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Mangrove Medicinal Plants: A Review

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Abstract: India has a rich heritage of knowledge on plant based drugs both for use in preventive and curative medicine. A country like India is very much suited for development of drugs from medicinal plants. A large number of these plants grow wild and exploited especially for use in indigenous pharmaceutical houses. Some of these plants produce valuable drugs which have high export potential. The use of plants and plant products as medicines could be traced as far back as the beginning of human civilization. Mangrove plants have been used in folklore medicines and extracts from mangrove species have proven inhibitory activity against human, animal and plant pathogens. The present review deals with the pharmacological activity of mangrove medicinal plants. Several species of mangrove produce bioactive compounds that may control microbial growth. Also, preliminary studies have demonstrated that the mangrove plant extracts have antibacterial activity against pathogenic bacterial strains. Mangrove extracts can also be the possible sources of mosquito larvicides, antifungal, antiviral, anti-cancer and anti-diabetic compounds.

Key words: Mangroves · Medicinal Plants · Pathogenic Microorganisms · Drug Resistance and Antimicrobial Activity

INTRODUCTION

Infectious diseases are the world's leading cause of premature deaths [1]. Furthermore, various hard work have been made to discover new antimicrobial compounds from many kinds of natural sources such as plants, animals, fungi, bacteria and other microorganism. It is because the phenomenon that many pathogenic bacteria become resistant to antibiotics. In addition, many synthetic antibiotics smoothly confirm the terrible effect in term of health and bacterial resistance. Contrary to the synthetic antibiotic, antimicrobials of plant origin are not associated with many side effects and have an enormous therapeutic potential to heal many infectious diseases [2].

Microorganisms have potential to cause human diseases. Most of the time viruses, bacteria and fungi act as major pathogenic organisms. The discovery of antibiotics in the early twentieth century provided an increasingly important tool to combat bacterial diseases. As antibiotics are increasingly used and misused, the bacterial strains become resistant to antibiotics rapidly. Therefore, screening of antibacterial activity of medicinal plants is very important since vast number of medicinal plants have been used for centuries as remedies for human diseases. Among them extracts from different parts of mangroves and mangrove associates are widely used throughout the world [3].

The marine world offers an extremely rich resource for important compounds of structurally novel and biologically active metabolites. It also represents a great challenge which requires inputs from various scientific areas to bring the marine chemical diversity up to its therapeutic potential. So far, many chemically unique compounds of marine origin, with different biological activities, have been isolated and a number of them are under investigation or development [4, 5].

Historically, plants have provided a source of inspiration for novel drug compounds, as plant derived medicines have made large contributions to human health and well-being. Medicinal plants represent a rich source of antimicrobial agents [6]. Because of the side effects and the resistance that pathogenic microorganisms build

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against antibiotics, many scientists have recently paid attention to extracts and biologically active compounds isolated from plant species used in herbal medicine [7]. Mangroves are woody trees or shrubs and the salt marsh halophytes are herbs and sledges. The mangrove plants are distributed in 121 countries and Pichavaram mangrove forest is one of the coastal ecosystems of Tamilnadu, India with rich vegetation. Mangroves are used in traditional medicine for the treatment of many diseases [8].

Mangrove forests are among one of the world's most 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. India harbors some of the best mangrove forests of the world which are located 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 [9-14]. It covers about 6,749 sq km along the 7,516.6 km long coast line, including Island territories [13].

Mangrove plants have been used in folklore medicines and extracts from mangrove species have proven inhibitory activity against human, animal and plant pathogens. Several species of mangrove produce bioactive compounds that may control microbial growth [15]. Also, preliminary studies have demonstrated that the mangrove plant extracts have antibacterial activity against pathogenic bacterial strains; *Staphylococcus* sp., *Escherichia coli* and *Pseudomonas* sp. and antibiotic resistant bacterial strains; *Staphylococcus* sp. and *Proteus* sp. [16]. Mangrove extracts can also be the possible sources of mosquito larvicides, antifungal, antiviral, anti-cancer and anti-diabetic compounds [17].

