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Medicinal Plants and its Antimicrobial Properties: A Review

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Abstract: The beneficial medicinal effects of plant materials typically result from the secondary products present in the plant although, it is usually not attributed to a single compound but a combination of the metabolites. The medicinal actions of plants are unique to a particular plant species or group, consistent with the concept that the combination of secondary products in a particular plant is taxonomically distinct. The screening of plants usually involves several approach; ethno botanical approach is one of the common methods that are employed in choosing the plant for pharmacological study. In the present review paper, antimicrobial properties of various medicinal plants were reviewed. The present review deals with the antibacterial and antifungal activity of various medicinal plants.

Key words: Medicinal Plants · Drug Resistance · Antimicrobial Activity · Antibacterial Activity and Antifungal Activity

INTRODUCTION

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 plant. Because of its vase and wide variations in soil and climate, the Indian sub-continent is suitable for cultivation of large number of medicinal and aromatic plant which can be used as raw materials for pharmaceutical, perfumery, cosmetics, flavour and food and agrochemical industries. 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 [1].

The use of plants and plant products as medicines could be traced as far back as the beginning of human civilization. The earliest mention of medicinal use of plants in Hindu culture is founds in "Rig veda", which is said to have been written between 4500-1600 B.C. and is supposed to be the oldest repository of human knowledge. It is Ayurveda, the foundation of medicinal science of Hindu culture, in its eight division deals with specific properties of drugs and various aspects of science of life and the art of healing [2].

In the modern world multiple drug resistance has developed against many microbial infections due to the indiscriminate use of commercial antimicrobial drugs commonly used in the treatment of infectious disease. In addition to this problem, antibiotics are sometimes associated with adverse effects on the host including hypersensitivity, immune-suppression and allergic reactions. This situation forced scientists to search for new antimicrobial substances. Given the alarming incidence of antibiotic resistance in bacteria of medical importance, there is a constant need for new and effective therapeutic agents. Therefore, there is a need to develop alternative antimicrobial drugs for the treatment of infectious diseases from medicinal plants [3, 4]. The antimicrobial drug resistance was also reviewed by Saranraj and Stella [5].

Ali Rehman *et al*. [6] proposed that the aqueous and ethanolic extracts of *Azadiracha indica* have antimicrobial activity against *Microsporum canis*, *Aspergillus fumigatus*, *Candida albicans*, *Escherichia coli* and *Staphylococcus aureus* by disc diffusion method. There was no zone of inhibition of *Acalypha indica* towards *Aspergillus fumigatus* and *Candida albicans*. The leaves and roots of the aqueous extract of *Azadiracha indica* inhibit the growth of *Microsporum*

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canis. There was no inhibition zone of inhibition of ethanol and aqueous extract of leaves, seeds roots and stem of *Acalypha indica* against *Staphylococcus aureus* and *Escherichia coli*.

Uma and Sasikumar [7] stated that different organic and alcoholic extracts of *Calotropis gigantia, Justica adhatoda*, *Moringa oleifera* and *Poper betle* have antimicrobial activity against certain bacterial pathogens *Escherichia coli, Staphylococcus aureus, Bacillus subtilis* and *Klebsiella pneumoniae* and fungal strains of *Aspergillus niger* and *Rhizopus sp*. The plant extracts exhibited broader and moderate activity against all the microbial pathogens at all 100mg/ml, 75mg/ml, 50mg/ml and 25mg/ml concentration.

Veeramuthu Duraipandiyan *et al*. [8] carried out the antimicrobial activity of 18 ethanomedical plant extracts against nine bacterial strains (*Bacillus subtilis*, *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Enterococcus faecalis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Erwinia* sp., *Proteus vulgaris*) and one fungal strain (*Candida albicans*). The results indicated that out of 18 plants, 10 plants exhibited antimicrobial at three different concentrations of 1.25, 2.5 and 5mg/disc. Among the plants tested, *Acalypha fruticosa*, *Peltophorum pterocarpus* and *Pucinia granatum* are effective against *Candida albicans*.

Leeja and Thoppil [9] tested the *In vitro* microbicidal activity of the methanol extract of *Origanum majorana* against seven fungi (*Fusarium solani*, *Candida albicans*, *Aspergillus niger*, *Aspergillus parasiticus*, *Rhizopus oryzae*, *Rhizoctonia oryzae* and *Alternaria brassicicola*) and six bacteria (*Bacillus subtilis*, *Bacillus megaterium*, *Escherichia coli*, *Proteus vulgaris*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*). The methanol extract of *Origanum majorana* can be used as an effective herbal protectant against different pathogenic bacteria and fungi. High toxicity against the growth of *Aspergillus niger* was diagnosed.

Ravi Kumar Patil *et al*. [10] tested the antimicrobial activity of ethanol extract obtained from *Thevetia peruviana* against bacterial species of *Escherichia coli*, *Streptococcus lactis*, *Enterobacter aerogenes*, *Alcaligenes faecalis*, *Pseudomonas aeruginosa*, *Proteus vulgaris* and fungal species of *Fusarium oxysporum*, *Alternaria helianthii*, *Curvularia lunata*, *Aspergillus niger* and *Penicillium* sp. Better antimicrobial activity was observed with the extracts showed maximum activity against *Escherichia coli*, *Enterobacter aerogenes*, *Alcaligenes faecalis*. Among different fungi tested *Aspergillus niger* and *Penicillium* sp. were found to be more sensitive to crude extract when compared to others.

Ayme Fernandez-Calienes Valdes *et al*. [11] performed an extensive *in vitro* antimicrobial profiling for three medicinal plants, namely *Simarouba glauca*, *Melaleuca leucadendron* and *Artemisia absinthium*. Ethanol extracts were tested for their antiprotozoal potential against *Trypanosoma brucei*, *Trypanosoma cruzi*, *Leishmania infantum* and *Plasmodium falciparum*. Antifungal activities were evaluated against *Microsporum canis* and *Candida albicans* whereas *Escherichia coli* and *Staphylococcus aureus* were used as test organisms for antibacterial activity. Cytotoxicity was assessed against human MRC-5 cells. Only *Melaleuca leucadendron* extract showed selective activity against microorganisms tested. Although *Simarouba glauca* exhibited strong activity against all protozoa, it must be considered non-specific.

Asha Devi and Deepak Ganjewala [12] evaluated the antimicrobial activity of *Acorus calamus* rhizome and leaf extracts obtained with different solvents *viz.,* petroleum ether, chloroform, hexane and ethyl acetate. Extracts obtained with ethyl acetate among others were found to be highly effective. Rhizomes and leaf ethyl acetate extracts exhibited pronounced antifungal activity with diameter zone of inhibition ranged from 20-28 and 18-25 mm as well as antiyeast activity with diameter zone of inhibition ranged from 22-25 and 20-23 mm, respectively. The minimum inhibitory concentration (MIC) of the rhizome and leaf extracts for antifungal activity measured was 2-4mg/ml, except *Penicillium chrysogenum* whereas against yeasts was relatively higher, 4-5 and 6-8 mg/ml. MIC value for antibacterial activity was comparatively very high 16 - 42 mg/ml.

Erturk [13] tested the antibacterial and antifungal activities of crude ethanolic extracts of 41 traditional medicinal plant species belonging to 26 families against four bacteria and two fungi: *Bacillus subtilis*, *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Candida albicans* and *Aspergillus niger*. Of the 41 plants tested, 39 showed antimicrobial activity against one or more species of microorganisms. The crude extracts from *Nigellea arvensis* did not show antimicrobial activity against the test microorganisms, *Pistasia lentiscus* showed only antifungal activity against *Aspergollus niger*. The most active antimicrobial plants were *Cuminum cyminum*, *Jasminium officinale*, *Thymus capitatus*, *Viscum album*, *Tanecetum sorbifolium*, *Pimpinella anisum*, *Galega officinalis*, *Liguidamber orientalis*, *Rhus coriaria*, *Alnus glutinosa*, *Pimental officinalis*, *Achillea coarctata* and *Cameli sinensis*.

Antibacterial Activity of Medicinal Plants: Antimicrobials of plant origin have enormous therapeutic potential. They are effective in the treatment of infectious diseases while simultaneously mitigating many of the side effects that are often associated with synthetic antimicrobials. The beneficial medicinal effects of plant materials typically result from the combinations of secondary products present in the plant. In plants, these compounds are mostly secondary metabolites such as alkaloids, steroids, tannins and phenol compounds, flavonoids, steroids, resins fatty acids gums which are capable of producing definite physiological action on body. Compounds extracted from different parts of the plants can be used to cure diarrhea, dysentery, cough, cold, cholera, fever, bronchitis, etc.

Dagmar Janovyska *et al.* [14] tested the antimicrobial activity of crude ethanolic extracts of 10 medicinal plants used in traditional medicine against five species of microorganisms: *Bacillus cereus*, *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Candida albicans*. Of the 10 plants tested, 5 showed antimicrobial activity against one or more species of microorganisms. The most active antimicrobial plants were *Chelidonium majus*, *Sanguisorba officinalis* and *Tussilago farfara*.

Nair *et al*. [15] screened nine plants for potential antibacterial activity. The plants screened were *Sapindus emarginatus*, *Hibiscus rosasinensis*, *Mirabilis jalapa*, *Rheo discolor*, *Nyctanthes arbortristis*, *Colocasia esculenta*, *Gracilaria corticata*, *Dictyota* sp. and *Pulicaria wightiana*. Antibacterial activity was tested against 6 bacterial strains, *Pseudomonas testosteroni*, *Staphylococcus epidermidis*, *Klebsiella pneumoniae*, *Bacillus subtilis*, *Proteus morganii* and *Micrococcus flavus*. Two methods, Agar disc diffusion and Agar disc diffusion, were used to study the antibacterial activity of all these plants. *Pseudomonas testosteroni* and *Klebsiella pneumoniae* were the most resistant bacterial strains. *Sapindus emarginatus* showed strong activity against the tested bacterial strains.

Ramasamy and Charles Manoharan [16] found the antibacterial activity of valuable compounds from various solvent extracts of *Anosomeles indica*, *Blumea lacera* and *Melia azadirachta* against *Escherichia coli*, *Pseudomonas aeruginosa*, *Serratia maraceseuns* and *Staphylococcus aureus* by tube diffusion method. Acetone and methanol extracts of all plants showed strong antibacterial effect, where as petroleum ether and aqueous did not exhibit any effect. *Pseudomonas aeruginosa* and *Serratia marcesenes* were relatively more sensitive.

Voravuthikunchai *et al*. [17] investigated the aqueous and ethanolic extract of ten traditional Thai medicinal plants for their ability to inhibit 35 hospital isolates of MRSA. Nine medicinal plants displayed activity against all isolates tested. Ethanolic extracts of *Garcinia mangostana*, *Pucinia granatum* and *Quercus infectoria* were more effective, with MICs for MRSA isolates of 0.05 -0.4, 0.2-0.4 and 0.2-0.4 mg/ml and for *Staphylococcus aureus* of 0.1, 0.2 and 0.1mg/ml. MBCs for MRSA isolates were 0.1-0.4, 1.6-3.2 and 0.4-1.6 mg/ml for *Staphylococcus aureus* were 0.4, 3.2 and 1.6 mg/ml.

Astal *et al*. [18] tested the aqueous extracts of sage and thyme had action against microorganisms. Phenolic extract of sage and thyme showed antibacterial activity against *Staphylococcus aureus* and *Enterococcus* sp. *Escherichia coli* was more affected by the ethanolic extract of parsley. While, that extract does not elicit pronounce effect on the tested Gram positive organisms. The results of commercial oils of sage, thyme and parsley displayed no antimicrobial activity against *Escherichia coli*, *Proteus mirabilis* and *Salmonella typhi*. The data obtained revealed that, among the 10 tested microorganisms, *Staphylococcus aureus* was the most susceptible microbe to most extracts of the three plants.

Kabir *et al*. [19] stated that both water and ethanol extracts of *Terminalia avicennioides*, *Phyllanthus discoideus*, *Ocimum gratissimum* and *Acalypha wilkesiana* were effective on MRSA. The MIC and MBC of the ethanol extract of these plants range from 18.2 to 24.0mcg/ml were recorded for ethanol and water extracts of *Bridella ferriginea* and *Ageratum conyzoides*. Higher MBC values were obtained for the two plants. All the four active plants contained at least trace amounts of Anthraquinones.

Poonkothai *et al*. [20] pointed out that petroleum ether, benzene ethyl acetate and acetone extract of *Galinisoga ciliate* leaves displays higher activity against Gram positive bacteria (*Staphylococcus aureus* and *Bacillus subtilis*) rather than Gram the negative bacteria (*Pseudomonas aeruginosa* and *Escherichia coli*). The toxicity against microorganisms may be done to the high amount of phenolic compounds present.

Deshpande *et al*. [21] isolated that petroleum ether, acetone and methanol extracts of *Abrus precatorius, Boswellia serrata, Careya arborea, Emblica officinalis, Syzygium cumini*, Wood F*ordia fruticosa* and *Sphaeranthus indicus* shows appreciable antibacterial activity against Gram positive bacteria (*Staphylococcus aureus* and *Bacillus cereus*) and Gram negative bacteria (*Escheriuchia coli*, *Proteus vulgaris* and *Pseudomonas aeruginosa*). Extracts of some other plants were active only against Gram positive bacteria.

According to Tambekatr and Kharate [22] *Ocimum sanctum* showed inhibitory effect on *Escherichia coli*, *Staphylococcus aureus*, *Proteus mirablis*, *Salmonella typhi*, *Enterococcus faecalis*, *Pseudomonas aeruginosa* and *Yersinia enterocolitica*. The leaves extract of various plants such as Tulsi, Pudina and Beetle showed antimicrobial activity of *Escherichia coli*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Salmonella typhi*, *Vibrio cholerae*, *Proteus mirablis*, *Pseudomonas aeruginosa*, *Yersinia enterolitica* while piper betel showed resistance to *Streptococcus pneumoniae*.

Panthi and Chaudhary [23] tested eighteen plant species used in folklore medicine for their antibacterial activity by the disk diffusion method. The bacteria employed were Gram positive (*Staphylococcus aureus*) and Gram negative (*Escherichia coli, Pseudomonas aeruginosa* and *Shigella boydii*). Extracts of eight plants showed encouraging result against three strains of bacteria, while other showed activity against one or two strains.

Balakrishnan *et al*. [24] performed antibacterial activity of *Mimosa pudica*, *Angle marmelos* and *Sida cordifolia* against *Bacillus subtilis*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Salmonella* typhi. The maximum inhibitory zone of inhibition *Sida coxdifolia* was against *Bacillus subtilis* (35 mm) and *Salmonella typhi* (26 mm). *Minosa pudica* and *Aegle marmelos* were found to be active against all the microorganisms tested and the maximum activity was noted against *Pseudomonas aeruginosa* and *Salmonella typhi*.

Attar Singh Chauhan *et al*. [25] screened Sea buckthorn (*Hippophae rhamnoides*) seeds aqueous extract for antioxidant and antibacterial activities. The antioxidant activities (Reducing power, DPPH and liposome model system) showed a good antioxidant activity. The extract was also found to possess antibacterial activity with a MIC values with respect to *Listeria monocytogenes* and *Yersinia enterocolitica* found to be 750 ppm and 1000 ppm respectively. The antioxidant and antimicrobial effects of the extract implicate its potential for natural preservation.

Bupesh *et al*. [26] evaluated the antibacterial activity in the leaf extracts of *Mentha piperita* against pathogenic bacteria like *Bacillus subtilis, Pseudomonas aureus, Pseudomonas aeruginosa, Serratia marcescens* and *Streptococcus aureus*. The aqueous as well as organic extracts of the leaves were found to posses strong antibacterial activity against a range of pathogenic bacteria as revealed by *in vitro* agar well diffusion method. The ethyl acetate leaf extract of *Mentha piperita* showed pronounced inhibition than chloroform, petroleum ether and water, leaf extracts being more on *Bacillus subtilis, Pseudomonas aeruginosa* than *Streptococcus aureus, Pseudomonas aureus* and *Serratia marcescens.*

Mohammad Ahanjan *et al*. [27] tested ethanol, methanol, chloroform, petroleum ether and aqueous extracts of leaves of *Parrotia persica* for antibacterial activity. The zone of inhibition varied from 13 mm to 22 mm. The highest inhibition was obtained with methanol and ethanol. Chloroform and petroleum ether extracts did not show any activity. The MIC value of the methanol extract for the test bacteria ranged between 3.12 mg/ml and 6.25 mg/ml and that of ethanol extract ranged between 6.25 mg/ml and 12.5 mg/ml. The results scientifically validate the use of this plant in the traditional medicine.

Priscila Ikeda Ushimaru *et al*. [28] evaluated the *in vitro* antimicrobial activity of methanolic extracts of some medicinal plants against *Escherichia coli*, *Salmonella typhimurium*, *Staphylococcus aureus* and *Enterococcus* sp. The methanolic extract of *Caryophyllus aromaticus* presented the highest anti-*Staphylococcus aureus* activity and was effective against all bacterial strains tested.

Sumathi and Pushpa [28] tested ten bacterial isolates for their sensitivity against standard antibiotics, aqueous and alcoholic extracts of five plant samples and the mixture. Only the growth of *Escherichia coli* was inhibited by the aqueous extracts of *Acalypha indica*. *Mollungo latoides* was found to be effective in inhibiting the growth of *Escherichia coli* at a concentration of 12.5mg/ml and 6.25mg/ml. The MIC of alcoholic extracts of *Nelumbo nucifera* was found to be 0.390 mg/ml for *Klebsiella pneumoniae*. All the plants extracts showed promising antibacterial properties.

Rupanjali Shan *et al*. [29] tested the antibacterial activity of different solvent extracts of the air dried bark of *Parkia javanica*, against five antibiotic resistant bacteria *viz*, *Bacillus subtilis*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Micrococcus luteus* and *Escherichia coli* by cup-plate diffusion method. MIC values of each active extract were determined. The results showed dose dependent positive activity against all the bacteria except *Escherichia coli*.

Vimala *et al*. [30] carried out the antimicrobial activity of *Ipomea kentrochulous* leaf extracts against several pathogenic microorganisms and microbial isolates by disc diffusion method. The crude, cold methanol, distillate and

residual extracts of *Ipomea kentrochulos* were tried on various microorganisms. The crude extract showed zones of inhibition ranging from 0.0 to 21mm, with maximum activity against isolated *Rhizopus* sp. and least activity against *Serratia marcense, Yersinia* sp. and *Salmonella typhimurium*. The zone of inhibition to cold methanol, residual extract and distillate ranged between 6-18 mm and 9-19 mm suggesting that the distillate was more effective than the crude, cold and residual extracts of *Ipomea kentrochulous* leaf extract against various pathogens and microbial isolates.

Kumar *et al*. [31] evaluated the antimicrobial activities of some Indian medicinal plants against these etiologic agents of *Acne vulgaris*. Ethanolic extracts of *Hemidesmus indicus* (Roots), *Eclipta alba* (Fruits), *Coscinium fenestratum* (Stems), *Curcubito pepo* (Seeds), *Tephrosia purpurea* (Roots), *Mentha piperita* (Leaves), *Pongamia pinnata* (Seeds), *Symplocos racemosa* (Barks), *Euphorbia hirta* (Roots), *Tinospora cordyfolia* (Roots), *Thespesia populnea* (Roots) and *Jasminum officinale* (Flowers) for antimicrobial activities by disc diffusion and broth dilution methods. The results from the disc diffusion method showed that 07 medicinal plants could inhibit the growth of *Propionibacterium acnes*. Among those *Hemidesmus indicus, Coscinium fenestratum, Tephrosia purpurea, Euphorbia hirta, Symplocos racemosa, Curcubito pepo* and *Eclipta alba* had strong inhibitory effects. Based on a broth dilution method, the *Coscinium fenestratum* extract had the greatest antimicrobial effect. The MIC values were the same (0.049 mg/ml) for both bacterial species and the MBC values were 0.049 and 0.165 mg/ml against *Propionibacterium acnes* and *Staphylococcus epidermidis*.

Bin Shah *et al*. [32] investigated the *in vitro* antibacterial activities of a total of 46 extracts from dietary spices and medicinal herbs agar-well diffusion method against five food borne bacteria (*Bacillus cereus*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Escherichia coli* and *Salmonella anatum*). Many herb and spice extracts contained high levels of phenolics and exhibited antibacterial activity against food borne pathogens. Gram-positive bacteria were generally more sensitive to the tested extracts than Gram negative ones. *Staphylococcus aureus* was the most sensitive, while *Escherichia coli* were the most resistant.

Khalid Mahmood *et al*. [33] evaluated the antibacterial activity of *Ocimum sanctum* essential oil against five human pathogenic bacterial species *Escherichia coli*, *Klebsiella* sp., *Proteus mirabilis*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* by disc-diffusion method. Six mm discs were impregnated with 5 and 10 µl of undiluted essential oil and seeded over the plates aseptically having test microorganisms. The zones of inhibition were measured after 24 hours at 378°C. The essential oil exhibited significant antibacterial activity against all the test pathogens, with maximum zone of inhibition against *Staphylococcus aureus* (20.0 mm and 41.5 mm) and minimum against *Escherichia coli* (10.2 mm and 17.8 mm) for 5 and 10 µl of essential oil, respectively. Similarly, the inhibition zones recorded in *Proteus mirabilis* were 15.1 mm and 26.0 mm, in *Pseudomonas aeruginosa* 10.2 mm and 20.0 mm, in *Klebsiella* sp. 11.1 mm and 19.4 mm for two given concentrations of essential oil.

Cock [34] reported the antimicrobial activity of *Ocimum sanctum* leaves against bacteria and yeast. The diameter of inhibition zone recorded in *Escherichia coli* was 18 mm for 22 µl of oil. These differences may be attributed due to presence of antibacterial component in high concentration in local variety enhancing the medicinal importance of indigenous essential oil.

Hadi Mehrgan *et al*. [35] collected the aerial parts of the plant from Alvand mountainside. The air-dried plant materials were ground to fine powder and then extracted by Soxhelet apparatus using methanol. The extract was tested at a concentration of 100 mg/ml against a panel of Gram-positive and Gram-negative bacteria using the disk diffusion technique. This methanolic extract demonstrated antibacterial activity against Gram positive bacteria including *Staphylococcus aureus,* Methicillin resistant *Staphylococcus aureus* (MRSA), *Streptococcus pyogenes*, *Enterococcus faecalis,* Vancomycin - resistant *Enterococcus faecalis* and *Micrococcus luteus* and produced inhibition zones with 8-16 mm diameters. It showed no activity against Gram negative bacteria, such as *Escherichia coli, Pseudomonas aeruginosa* and *Salmonella* spp. Minimum concentrations (MC) of the extract forming a clear zone were determined against susceptible bacteria.

Roopashree *et al*. [36] studied the antibacterial activity with respect to their traditional use as anti psoriatic agents. The herbs were subjected to successive extraction using different solvents and the extracts were subjected to antibacterial evaluation against both Gram positive and Gram negative organisms by Cup plate technique. Among the various extracts, aqueous extracts were found to be more effective against all the bacteria. *Staphylococcus aureus* was more susceptible to the aqueous extracts among the tested organisms.

Koshy Philip *et al*. [37] screened 32 extracts from eight selected medicinal plants, namely *Pereskia bleo*, *Pereskia grandifolia*, *Curcuma aeruginosa*, *Curcuma zedoria*, *Curcuma mangga*, *Curcuma inodora*, *Zingiber officinale* and *Zingiber officinale* for their antimicrobial activity against both Gram-positive bacteria and Gram-negative bacteria using agar disc diffusion assay. The efficacy of the extracts was compared to the commercially prepared antibiotic diffusion discs. No inhibition was observed with the water fractions. None of the plants tested showed inhibition against *Escherichia coli*. *Curcuma mangga* showed some remarked inhibition against the bacteria.

Bishnu Joshi *et al*. [38] assessed the antibacterial properties of selected medicinal plants *viz*. *Ocimum sanctum* (Tulsi), *Origanum majorana* (Ram Tulsi), *Cinnamomum zeylanicum* (Dalchini) and *Xanthoxylum armatum* (Timur), for potential antibacterial activity against 10 medically important bacterial strains, *Bacillus subtilis, Bacillus cereus, Bacillus thuringiensis, Staphylococcus aureus, Pseudomonas* sp, *Proteus* sp, *Salmonella typhi, Escherichia coli, Shigella dysentriae, Klebsiella pneumoniae.* The antibacterial activity of ethanol extracts was determined by agar well diffusion method. The plant extracts were more active against Gram positive bacteria than against Gram negative bacteria. The most susceptible bacteria were *Bacillus subtilis*, followed by *Staphylococcus aureus*, while the most resistant bacteria were *Escherichia coli*, followed by *Shigella dysenteriae, Klebsiella pneumoniae* and *Salmonella typhi*. *Origanum majorana* showed the best antibacterial activity. The largest zone of inhibition was obtained with *Xanthoxylum armatum* against *Bacillus subtilis* (23 mm).

Warda *et al*. [39] tested four plants (*Marrubium vulgare, Thymus pallidus*, *Eryngium ilicifolium* and *Lavandula stoechas*) against *Streptococcus pneumoniae* responsible for pharyngitis, rhinitis, otitis and sinusitis infections. Aqueous and methanol extracts have been prepared and tested on *Streptococcus pneumoniae* collected in four regions. A significant activity has been observed with methanol extracts of three plants; *Marrubium vulgare, Thymus pallidus* and *Lavandula stoechas*.

Doss *et al*. [40] isolated compounds of pharmacological interest (Tannins) from the plant species, *Solanum trilobatum* and assayed against the bacteria, *Staphylococcus aureus*, *Streptococcus pyrogens*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Proteus vulgaris* and *Escherichia coli* using agar diffusion method. Tannins exhibited antibacterial activities against all the tested microorganisms. *Staphylococcus aureus* was the most resistant to tannins isolated from the plant material followed by *Streptococcus pyrogens*, *Salmonella typhi*, *Escherichia coli*, *Proteus vulgaris* and *Pseudomonas aeruginosa*. Minimum inhibitory concentration of the tannins ranged between 1.0 and 2.0 mg/ml while the minimum bactericidal concentration ranged between 1.5 and 2.0 mg/ml.

Sukanya *et al*. [41] examined the ethnobotanical efficacy of Indian medicinal plants; *Achyranthes aspera, Artemisia parviflora, Azadirachta indica, Calotropis gigantean, Lawsonia inermis, Mimosa pudica, Ixora coccinea, Parthenium hysterophorus* and *Chromolaena odorata* using agar disc diffusion method against clinical bacteria (*Escherichia coli* and *Staphylococcus aureus*) and phytopathogenic bacteria (*Xanthomonas vesicatoria* and *Ralstonia solanacearum*). Leaves were extracted using different solvents such as methanol, ethanol, ethyl acetate and chloroform. Among treatments, maximum *in vitro* inhibition was scored in methanol extracts of *Chromolaena odorata* which offered inhibition zone of 10, 9, 12 and 12 mm against *Escherichia coli, Staphylococcus aureus, Xanthomonas vesicatoria and Ralstonia solanaccearum*, followed by chloroform extract of the same plant leaf with inhibition zone of 8, 4, 4 and 4 mm. A significant inhibition of *Escherichia coli* was found in aqueous and in all tested solvent extracts of *Acalypha indica*. In case of *Staphylococcus aureus*, maximum inhibition of 8 mm was obtained in aqueous extracts of *Acalypha indica* and 6 mm from methanol extract of *Lawsonia inermis*.

Swati Chauhan *et al*. [42] assessed the antibacterial activity of standard routine antibiotics along with 23 plant extracts by disc diffusion procedure (Bauer-Kirby method) against *Klebsiella pneumoniae* isolated from nasal samples of pneumonic Barbari goats. The isolate was characterized using biochemical methods and was identified as *Klebsiella pneumoniae*. The organism was found to be resistant against Amoxicillin, Erythromycin, Cephadroxil, Cefaclor, Roxithromycin and Cephalexin. *Terminalia catappa* (Leaves), *Punica granatum* (Bark), *Syzygium cumini* (bark) and *Azadirachta indica* (leaves) showed potential activity with MICs at 62.5 mg/ml, 31.2 mg/ml, 62.5 mg/ml and 125 mg/ml respectively.

Sheeba [43] detected the antibacterial activity against *Staphylococcus aureus*, *Streptococcus* sp., *Bacillus subtilis*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Shigella dysenteriae* and *Vibrio cholerae*. The highest antibacterial activity was

observed in 500 µg concentration of leaf extracts of all bacteria screened except *Shigella dysenteriae*. The minimum zone of inhibition observed in 25 µg concentration of leaf extract except *Pseudomonas aeruginosa* and *Shigella dysenteriae*. These results indicate that the extracts were bacteriostatic at higher concentrations.

Akinjogunla *et al*. [44] assessed the antibacterial activity of extracts of the root and leaf of *Phyllanthus amarus* against extend spectrum lactamase (ESBL) producing *Escherichia coli* isolated from the stool samples of HIV sero-positive patients with or without diarrhoea using Bauer disc diffusion method. The phenotypic confirmation of ESBL - *Escherichia coli* were done by Double Disc Synergistic Methods (DDST). The phytochemical analysis of both root and leaf revealed the presence of alkaloids, flavonoids, saponins, tannins, cardiac glycoside, terpenes and anthraquinones. The strains isolated from both HIV sero- positive patients were susceptible to various concentrations of the extracts (5 mg ml-1, 10 mg ml-1, 20 mg ml-1, 40 mg ml-1 and 80 mg ml-1).

Adegoke *et al*. [45] investigated the phytochemical screening and antimicrobial potentiality of *Phyllanthus amarus* against multidrug resistant pathogens using standard microbiological techniques. The extracts were tested by agar well diffusion method for activity against *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa* and *Klebsiella* sp. isolated from clinical samples. The susceptibility patterns of the test isolates against the crude extract was determined at extract concentrations of 10 mg/ml, 50 mg/ml, 100 mg/ml and 150 mg/ml respectively. The results revealed that the extracts did not inhibit the growth of *Escherichia coli, Pseudomonas* sp. and *Klebsiella* sp. at 10mg/ml but the largest zones of growth inhibition for the ethanolic extract was recorded with *Staphylococcus aureus, Escherichia coli* and *Klebsiella* sp. with a mean zone diameter of 20 mm concentrations. The minimum inhibitory concentration (MIC) of the ethanolic plant extracts on *Escherichia coli*, *Staphylococcus aureus, Pseudomonas aeruginosa* and *Klebsiella* sp. were at 10 mg/ml, 50 mg/ml, 150 mg/ml and 100 mg/ml while the MBC were at 50 mg/ml, 100 mg/ml, 150 mg/ml and 150 mg/ml respectively.

Ajayi and Akintola [46] screened the leave extracts from medicinal plants *in vitro* in the laboratory for their antibacterial activity against two prominent enteric bacteria, *Escherichia coli* and *Salmonella typhimurium* using the agar disc diffusion method. The tyndalized leave extract of *C. zambesicus* showing antibacterial inhibition zone of 4 and 2 mm against *Salmonella typhimurium* and *Escherichia coli* exhibited highest activity than the autoclaved samples and other plant sources tested independently or combined, showing that the combinations of the extract samples do not exhibit synergistic effects.

Saranraj *et al*. [47] 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 [48] 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*. [49] 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 [50] 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.

Saranraj *et al*. [51] 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 2mg/ml and 4mg/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.

Antifungal Activity of Medicinal Plants: Kharat *et al*. [52] showed that acetone extracts of five medicinal plants *viz*., *Catunaregum spinosa*, *Psoralea corylifolia, Woodfordia fructicosa, Solanum virginianum* and *Syzygium cumini* were effective against the standard fungal culture of *Fusarium oxysporum* and *Alternaria alternate*. All the plant extracts were found to be inhibitory for the growth of *Fusarium oxysporum*. The present inhibition was maximum of *Psoralea corylifolia* followed by *Calunaregum spinosa*. All the plant extracts except *Syzygium* cumini were found to be inhibitory for growth of *Alternaria alternate*. Present inhibition was maximum with *Catunaregum spinosa* and *Solanum virginianum* extract.

Sanjay Guleria and Ashok Kumar [53] investigated lipophilic (Dichloromethane) leaf extract of medicinal plants used by Himalayan people. *Alternaria alternata* and *Curvularia lunata* were used as test organism in bioautography. The results indicated that five plant species, among the 12 investigated, showed antifungal activity. CH3OH (1:9, v/v) was used as a solvent to develop silica gel TLC plates. Clear inhibition zones were observed for lipophilic extracts of *Vitex negundo* (R*F* value 0.85), *Ipomea carnea* (R*F* value 0.86), *Thuja orientalis* (R*F* value 0.80) and *Cinnamomum camphora* (R*F* value 0.89). The best antifungal activity was shown by lipophilic leaf extract of *Thuja orientalis*.

Sonia Pereira Leite *et al*. [54] described various organic and aqueous extracts of leaves of *Indigofera suffruticose* (Fabaceae) 17 fungal strains by the agar solid diffusion method. