGASTUTI, A. (2023). Optimization of L-asparaginase production from endophytic bacteria isolated from the mangrove Rhizophora mucronata. *Nusantara Bioscience*, *15*(2). https://doi.org/10.13057/nusbiosci/n150215
42. Nag, S., Dutta, R., Chakraborty, S., Bagchi, A., Mitra, O., Samanta, S., & Pandey, P. (2024). Halotolerant and halophilic bacteria present in the mangrove ecosystem: Emerging Bioengineering potentials. In *Biotechnology of Emerging Microbes* (pp. 143–162). Elsevier. https://doi.org/10.1016/B978-0-443-15397-6.00010-3
43. Neamul Kabir Zihad, S. M., Hasan, M. T., Sultana, M. S., Nath, S., Nahar, L., Rashid, M. A., Uddin, S. J., Sarker, S. D., & Shilpi, J. A. (2022). Isolation and Characterization of Antibacterial Compounds from Aspergillus fumigatus: An Endophytic Fungus from a Mangrove Plant of the Sundarbans. *Evidence-Based Complementary and Alternative Medicine*, *2022*. https://doi.org/10.1155/2022/9600079
44. Nurunnabi, T., Al-Majmaie, S., Nakouti, I., Nahar, L., Rahman, S., Sohrab, M., Billah, M., Ismail, F., Sharples, G., & Sarker, S. D. (2018). Antimicrobial activity of kojic acid from endophytic fungus Colletotrichum gloeosporioides isolated from Sonneratia apetala, a mangrove plant of the Sundarbans. *Asian Pacific Journal of Tropical Medicine*, *11*(5), 350–354. https://doi.org/10.4103/1995-7645.233183
45. Nurunnabi, T. R., Nahar, L., Al-Majmaie, S., Rahman, S. M. M., Sohrab, M. H., Billah, M. M., Ismail, F. M. D., Rahman, M. M., Sharples, G. P., & Sarker, S. D. (2018). Anti-MRSA activity of oxysporone and xylitol from the endophytic fungus Pestalotia sp. growing on the Sundarbans mangrove plant Heritiera fomes. *Phytotherapy Research*, *32*(2), 348–354. https://doi.org/10.1002/ptr.5983
46. Nurunnabi, T. R., Sabrin, F., Sharif, D. I., Nahar, L., Sohrab, M. H., Sarker, S. D., Rahman, S. M. M., & Billah, M. M. (2020). Antimicrobial activity of endophytic fungi isolated from the mangrove plant Sonneratia apetala (Buch.-Ham) from the Sundarbans mangrove forest. *Advances in Traditional Medicine*, *20*(3), 419–425. https://doi.org/10.1007/s13596-019-00422-9
47. Parkinson, J. R. (n.d.). *Also of Interest Bangladesh: The Test Case for Development*.
48. Paul, S., Siddiqua, F., & Tayung, K. (2023). Exploration of Mangroves Associated Microbes for Bioactive Metabolites. *INTERNATIONAL JOURNAL OF PLANT AND ENVIRONMENT*, *9*(03), 202–209. https://doi.org/10.18811/ijpen.v9i03.03
49. Quach, N. T., Bui, T. L., Vu, T. H. N., Nguyen, T. T. A., Chu, H. H., & Phi, Q. T. (2022). Endophytic actinomycetes from mangrove plant \(\textit{Avicennia marina}\) in Quang Ninh province, Vietnam: distribution, cytotoxicity, and antioxidant activities. *Academia Journal of Biology*, *44*(3), 87–98. https://doi.org/10.15625/2615-9023/17492
50. Rahaman, M. S., Siraj, M. A., Sultana, S., Seidel, V., & Islam, M. A. (2020a). Molecular Phylogenetics and Biological Potential of Fungal Endophytes From Plants of the Sundarbans Mangrove. *Frontiers in Microbiology*, *11*. https://doi.org/10.3389/fmicb.2020.570855
51. Rahaman, M. S., Siraj, M. A., Sultana, S., Seidel, V., & Islam, M. A. (2020b). Molecular Phylogenetics and Biological Potential of Fungal Endophytes From Plants of the Sundarbans Mangrove. *Frontiers in Microbiology*, *11*. https://doi.org/10.3389/fmicb.2020.570855
52. Rahmawati, S. I., Izzati, F. N., Hapsari, Y., Septiana, E., Rachman, F., Bustanussalam, & Simanjuntak, P. (2019). Endophytic microbes and antioxidant activities of secondary metabolites from mangroves Avicennia marina and Xylocarpus granatum. *IOP Conference Series: Earth and Environmental Science*, *278*(1), 012065. https://doi.org/10.1088/1755-1315/278/1/012065
53. Rutkowska, N., Drożdżyński, P., Ryngajłło, M., & Marchut-Mikołajczyk, O. (2023). Plants as the Extended Phenotype of Endophytes—The Actual Source of Bioactive Compounds. *International Journal of Molecular Sciences*, *24*(12). https://doi.org/10.3390/ijms241210096
54. Sandrawati, N., Ningsih, W., Layla, R., Putra, A. E., Ismed, F., Tallei, T. E., & Handayani, D. (2023). Endophytic Fungi from Mangrove Plant Acanthus ilicifolius L.: Antimicrobial, Anticancer, and Species Determination. *Trends in Sciences*, *20*(7). https://doi.org/10.48048/tis.2023.5089
55. Schulz, B., & Boyle, C. (2006). *What are Endophytes? 9*, 1–2.
56. Siddiqui, A. H. (2019). *Flora of the Sundarbans*. https://www.researchgate.net/publication/353839905
57. Sopalun, K., Laosripaiboon, W., Wachirachaikarn, A., & Iamtham, S. (2021). Biological potential and chemical composition of bioactive compounds from endophytic fungi associated with thai mangrove plants. *South African Journal of Botany*, *141*, 66–76. https://doi.org/10.1016/j.sajb.2021.04.031
58. Strobel, G. (2018). The emergence of endophytic microbes and their biological promise. *Journal of Fungi*, *4*(2). https://doi.org/10.3390/jof4020057
59. Strobel, G., & Daisy, B. (2003). Bioprospecting for Microbial Endophytes and Their Natural Products. *Microbiology and Molecular Biology Reviews*, *67*(4), 491–502. https://doi.org/10.1128/mmbr.67.4.491-502.2003
60. Vaish, S., & Pathak, B. (2023). Mangrove synthesized bio-nanomaterial and its applications: A review. *Environmental Nanotechnology, Monitoring & Management*, *20*, 100866. https://doi.org/10.1016/j.enmm.2023.100866
61. White, J. F. (2020). An Overview of Endophytic Microbes: Endophytism Defined. *Microbial Endophytes*, *January 2000*, 17–44. https://doi.org/10.1201/9781482277302-1

62. Zhou, J., Feng, Z., Zhang, W., & Xu, J. (2022). Evaluation of the antimicrobial and cytotoxic potential of endophytic fungi extracts from mangrove plants Rhizophora stylosa and R. mucronata. *Scientific Reports*, *12*(1). https://doi.org/10.1038/s41598-022-06711-9
63. Zihad, S. M. N. K., Hasan, Md. T., Sultana, M. S., Nath, S., Nahar, L., Rashid, M. A., Uddin, S. J., Sarker, S. D., & Shilpi, J. A. (2022). Isolation and Characterization of Antibacterial Compounds from Aspergillus fumigatus: An Endophytic Fungus from a Mangrove Plant of the Sundarbans. *Evidence-Based Complementary and Alternative Medicine*, *2022*, 1–10. https://doi.org/10.1155/2022/9600079