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ENDOPHYTIC FUNGI FROM MANGROVES - REVIEW

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ABSTRACT: Mangrove plants are used in medicines, and extracts from mangrove species have proven inhibitory activity against human, animal, and plant pathogens. Endophytic fungi are an important component, are universal, and occur within all know plants, including a broad range of hosts in various ecosystems, and therefore play an important role in the natural environment. Numerous species of mangrove produce bioactive compounds that can control microbial growth. Mangrove extracts can also be the likely sources of mosquito larvicides, antifungal, antiviral, anti-cancer, and anti-diabetic complexes. Mangrove endophytic fungi with promising antioxidant activities that may be useful to humans as novel physiological agents. The present review deals with the endophytic fungi from mangrove plants.

INTRODUCTION: Mangroves are woody trees or shrubs and salt marsh halophytes. The mangrove plants are distributed in 121 countries. Pichavaram mangrove forest is an important coastal ecosystem of Tamil Nadu. Mangroves are used in traditional medicine for the treatment of many diseases [1]. The specific regions where mangrove plants grow are called the Mangrove ecosystem. Mangroves are fast decreasing in the number of species with increasing freedom [2]. Mangroves include salt-tolerant plant species that occur along intertidal zones of rivers and seas in the form of narrow strips or as extensive patches in estuarine habitats and river deltas of tropical and sub-tropical regions. The mangrove plants have a great potential to adapt to the changes in climate, rise in sea levels, and to solar ultraviolet -B radiation.

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Mangrove vegetation propagation delivers a prospect to harness and exploit genetic variation directly [3]. Mangrove forests and their long-standing value have been recognized from ancient times (since 6500 B.C) from archaeological evidence and demonstrated. They were used as food, fuel, medicine and tanning leather [4]. Globally, an area of 14 million was covered by mangrove forests, which spread along the coasts consisting of third world nations. The Indian Ocean and west pacific region together account for 20 percent of the world's total area of mangroves [5]. Mangroves are an accumulation of halophytic woody plants that present tropic and subtropic estuarine or brackish habitats. About 75% of the world's tropical coastline is covered with mangroves. These estuarine environments are strongly dynamic in nature, freshwater from numerous channels and creeks and tidal saline water alternatively washes these very special coastlands [6].

Avicennia species were cheap and nutritive feed for buffaloes, sheep, goats, and camels. These animals are allowed to graze in mangrove areas, especially

camels are periodically taken to uninhabited islands with a good mangrove cover for grazing.

This is very common in India, Pakistan Gulf region, and Indonesia [1]. For example, they may confer tolerance to various stresses such as salinity, oxidative stress, hyperosmotic stress, and drought and nutrient stress [7-9].

Kathiresan 2012 [10] reported that extracts from mangroves had the potential to treat human, animal and plant pathogens and for the treatment of incurable viral diseases like AIDS. According to Kathiresan and Bingham 2001 [11] the role of mangroves was known to remove CO_2 from the atmosphere through photosynthesis, and that perhaps reduced the problems with the 'Greenhouse gases' and global warming.

The world mangrove experts were of the opinion that the long-term survival of mangroves is at great risk due to the disintegration of the habitats and that the services by the mangroves may likely be lost within 100 years [12].

Mangrove forests are the important productive tropical ecosystems and are highly potential because the ecosystem is always under stress, which leads to the production of certain compounds for their survival. Indian harbors are the best mangrove forests of the world as they are in the alluvial deltas of the major rivers such as the Ganga, Mahanadi, Godavari, Krishna, Cauvery and also on the bay of Andaman and Nicobar Islands [13-17]. It covers about 6,749 sq km along the 7,516.6 km long coastline, including Islands territories [16].

Among Rhizophoraceae, *Bruguiera*, *Ceriops, Kandelia,* and *Rhizophora*, genera *Rhizophora* has the widest distribution. *R. apiculata, R. mucronata*, and *R. stylosa*, could be found populating in mangrove forest [12]. *Rhizophora mucronata* is characterized by its broadly elliptic to oblong leaves with yellowish stalked flowers [18-19].

There are modifications or alterations in other physiological processes such as carbohydrate metabolism or polyphenol synthesis and due to these reasons, they may have chemical compounds, which protect them from these destructive elements. *Ceriops decandra* is an evergreen tree in the inner mangrove forests. It is a straight columnar tree, usually small to medium-sized, and it belongs to the family Rhizophoraceae, and its vernacular name is "calhasu". It is used in traditional medicine to cure hepatitis and ulcers [20]. The comprehensive account on vegetation was given and divided Sunderban mangroves into three major regions *viz*., Southern, Northern and Central zones [21].

Endophytes: Endophytic fungi are a group of fungi that colonize living and internal tissues of plants without causing any immediate, explicit negative effects [22]. Endophytes are isolated from internal symptomless plant tissues or fungi and bacteria. It attacks the tissues of living plants and cause unclear infections entirely within plant tissues, but cause no symptoms of disease [23].

Endophytes are very important in mangrove fungi that have resulted in the identification of a large number of new bioactive metabolites of nutraceutical and pharmaceutical importance. These include antibiotics, anticancer, antidiabetic, antioxidant, antiviral, anti-inflammatory, and immunosuppressive drugs, along with other pharmaceutical agents [24].

Endophytes are gaining importance because of their enormous potential to produce bioactive compounds. One of the crucial aspects of a successful natural product-based drug discovery program is the selection of natural sources. This discovery of 'taxol' (generic name paclitaxel), a potent anticancer drug from an endophytic fungus, Taxomyces Andreana of yew plant *Taxus brevifolia* Nutt, attracted world's attention on drug discovery and increased their relevance and discovery of ' taxol' a new possibility of cheaper and more widely available product *via* industrial fermentation. The amount of taxol so far produced by most endophytic fungi is relatively small when compared with the produce from trees. However, the short generation time and high growth rate of fungi make it worthwhile to examine these species for production of valuable drugs [25].

Some taxol produced endophytes are *viz*. *Pestalotiopsist microspora Pestalotionpstsguepini*, *Periconia*sp, *Sporormia minima, Trichothecium* sp. *Stegolerium kukenani* strobe, *Tubercularia* sp. *Pestalotia* sp. *Fusarium*sp. *Alternaria* sp, *Pithomyces sp*, *Monochaetia* sp which were

isolated from view as well as other plants. In India, attempts were made to isolated taxol with potent cytotoxic action from two endophytes, *viz*. *Colletotrichum gloeosporioides* and *Bartalinia robilardodies* Tassi isolated from *Justicia gendarussa* burm and *Aegle marmelos*, respectively [26].

Fungi: Fungi are important components in every ecosystem, intimately associated with crucial processes like the decomposition, recycling, and transportation of nutrients in different environments. It has been estimated that there may be over a million different fungal species on this Earth, of which only a small fraction (approx. 5%) have been identified [27].

Hyde, 1990 [28] listed almost 120 fungal species that colonize 29 mangrove plants globally, including 87 ascomycetes, 31 mitosporic fungi, and 2 basidiomycetes. The phenomenon of zonation is one of the most features of the mangrove forests. In 625 mangrove-associated fungi, including 279 Ascomycetes, 277 Mitosporic fungi, and 29 Basidiomycetes, 3 Chytridiomycetes, 2 myxomycetes, 14 Oomycetes, 9 thraustochytrids and 12 Zygomytes was reported Schmit and Shearer, 2003; Liu, 2007 [29-30]. Fungi are one of the important microbial components of the plants. It makes a very important part of the ecosystem along with other microbes [28, 31]. Fungi of Mangroves are called Manglicolous fungi. They are important for nutrient cycling, and they can yield all the required enzymes to degrade lignin, cellulose, and other plant components [32-34]. Fungi are growing on mangroves from different parts of the world, the species diversity and seasonal occurrence of fungi on seedlings of mangroves [35].

Fungi may occur as saprophytes, symbiotically or as a parasite in the mangrove ecosystem and these fungi belong to both the lower class, such as oomycetes and thraustochytrids, and the upper class, such as ascomycetes and basidiomycetes. Fungal secondary metabolites are structurally quite diverse, and their functions frequently are subject to self-defense against other microorganisms. Most often, mangrove fungi ornament in challenging habitats, making them a rich source of bioactive metabolites [36]. Many researchers were engrossed in marine mangrove fungi because of their diversity, the discovery of several novel natural products. With the remarkable progressions in spectroscopic techniques, separation methods and microplate-based sensitive *in-vitro* assays, the natural product exploration of mangrove fungi have attracted special attention regarding novel and unexplored chemical scaffolds [37].

Higher Marine Fungi Occurring on Mangroves: Apart from driftwood, submerged parts of mangroves are also becoming an important source for higher marine fungi in the tropical marine environment. The first report of marine fungi from mangrove came from Australia [38-39].

Endophytic Fungi: Ever since Cribb first described endophytic fungi isolated from mangrove roots in 1955, several studies have been conducted on the fungi living in mangroves along the coastlines of the Indian, Pacific, and Atlantic Oceans have been conducted [38] Cribb and Cribb, 1955. Endophytic fungi are known to be a rich source of bioactive compounds like therapeutics and enzymes. Endophytic fungi occupy a relatively unexplored area in microorganism isolation and thus represent a new source for obtaining enzymes with different potentialities Endophytic fungi are one among these endophytes living inside the plants without causing any apparent symptoms, nearly one million endophytic species present over in all plants [40].

Mangrove endophytic fungi are one of the second-largest ecological groups of marine fungi, encourage the survival of host plants under harsh environmental conditions through long-term plant-fungi interactions [41-43]. Numerous communities were using local plants in many ways to treat various diseases, including gastroenteritis. Medicinal plants establish an actual source of both traditional and modern medicine. Though some plants are assumed to produce metabolites with biological activities, it has been reported recently that fungal endophytes residing within these plants could also produce metabolites similar to or with more activity than that of their respective hosts [44]. Fungal endophytes were found to be universally distributed in nearly 300,000 plant species, complete at least part of their life cycle within healthy plant tissues without causing any apparent disease [45-46].

Endophytic fungi were regarded as new sources of novel active compounds, biological activity, and biotechnological developments; their true potential remains underexplored [47]. In general, leaves have a more diverse fungal endophytes community when compared to other parts of the plant [49-50]. For endophytic fungi of mangrove leaf origin, significant biological activities [51-53].

Alternaria, Aspergillus, Cladosporium, Clolleto-trichum, Fusarium, Paecilamyces, Penicillium, Pestalotiopsis, Phoma, Phomopsis, Phyllosticta, and Trichodema have been recognized as the predominant culturable endophytic fungi in mangroves [30]. An earlier study in secondary metabolites of endophytic fungi from mangrove visible that the fungi produced antibiotic like *Griseofulvin*, which generally found in *Penicillium griseofulvum* [55] on the plant itself, several studies were showed on microorganisms associated with *R. mucronata*, including fungal endophytes. *Penicillium*, *Ampelomyces*, and *Fusarium* were isolated from *R. mucronata* were found to be active against *E. coli*, whereas several others originating from *R. apiculata*, have led to the discovery of novel compounds including acropyrone, bicytosporone D, waol acid, and pestalotiopene [54-55].

The secondary metabolites of endophytic fungi of mangrove are classified as alkaloids, terpenes, coumarins, chromones, quinones, anthraquinones, peptides, phenolic acids, lactones. Halotolerant *Rhizophora stylosa* was isolated from Pestalotiopsis sp, it is capable of producing lignin degrading enzymes. They secreted over 400 salt adapted lignocellulotytic enzymes which develop the salt adaptation of mangrove hosts giving to the occurrence of their presence, Alternaria, Aspergillus, Cladosporium, Colletotrichum, Fusarium, Paecilomyces, Penicillum, Pestalotiopsis, Phoma, Phomopsis, Phyllosticta and Trichoderma have been recognized as the predominant culturable mangrove endophytic fungi [9].

Endophytic fungi have been evaluated as potential pharmaceutical and agricultural resources. Recent studies have investigated the biodiversity and distribution of mangrove endophytic fungi in the South China Sea. The taxonomic identities and diversity of endophytic fungal groups isolated from five species of the genus *Sonneratia*, namely, *S. caseolaris, S. hainanensis*, *S. ovata*, S. *Paracaseolaris*, and *S. apetala. Ceriopstagal, R. apiculata, R. stylosa*, and *Bruguiera sexangula* var. rhynchopetala have been addressed. Although, endophytic fungi from the above-mentioned mangrove species have already been found on leaves, the fungal diversity and associated antioxidant potential of the various tissues of *R. stylosa* and *R. mucronata* in the South China Sea have only rarely been studied [56, 9].

Relationship between Endophytic Fungi and the Host Plant: Endophytic fungi live in various tissues of a host plant, asymptomatically, without causing any negative effect to the host plant [45]. When a host plant harbors endophytes, their agreement may help the host to adjust to biotic and abiotic stress factors [57-60]. The studies of endophytic fungi and their relationships with the host plants are shelter light on the ecology and evolution of both the endophytes and their hosts. The evolution of endophyte plant symbioses and the ecological factors that influence the direction and strength of the endophyte host plant interaction [60]. A variety of associations exist between fungal endophytes and their host plants, ranging from mutualistic or symbiotic to antagonistic or slightly pathogenic. Endophytes may produce an excess of substances of potential use to agriculture, industry, and modern medicine such as novel antibiotics, antimycotics, and anticancer compounds [61].

Six thousand five hundred endophytic fungi were isolated from herbaceous plants and trees then screened them for biologically active compounds. They found a relationship between biological activity and biotope. They become a higher proportion of the fungal endophytes, in contrast to the soil isolates, suppressed at least one of the test organisms for antialgal and herbicidal activities [62].

Bioprospecting Potential of Mangrove Endophytic Fungi: The method of searching for useful products derived from bioresources is known as bioprospecting. The products derived from bioresources includes genes, organism, chemical compounds, and also the products used in medical, industrial, agricultural, and food sectors. This method helps in conserving and utilizing the bio-resources.

Medicinal plants have been recognized as a repository of fungal endophytes with novel metabolites of pharmaceutical position [63-64]. The various natural products produced by endophytic fungi have single structures and great bioactivities, representing a huge reservoir that suggestions an enormous potential for manipulation for medicinal, agricultural and industrial uses [46, 65].

Mangrove resources have rich bioprospecting potential, which can tolerate salinity and flood. Mangrove extract is used to develop drugs to cure human diseases. Many types of research have proved that mangroves have greater scope in clinical medicines, which lead to the development of patents, which act as a source of employment and revenue opportunities. Thus, in upcoming year mangroves can be raised as "cash crops" [66]. The leaves are having more diverse fungal endophytes community when compared to other parts of the plant. In *R. mucronata*, parts like the bark and leaves were used predictably as sharp and sterile, and they showed to keep activities against bacteria, ulcers, and inflammation [67-69].

Mangrove-Derived Substances to Control Harmful Microbes: Quorum sensing (QS) is the phenomenon by which bacteria secrete and release autoinducers through which it communicates with each other. Gram-negative bacteria utilize N-acyl homoserine lactone as autoinducer, while Gram-positive bacteria utilize oligopeptides. These autoinducer molecules stimulate virulence factor, biofilm formation, and also other expressions of bacterial characters that are necessary for the survival of pathogenic bacteria. The virulence and biofilm formation of bacteria [70-71].

Microbial Diseases and its Drug Resistance: Bacterial diseases are responsible for heavy mortality in human beings. Antibiotics used in both human as well as veterinary medicines have been tried experimentally to treat bacterial infections of fish [71]. Bacterial resistance to antibiotics has been a great problem for many years. Due to the selective use of antibacterial drugs, the microorganisms have developed resistance to many commercial antibiotics, and the development of the disease-causing pathogens and evolution of existing micro-organisms has resulting severe consequences, including mortality of patients [72-73].

Plant Growth Regulator (PGR) of Mangrove Endophytes: Gomathinayagam and Arunprasath 2015 [74] used *Ceriopsis decandra* propagule cuttings of vegetative propagation is minimum expensive, and its success is still limited to mangroves and studied the effect of plant growth regulator (PGR) on rooting, root number leaf formation and fresh, dry weight of roots by applying growth hormone substances. The achievement of this method requires proper hormonal balance, temperature, rainfall, humidity, nature of media, and light, collectively decide the status of regeneration of roots in cuttings [75].

Antimicrobial Activities of Fungal Endophytes of Mangrove Plants: Endophytes are a rich source of natural products displaying a spectrum of biological activates Many endophytic fungi are known to produce antimicrobial substances. The crude extracts from culture broths of endophytic fungi have shown antimicrobial activity against pathogenic fungi, bacteria, and yeasts. There are numerous studies on the antimicrobial activity of endophytic fungi isolated from different geographical locations. There are scanty reports from different ecological settings in India [76-77].

Maria *et al*., 2005 [77] studied antifungal and antibacterial activities of 14 endophytic fungi isolated from two mangrove plants, *viz*. *Acanthus ilicifolius* and *Acrostichum aureum* and indicated that many endophytes of mangrove plants are likely to possess novel metabolites of leaf, stem, and bark from eight medicinally important plant hosts from Western Ghats of India. Partially purified extracts of *Alternaria* sp and *Nigrospora oryzae* exhibited considerable antimicrobial activity selected bacteria and fungi.

Abeysinghe and Wanigatunge, 2006 [78] reported that ethyl acetate extract from the matured leaves of *Avicennia marina* and methanol extract of *Excoecaria agallocha* leaves and shoots shows antimicrobial activity methanolic extract of *Exoecaria agallocha* and *Bruguiera gymnorrhiza* trunks was also show antifungal activity. Recent research shows that Indian mangroves contained antibacterial and antifungal properties.

Two hundred bioactive metabolites isolated were from mangroves of tropical and subtropical

populations. According to their chemical structure, most of the isolated compounds belong to steroids, triterpenes, saponins, flavonoids, alkaloids, tannins and phenolics which have a wide range of therapeutic possibilities [79, 80].

Wu *et al*., 2008, [81] reported that the antibacterial activity of matured leaves, tender leaves and bark extracts of *Avicennia marina, Avicennia officinalis,* and *Bruguiera sexangula*. The antibacterial activity was screened against pathogenic bacteria species of *Staphylococcus* sp., *Proteus* sp., *Escherichia coli, Shigella* sp. and *Pseudomonas* sp. Twelve different plant extracts in *A. marina, A. officinalis* and *B. sexangula* displayed a different degree of growth inhibition against tested bacterial strains. Mature leaf extracts of *A. marina* and tender leaf extracts of *A. officinalis* in ethyl acetate showed antibacterial activity than other plant extracts.

Chandrasekaran *et al*., 2009 [82] reported that antimicrobial activity of *Rhizophora conjugata* and using the extraction of hexane, chloroform, and methanol. The antimicrobial activities of the organic solvent extracts on the various test microorganisms, including bacteria and fungi, studied using agar well diffusion technique. Methanol extracts showed high antimicrobial activity than chloroform and hexane extracts. Among all tested microorganisms *L. acidophilus* (22 mm) showing the highest result followed by *S. salivarius* (19 mm), *A. hydrophila, S.mutans,* and lowest activity was showed with *C. herbarum, F. oxysporum, S. anginosus* and *S. mitis* with concentration 100 mg/ml.

Pradeep Khajure and Rathod, 2010 [83] reported that the antimicrobial activity of n-hexane, chloroform and methanol extracts of leaves and roots of the plant *Acanthus ilicifolius*. Ampicillin and clotrimazole were used as a standard of antibacterial and antifungal. The result of the study exposed that the n-hexane extract and chloroform extract of leaves exhibited strong inhibitory action against *Bacillus subtilis, Staphylococcus aureus, Candida albicans, Aspergillus fumigatus, Aspergillus niger*against *Pseudomonas aeruginosa* and *Proteus vulgaris.*

Rafat *et al*., 2010 [84] reported that the antimicrobial activity of the mangrove plant *Sonneratia apetala* of the extracts was determined by the good diffusion method. *In-vitro* screening of activity *Sonneratia apetala* mangrove plant extracts showed species-specific activity in inhibiting the growth of bacteria and fungi. Hexane, chloroform and methanol extracts showed good activity against all the pathogens, whereas methanolic extracts were active against most of the pathogens.

Anticancer Activities of Mangrove Endophytic Fungi: *Sonneratia apetala* exhibited the two new metabolites, such as 3R,5R-Sonnerlactone, 3R,5S-Snerlactoonne, and two known compounds namely 3,4-dihydro-4,8-dihydroxy-7- (2-hydroxyethyl)- 6-methoxy- 1(2H)- naphthalen- 1- one and 10-norparvulenone. Antiproliferative activity of new compounds was evaluated against multi-drug resistant human oral floor carcinoma (KV/MDR) cells. Both the compounds inhibited KV/MDR cell growth by 42.4 and 41.6% at 100μM, respectively Li *et al*., 2010 and Li, G., and Kusari, 2017 [85-86].

Bhimba *et al*., 2011, [87] reported fungal strain Irpex hynoides isolated from the leaves of *Rhizophora mucronata* and *Avicennia officinalis*. They have proved the cytotoxic activity against HEp2 cell line and the bioactive metabolite in the extract was tetradecane.

F. oxysporum from *Rhizophora annamalayana* was identified as taxol-producing fungus. The amount of taxol produced by the fungus was found to be 172.3 μg/L. Anthracenedione derivatives were extracted from the secondary metabolites of mangrove endophytic fungi *Halorosellinia* sp. and *Guignardia* sp. isolated from *Kandelia* woody tissue from the South China Sea. of the 14 compounds investigated, 1- hydroxy- 3-methyl anthracene-9, 10-dione (115) induced apoptosis in KB and KBv200 cells and displayed cytotoxicity with IC_{50} values of 3.17 and 3.21 μM respectively Zhang J. Y. *et al*., 2010 and Elavarasi *et al*., 2012; Fazilath Uzma *et al*., 2018 [88-90].

The Mangrove endophytic fungi of *Fusarium* sp. was isolated from the fresh stems of *Kandelia candel* in Rhizophoraceae and metabolite analysis exposed the presence of a new isoflavone 5-O-methyl-2′- methoxy-3′- methylalpinumisoflavone together with four known compounds such as6-methoxy-5, 7, 4′-trihydroxyisoflavone, 6-methoxy-

7,4′-dihydroxyisoflavone, (+)-marmesin and 4-methylbenzoic acid carboxymethyl ester. Cytotoxic activity studies against the HEp2 and HepG2 cell lines revealed that compound 123 inhibits cell proliferation significantly with IC_{50} values of 4 and 11 μM [91].

Five highly oxygenated chromones named rhytidchromones A-E were isolated from the endophytic fungus of *Rhytidhysteron rufulum*. The fungal strain was isolated from the healthy leaves of *Bruguiera gymnorrhiza* collected from Pak Nam Pran, Prachuab Kiri Khan Province, Thailand. The isolated compounds were tested for their cytotoxicity on a panel of cancer cell lines (MCF7, HepG2, Kato-3, and CaSki). All the compounds excluding rhytidchromone D, displayed cytotoxicity toward Kato-3 cell lines with IC50 values ranging from 16.0 to 23.3 μM, Chokpaiboon *et al.*, 2016 [92]. Meleagrin was isolated from the endophytic fungus *Penicillium* sp. Compound Meleagrin showed potent cytotoxic activity against two tumor cell lines, HL60 and A549, with IC_{50} values of 9.7 and 8.3 M [93].

A new isobenzofuranone, 4-(methoxymethyl)-7-methoxy-6-methyl-1(3H)-isobenzofuranone , was isolated from the mangrove endophytic fungus, *Penicillium* sp, which was associated with the leaves of mangrove tree *Avicennia* from Dong Sai, Hainan, on the South China Sea coast. These showed cytotoxic activity against the KB and KBV200 cell lines with IC_{50} values of 6 and 10 g/mL [94].

Penicillium sp. ZH16, a mangrove endophytic fungus, obtained from the South China Sea, was the source of the furanocoumarin 5-methyl-8-(3-methylbut-2-enyl) furanocoumarin and they exhibited cytotoxicity against the KB and KBV200 cell lines with IC_{50} values of 5 and 10 g/mL [95].

Polythene and Plastic Degrading Microbes: Microbes were isolated from mangrove sediment and measured for their capability of degrading the polythene and plastics. A bacterial species *Pseudomonas* sp is accomplished of degrading 20.54% of polythene and 8.16% of plastics. A fungal species *Aspergillus glaucus* has an efficiency of degrading 28.8% of polythene and 7.26% of plastics [96].

Mosquito Repellents and Larvicides from Mangrove Endophytic Fungi: Mangrove extracts to kill the mosquito larvae of *Aedes aegypti*, *Culex tritaeniorhynchus* and *Anopheles stephensi* separately the vectors of dengue fever, filariasis, and malaria. The extract of aerial root from *Rhizophora apiculata* shows high mosquito larvicidal activity at very low concentrations. The bioactive compound was existing in the mangrove extract is pyrethrum derivatives. When mangrove extract is applied as an ointment on human skin and showed repellant activity against the adult mosquito of *Aedes aegypti* some extracts show potent smoke repellency and produce a lethal effect on adult mosquito of *Culex quinquefasciatus* and *A. aegypti* [97].

Anti-diabetic Activity of Mangroves: Nabell *et al*., 2010 [98] reported that mangrove plant *Ceriops decandra* showed anti-diabetic activity at a dose of 120mg/kg comparable to commercial drug, glibenclamide, and diabetics is a disorder characterized by increased fasting, postprandial glucose concentration, insulin deficiency and decrease insulin action.

Biofertilizer Production from Mangrove Endophytic Fungi: The fungus *Trichoderma* was isolated from mangrove soil is gifted of phosphate solubilization and phytase enzyme production and Saravana Kumar *et al*., 2013 [99] proved that the fungal treatment improves the mangrove soil fertility as well as growth and biomass production of mangrove seedlings like *Avicennia marina* and *Rhizophora mucronata* and *R. apiculata*.

Valuable Genes from Mangrove: M.S. Swaminathan Research Foundation (MSSRF) has isolated a salt-tolerant gene (AM 244) from the mangrove species of *Avicennia marina*, and introduced it into a paddy crop (Pusa Basmati and IR64) *via* Agrobacterium. MSSRF has a vision of transferring the gene responsible for salt tolerance from mangroves to crop plants, thereby cultivating the crop plants along the cost using the saltwater irrigation. The salt-tolerant paddy variety is under experimental trial. With the increasing seawater disturbance due to coastal climate change, it is needed to find out high salt-tolerant genotypes of mangroves. This will have a bearing on the

flexibility and recovery of mangrove species under the changing coastal climate condition.

CONCLUSION: Mangroves are a productive and biologically important ecosystem on this planet, providing vital ecosystem goods and services. Mangroves are considered the most specialized ecological assemblages of halophytic plants acting as a transient zone between land and ocean. This review shows that many endophytes inhabiting the diverse forests of the world, importantly fungi have proved themselves to be rich sources of new bioactive metabolites.

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