Secondary metabolites like alkaloids, phenolics, steroids and terpenoids have been characterized from mangroves and have toxicological, pharmacological and ecological importance. However, these studies are restricted to the mangroves of muddy region. Only few species like *Pemphis acidula* are growing only in coral sand substrates [18]. Studies on such species do not exist too much. At present, there is a need to search for new antimicrobial agents because infectious diseases are still a global problem because of the development and spread of drug-resistant pathogens. Encouraged by the idea of "Drugs from the Sea", the chemists have identified lots of bioactive compounds with novel structures from the rich marine bioresource in the recent fifty years. Among them, marine derived microbes have contributed an important proportion. Microbes have been known to be a major source of active compounds used in medicine. In the present study, three different mangrove medicinal plants were evaluated for its antimicrobial activity against human pathogens.

Microbial Diseases and its Drug Resistance: Bacterial diseases are responsible for heavy mortality in human beings. The problems in the farms are usually tackled by preventing disease outbreaks or by treating the actual disease with drugs or chemicals. Antibiotics used in both human as well as veterinary medicines have been tried experimentally to treat bacterial infections of fish. Problems including solubility, palatability, toxicity, cost, delivery and governmental restrictions have limited the available antibiotics to a select few, especially in food fish culture. Decreased efficacy and resistance of pathogens to antibiotics has necessitated development of new alternatives [19].

Bacterial resistance to antibiotics has been a great problem for many years. Due to the in discriminating use of antibacterial drugs, the microorganisms have developed resistance to many commercial antibiotics [20]. Development of such newer disease causing pathogens and evolution of existing microorganisms has resulting severe consequences including mortality of patients [21, 22].

The expanding bacterial resistance to antibiotics has become a growing concern worldwide [23]. Intensive care physicians consider antibiotic resistance bacterial a significant problem in the treatment of patients [24]. Increasing bacterial resistance is prompting resurgence in research of the antimicrobial role of herbs against resistant strains [25, 26]. A vast number of medicinal plants have been recognized as valuable resources of natural antimicrobial compounds [27]. Medicinal plant extracts offer considerable potential for the development of new agents effective against infections currently difficult to treat [2].

The indiscriminate use of commercial antimicrobial drugs has caused multiple drug resistance in human pathogenic microorganisms [28]. Plants containing active compounds are able to inhibit the microbial growth. Studying plant based antimicrobial properties provides additional information in developing natural antibiotics and discovering the alternative of antimicrobial drugs for the treatment of infectious diseases [29].

Antibiotics since their introduction are one of the most important weapons in fighting against bacterial infections and have largely benefited humans. Many pathogenic organisms are developing plasmid-mediated resistance to the prevailing drugs. Hence, there is a need for novel natural compounds that can be obtained from the plants or microorganisms. Plants, in particular, have been a source of inspiration for novel drug compounds since days immemorable. The search for newer sources of antibiotics is a global challenge preoccupying research institutions, pharmaceutical companies and academia, since many infectious agents are becoming resistant to synthetic drugs [30]. In developing countries were medicines are quite expensive, the investigation on antimicrobial activities from ethnomedicinal plants may still be needed.

Medicinal Plants and its Pharmacological Activity: Disease is as old as life itself and man has always been in search of agents to cure diseases. Medicinal plants and herbs have been used for the eradication of disease and human suffering since antiquity. Plants that possess therapeutic properties or exert beneficial pharmacological effects on an organism are generally known as "medicinal plants". Many indigenous medicinal plants are being discovered everyday. Medicinal plants used in traditional medicine should be collected at the right time, the right season and the right stage of their growth so that the constituents can be optimally harvested [31].

Plants have the major advantage of being the most effective and cheaper alternative source of drugs [32]. The local use of natural plants as primary health remedies, due to their pharmacological properties is quiet common in Asia, Latin America and Africa [33]. Medicinal plants contain substances that can be used for therapeutic purposes or which are used as precursors for the synthesis of useful drugs [34]. Researches on use of plants as the source of drugs and dietary supplements are increasing in recent years. Plants have been found *in vitro* to have antimicrobial property as they are rich in a wide variety of secondary metabolites [35, 36].

Potential of higher plants as source of new drugs is still largely unexplored. Among the estimated 250,000 – 500,000 plant species, only a small percentage has been investigated phytochemically and the fraction submitted to biological and pharmacological screening is even smaller. Thus, any phytochemical investigation of a given plant will reveal only a very narrow spectrum of its constituents. Historically, pharmacological screening of compounds of natural or synthetic origin has been the source of innumerable therapeutic agents. Random screening as tool in discovering new biologically active molecules has been most productive in the area of antibiotics [37].

Researchers are increasingly turning their attention to natural products looking for leads to develop better drugs against many microbial infections [38, 39]. More than 80% of the world's population relies on traditional medicine for their primary healthcare needs. Plants used in traditional medicine contain a wide range of ingredients that can be used to treat chronic as well as infectious diseases. A vast knowledge of how to use the plants accumulated in areas where the use of plants is still of great importance [40]. The medicinal value of plant lies in some chemical substances present in them. The most important of these bioactive compounds of plants are alkaloids, tannins and phenolic compounds [41].

Consumers are increasingly interested in complementary and alternative medicines, including herbal medicine, as they perceive these forms of healing as being both safe and effective. This trend in use of alternative and complementary healthcare has prompted scientists to investigate the various biological activities of medicinal plants. A number of medicinal plants have been documented as important source of bioactive compounds [42].

Saranraj *et al*. [43] evaluated the antibacterial potentiality of ethanol and ethyl acetate solvent extracts of mature leaves of *Acalypha indica* against nine pathogenic bacterial isolates *viz*., *Staphylococcus aureus, Bacillus subtilis, Bacillus cereus, Escherichia coli, Salmonella typhi, Shigella flexneri, Klebsiella pneumoniae, Vibrio cholerae* and *Pseudomonas aeruginosa*. The turbidity of the bacterial inoculums was compared with 0.5 Mc Farland standards and the antibacterial potential of *Acalypha indica* ethanol extract was tested by using Agar well diffusion method. The ethanol extract of *Acalypha indica* (100 mg/ml) showed maximum zone of inhibition (30 mm) against *Pseudomonas aeruginosa, Escherichia coli* and *Bacillus subtilis*. *Staphylococcus aureus* showed less zone of inhibition (12 mm). The ethyl acetate extract of *Acalypha indica* (100 mg/ml) showed maximum zone of inhibition (23 mm) against *Escherichia coli*.

Murugan and Saranraj [44] tested the herbal plant *Acalypha indica* for its antibacterial activity against Nosocomial infection causing bacteria. The *Acalypha indica* was shade dried and the antimicrobial principles were extracted with Methanol, Acetone, Chloroform, Petroleum Ether and Hexane. The antibacterial activity of *Acalypha indica* was determined by Agar Well Diffusion Method. It was found that 50mg/ml of methanolic extract of the plant able to inhibit the growth of nosocomial infection causing bacteria when compared to other solvent extracts. From this it was concluded that the solvent methanol able to leach out antimicrobial principle very effectively from the plant than the other solvents. The phytochemicals present in the *Acalypha indica* was tested and it conferred that the possible antibacterial principle resided in tannins and alkaloids.

Siva Sakthi *et al*. [45] evaluated the antibacterial potentiality of ethanol and ethyl acetate solvent extracts of mature leaves of *Datura metel* against nine pathogenic bacterial isolates *viz*., *Staphylococcus aureus, Bacillus subtilis, Bacillus cereus, Escherichia coli, Salmonella typhi, Shigella flexneri, Klebsiella pneumoniae, Vibrio cholerae* and *Pseudomonas aeruginosa*. The turbidity of the bacterial inoculums was compared with 0.5 Mc Farland standards and the antibacterial potential of *Datura metel* ethanol extract was tested by using Agar well diffusion method. The ethanol extract of *Datura metel* (100 mg/ml) showed maximum zone of inhibition (26 mm) against *Pseudomonas aeruginosa, Escherichia coli* and *Bacillus subtilis*. *Staphylococcus aureus* showed less zone of inhibition (8 mm). The ethyl acetate extract of *Datura metel* (100 mg/ml) showed maximum zone of inhibition (19 mm) against *Escherichia coli*. There was no zone of inhibition against *Pseudomonas aeruginosa*.

Saranraj and Sivasakthivelan [46] tested the antibacterial activity of *Phyllanthus amarus* was tested against Urinary tract infection causing bacterial isolates *viz*., *Staphylococcus aureus*, *Serratia marcescens*, *Escherichia coli*, *Enterobacter* sp., *Streptococcus faecalis*, *Klebsiella pneumoniae*, *Proteus mirabilis* and *Pseudomonas aeruginosa*. The *Phyllanthus amarus* was shade dried and the antimicrobial principles were extracted with methanol, acetone, chloroform, petroleum ether and hexane. The antibacterial activity of *Phyllanthus amarus* was determined by Agar Well Diffusion Method. It was found that methanol extract of *Phyllanthus amarus* showed more inhibitory activity against UTI causing bacterial pathogens when compared to other solvent extracts.

Siva Sakthi *et al*. [45] screened the pharmacological activity of the ethanol and ethyl acetate extract of *Datura metel* and *Acalypha indica* for its antifungal activity against pathogenic fungi. Six different fungal isolates *viz*., *Candida albicans*, *Candida glabrata*, *Aspergillus fumigatus*, *Aspergillus flavus*, *Aspergillus niger* and *Penicillium chrysogenum* were tested for its antifungal activity. The collected leaf samples were powdered and the bioactive compounds were extracted by using ethanol and ethyl acetate in a Soxhelet extractor. The antifungal activity was determined by using Well diffusion method. Ethanol and ethyl acetate extracts with different concentrations (100 mg/ml, 200 mg/ml and 300 mg/ml) were mixed with 1 ml of Dimethyl sulfoxide (DMSO) and added into the well. The inhibitory effect of ethanol extract was relatively high when compared to ethyl acetate extract. The extract of *Datura metel* showed maximum zone of inhibition against fungal pathogens when compared to *Acalypha indica*.

Saranraj *et al*. [47] evaluated the bioactivity of *Mangifera indica* ethanol extract against human pathogenic bacteria and fungi. The plant material was collected, shade dried and powdered. The powdered material was extracted using the organic solvent ethanol. Antimicrobial activity of *Mangifera indica* ethanol extract was determined by Disc diffusion method. The zone of inhibition of *Mangifera indica* ethanol extract against bacteria was maximum against *Vibrio cholerae* followed by *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Proteus mirabilis*, *Pseudomonas aeruginosa* and *Escherichia coli*. The least zone of inhibition was recorded against *Salmonella typhi*. The Minimum Inhibitory Concentration (MIC) was ranged from 2 mg/ml to 4 mg/ml. The Minimum Bactericidal Concentration (MBC) value ranged between 2 mg/ml and 4 mg/ml. For fungi, the zone of inhibition was maximum against *Candida albicans*, followed by *Aspergillus fumigatus*, *Aspergillus flavus*, *Aspergillus niger*, *Candida tropicalis* and *Candida cruzei*. The least zone of inhibition was recorded against *Penicillium* sp. The MIC was 0.5 mg/ml and the MFC value was 1 mg/ml.

Sekar *et al*. [48] screened the pharmacological activity of the ethanol and acetone extract of *Phyllanthus amarus, Acalypha* and *indica Datura metel* for its antimicrobial activity against selected pathogen. The antimicrobial activity was determined by using Disc diffusion method. Ethanol and acetone extracts with different concentrations (100 mg/ml, 200 mg/ml and 300 mg/ml) were mixed with 1 ml of Dimethyl sulfoxide (DMSO). The inhibitory effect of ethanol extract was relatively high when compared to acetone extract. The study of antimicrobial activity of herbal plant extract of *Datura metel*, *Acalypha indica* and *Phyllanthus amarus* showed that the ethanol extract shows promising antimicrobial activity against bacterial and fungal human pathogens when compared to acetone extract.

Mangroves Plants and its Antimicrobial Properties: Mangroves are assemblages of halophytic woody plants that inhibit tropic and sub tropic 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 coastal wetlands. Being flashed by the saline water twice a day, the evergreen floral community occupying these environments is well adjusted to water stress, possesses mechanisms that allow water consumption versus salinity gradient, has broad and specified root systems has marked tendency to vivipary and exhibits xerophytic adaptation techniques. Mangroves, as a matter of fact, are composed of a diverse collection of taxonomically uncorrelated plant species containing both shrubs as well as trees. However, despite of being taxonomically unrelated, these plants express resemblance in physical feature and structural adaption to their habitat as a result of confluent evolution. Though, all members of mangroves can grow well at minimum temperature average is 20°C. Each mangroves species may vary in their salinity tolerance, degree both in their salinity tolerance and the degree to which salinity may be necessary to maintain their growth and competitive dominance. Due to their distribution along inter-tidal coastlines, mangroves are subjected to salt stress. To survive in such stressful habitat, mangroves possess salinity tolerant adaptive 2 mechanisms. Restriction of salt entrance into plants and salt secretion through special salt glands in leaves are common adaptive measures [49].

Mangroves are usually found only in tropical climates, as they need consistently warm conditions for development and survival. They occur in approximately 112 countries and territories and are largely confined to the regions between 30º north and south of the equator [50]. Medicinal plants are known to produce certain bioactive molecules which react with other organisms in the environment; inhibiting bacterial or fungal growth. Antimicrobial properties of medicinal plants are being increasingly reported from different parts of the world [51].

Mangrove plant extracts have been used for centuries as a popular method for treating several health disorders. Plant-derived substances have recently become of great interest owing to their versatile applications. Mangroves are biochemically unique, producing a wide array of novel natural products. Mangrove and mangrove associates contain biologically active antiviral, antibacterial and antifungal compounds. The effects of Mangrove extracts on some microorganisms including *Shigella* sp., *Staphylococcus* sp., *Pseudomonas* sp. has been reported in some studies in the area of pharmacology [52]. Also different type of solvents including ethanol, chloroform and ethyl acetate have been used for extraction [53].

Mangrove forests not only play an essential role as the source of food for marine organisms but are also a good source of food for human consumption based on their nutrient potential [54, 55]. Several mangrove plants are consumed as medicinal plants in traditional medicine for many years [50]. Some recent studies confirmed the medicinal properties in some mangrove plants which were consumed in folkloric medicine. For example, 3',4',5,7- Tetrahydroxy flavone isolated from *Sonneratia caseolaris*, a mangrove plant showed a significant inhibition activity against cell proliferation of SMMC-7721 human hepatoma cells in an *in vitro* cytotoxic assay carried out by Minqing *et al*. [56].

Pharmaceutical potential of mangrove plants including antibacterial and antifungal properties have also been reported. Abeysinghe and Wanigatunge [57] reported promising antimicrobial activity with ethyl acetate extract of *Avicennia marina* mature leaves while Chandrasekaran *et al*. [58] showed the antimicrobial potential of the methanol extract of *Excoecaria agallocha* leaves and shoots. Antifungal activity of methanol extract of *Exoecaria agallocha* and *Bruguiera gymnorrhiza* trunks was also shown [59, 60]. The mangrove plants have also been proved for antiviral, antibacterial and anti-ulcer properties [61-63]

Recent research evidenced that Indian mangroves contained antibacterial [58] and antifungal [64] properties. Until now, more than 200 bioactive metabolites have been isolated from true mangroves of tropical and subtropical populations [65]. According to their chemical structure, most of the isolated compounds belong to steroids, triterpenes, saponins, flavonoids, alkaloids, tannins and phenolics which having a wide range of therapeutic possibilities [66].

Wu *et al*. [65] evaluated the antibacterial activity of mature leaves, tender leaves and bark extracts of *Avicennia marina*, *Avicennia officinalis* and *Bruguiera sexangula*. The antibacterial activity was screened by using agar diffusion technique 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* exhibited 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 exhibited promising antibacterial activity than other plant extracts. All plant extracts in ethyl acetate showed strong inhibition compared to other extracts on all tested bacterial strains. Among all bacterial strains, *Pseudomonas* sp. and *E. coli* showed considerable growth inhibition against almost all plant extracts.

Henriquez *et al*. [67] reported the different antioxidant activities of five Chile apple cultivars. Different parts of a plant might also show different bioactivity potentials. For example, dissimilar antioxidant values from different parts of *Andrographis paniculata* were reported by Rafat *et al*. [68]. The method of plant extraction can also affect bioactivity potential. For example, methanol extract of *Borreria hispida* had higher antibacterial activity than both ethyl acetate and petroleum ether extracts. These references also suggest the application of combination of different assays to indicate a specific bioactivity. As an example, the antioxidant capacity of *Oenanthe javanica* was higher than *Euodia redlevi* using DPPH free radical scavenging assay while the results of superoxide dismutase activity assay showed the higher antioxidant potential of *Euodia redlevi* compare to *O. javanica* from the same plant extracts.

Rafat *et al*. [68] investigated the antimicrobial activity of the mangrove plant extract of *Sonneratia apetala* on the various test microorganisms, including clinical multiple antibiotic resistant bacteria and phytopathogens. Antimicrobial activities of the extracts were determined by the well diffusion method. *In vitro* screening of *Sonneratia apetala* mangrove plant extracts of showed species specific activity in inhibiting the growth of bacteria and fungi. Hexane, chloroform and methanol extracts showed good activity against all the pathogens, where as methanolic extracts were active against most of the pathogens.

Chandrasekaran *et al*. [58] studied the antibacterial activity of aqueous and methanol extracts of leaves/shoots of five salt marsh halophytes and six mangroves against Methicillin resistant, clinical isolates of *Staphylococcus aureus*. There was a clear comparability between the salt marsh halophytes and mangroves in their antibacterial action. The mangrove plants possessed higher antibacterial potency than the salt marsh halophytes. The highest activity was recorded with the methanol extract of *Excoecaria agallocha* followed by the methanol extracts of *Aegiceras corniculatum*, *Lumnitzera racemosa* and *Ceriops decandra*. The minimum inhibitory concentration (MIC) values ranged from 0.125 to 4 mg/mL and 1 to 16 mg/mL for methanol and aqueous extracts.

Chandrasekaran *et al*. [58] collected the *Rhizophora conjugata* and extracted successively with hexane, chloroform and methanol using the soxhlet extraction apparatus. The antimicrobial activities of the organic solvent extracts on the various test microorganisms, including bacteria and fungi investigated using agar well diffusion technique. Methanol extracts exhibited promising antimicrobial activity than chloroform and hexane extracts. Among all tested microorganisms *L. acidophilus* (22 mm) showing highest susceptibility followed by *S. salivarius* (19 mm) and *A. hydrophila, S. mutans* and lowest activity was found with *C. herbarum, F.oxysporum, S. anginosus* and *S.mitis* with concentration 100 mg/ml.

Pradeep Khajure and Rathod [69] studied 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 standard antibacterial and antifungal agents respectively. The result of the study revealed that the n-hexane extract and chloroform extract of leaves exhibited strong inhibitory action against *Bacillus subtilis, Staphylococcus aureus, Candida albicans, Aspergillus fumigatus* and *Aspergillus niger* and moderate inhibitory action against *Pseudomonas aeruginosa* and *Proteus vulgaris.* The rest of the extracts showed good inhibitory activity.

Ravikumar *et al*. [53] screened the antibacterial activity of chloroform extract of *Exoecaria agallocha*. Chloroform extract of leaves exhibited strong inhibitory activity against all the pathogens tested. The six chloroform fractions of *E. agallocha* leaf extracts were collected and tested against the fish pathogens. The 3rd fraction of chloroform from the leaf extracts were showed maximum activity against *Bacillus subtilis*, followed by *Aeromonas hydrophyla*, *Vibrio parahaemolyticus*, *V. harveyi* and *Serratia* sp., respectively. Of these 3rd fraction showed maximum activity (12 mm) against *Vibrio parahaemolyticus,* followed by *Bacillus subtilis* (10 mm), *V. harveyi*, (10 mm) and *A. hydrophyla* (8 mm).

Rai *et al*. [70] examined the antioxidant and antimicrobial properties of ethanol, methanol and chloroform extracts of *Rhizophora mucronata* leaves. Ethanol, chloroform and methanol extracts of the leaves showed the highest antioxidant potential in superoxide dismutase, erythrocyte haemolysis and free radical scavenging assays respectively. The highest total phenolic content was found in ethanol extract followed by methanol extract. Paper disk diffusion method was applied to determine the antimicrobial activities of ethanol and methanol extracts of the leaves. Both ethanol and methanol extracts could inhibit the growth of *Escherichia coli*, *Staphylococcus aureus* and *Bacillus cereus* while no inhibition was detected against *Pseudomonas aeruginosa*.

Rai *et al*. [51] investigated the antibacterial activity of leaves and bark extracts of *Ceriops tagal* and *Pemphis acidula* using acetone, methanol, ethanol and water extract against human pathogens such as *Pseudomonas aeruginosa, Klebsiella pneumoniae, Vibrio parahaemolyticus, Staphylococcus aureus* and *Vibrio cholera*. The *Pempis acidula* possessed higher antibacterial potency than the *Ceriops tagal*, with which the highest activity was recorded in methanol extract of bark, more active against *Staphylococcus aureus* (17.2 ± 0.1 mm). The minimum inhibitory concentration (MIC) value was obtained as 75 mg/mL for methanol extract of the same.

Jaimini *et al*. [71] evaluate the antibacterial potential of a mangrove plant *Sonneratia apetala*. Acetone extract was prepared from the leaves and was tested against various bacterial pathogens. For this purpose, both Gram-negative as well as Gram-positive bacterial strains were tested in this study. Antibacterial potency of the extract was tested by standard growth inhibitory assay methods. The tested extract showed to varying degrees of antibacterial potential against tested Gram - negative as well as Gram - positive bacteria. These promising findings suggest antibacterial activity of the plant material indicating presence of bioactive compounds against bacterial pathogens and exhibiting an alternative source of antimicrobial compounds against diseases caused by these microorganisms.

Ravikumar *et al*. [53] tested the antibacterial activity of the mangrove leaves of *Avicennia marina, Ceriops decandra* and *Bruguiera cylindrica* against antibiotic resistant pathogens *viz*. *Staphylococcus aureus, Streptococcus pneumoniae, Klebsiella pneumoniae, Pseudomonas aeruginosa* and eye pathogens *viz. Escherichia coli, Proteus, Acinetobacter* and *Staphylococcus epidermidis.* Most of the plant extracts showed promising antibacterial activity against both the bacterial groups. However, Maximum antibacterial activity was observed with the leaf extract of *A. marina* with the zone of inhibition 7.12±0.11mm against *P. aeruginosa* followed by *B. cylindrical* (6.8±0.84mm) and *C. decandra* (6.02±0.02). Moreover, the leaf extract of *A. marina* (11.21±0.74 mm) showed highest zone of inhibition against eye pathogens of *S. epidermidis* followed by and against *Acinetobacter* 9.21±0.94 and *E. coli* 8.23±0.86 respectively. The *A. marina* has Minimum Inhibitory Concentration value of 50 µg ml/1 as against *Pseudomonas aeruginosa, Acinetobacter* sp. and *Escherichia coli* followed by MIC value of 100 µg ml/1 against *Klebsiella pneumoniae* and *Staphylococcus epidermidis*.

Ravikumar and Gnanadesigan [72] evaluated the extracts of stem and root of *Avicennia officinalis* for their antibacterial activity was evaluated against *Escherichia coli*, *Enterobacter aerogenes*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Lactobacillus delbrueckii*, *Staphylococcus aureus* and *Streptococcus pyogenes* by agar well diffusion method. The stem and root extracts in acetone demonstrated best antibacterial activity. However, extracts prepared in other solvents also showed antibacterial activity against the test organisms. The extracts that possessed antibacterial activity were further used for the determination of the Minimum Inhibitory Concentration (MIC) taking different concentrations *viz*., 1.25, 2.5 and 5.0 mg /100 µl. The value of MIC was found to be ranged from 1.25 mg/100 µl to 5 mg/100 µl for different test organisms.

Gnanadesigan *et al*. [73] tested different levels of mangrove extract from *Avicenna marina* for its antimicrobial effect. A pathogen, gram negative bacteria *Escherichia coli* and a rotten fungi, *Penicillium digitatum* has been affected by mangrove extract using disc inhibitory zone. The length of inhibition zone was measured in millimeters. Results showed that mangrove extract has inhibitory effect on both tested fungi and pathogen but its effect on pathogen is stronger and more considerable.

Rahmi Nurdiani *et al*. [74] examined the phytochemical content and antibacterial activity potency of methanol extract of *Rhyzophora mucronata*. The phytochemical screening was assayed by qualitative analysis and the antibacterial assay determined by disk diffusion method. The results of phytochemical analysis showed that all methanol extract of root, bark, leaf, fruit and flower of *R. mucronata* contained alkaloid, tannin and flavonoid, in addition fruit contained steroid respectively. The antibacterial activity in gram positive bacteria (*Staphylococcus aureus*) and Gram negative bacteria (*Escherichia coli*) was showed by almost all extracts of root, bark, wood, flower and leaf of *R. mucronata*.

Kazuhiko [59] studied the antibacterial activity and phytochemical analysis of Mangrove plant *Avicennia alba.* Leaf and stem extracts of *A. alba*. The resulted extracts of the plant were screened for antibacterial activity against *Micrococcus luteus*, *Arthrobacter* *protophormiae*, *Rhodococcus rhodochrous*, *Alcaligens faecalis*, *Proteus mirabilis*, *Enterobacter aerogenes*, *Proteus vulgaris*, *Bacillus megaterium*, *Enterococcus faecalis*, *Streptococcus mutans*, *Salmonella enterica*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Bacillus subtilis*. Of the six solvent extracts of *A. alba*, ethyl acetate and acetone extracts of leaf and stem, with few exceptions, showed relatively high antibacterial activity. Benzene and chloroform extracts of *A. alba* showed a larger zone of inhibition against *Salmonella enterica* than other bacteria. *A. alba* leaf and stem extracts of different solvents showed good antibacterial activity against Gram negative bacteria than the Gram positive bacteria tested.

Laith *et al*. [75] investigated the antibacterial activity of leaf extracts of *Rhizophora mucronata* and *Salichornia brachiata* using ethanol against shrimp pathogens such as *Vibrio harveyi, Vibrio vulnificus*, *Vibrio alginolyticus*, *Vibrio anginllarum* and *Vibrio lohi* and fish pathogens such as *Bacillus subtilis, Serratia* sp. *Aeromonas hydrophila, Vibrio harveyi* and *Vibrio parahaemolyticus.* The *Salichornia brachiata* possessed higher antibacterial potency than the *Rhizophora mucronata,* with the highest activity recorded against shrimp pathogens of *Vibrio alginolyticus* (14 mm) and fish pathogens of *Vibrio parahaemolyticus* (15 mm).

Varahalarao Vadlapudi [76] evaluated the antimicrobial activity of aerial parts of *Avicennia alba* against the resistant pathogens The antimicrobial activities of the organic solvent extracts were investigated using agar well diffusion technique. Methanol and chloroform extracts exhibited promising antimicrobial activity than hexane extracts. The zone of inhibition of chloroform varies from (9 to 17 mm) where as with methanol (11 to 28 mm) at 100 mg/ml concentration. Among all microorganisms studied, *Erwinia caratovara* and *Pseudomonas syringae* showed the considerable growth inhibition with chloroform and methanolic extracts. *A. alba* can be used in the treatment of infectious diseases caused by resistant pathogenic microorganisms.

Dhanalakshmi *et al*. [77] studied the antibacterial activity of leaves and seed of *Pongamia pinnata* and *Lawsonia innermis* using agar well diffusion method. The selected bacterial strains, namely *Bacillus subtilis, Escherichia coli, Enterobacter aerogenes*, *Micrococcus luteus* and *Pseudomonas aeruginosa* were selected for the study. Maximum zone of inhibition of the active compounds was evaluated by using NCCLS Method. The plant extracts were tested with the standard positive control chloramphenicol. Among the three solvents analyzed, ethanolic leaf extract of *Pongamia pinnata* and *Lowsonia innermis* exhibited a maximum resistance against *Bacillus subtilis* and possessed a highest inhibitory zone against *Pseudomonas aeruginosa* and *Micrococcus luteus* respectively when compared to other bacterial strains.

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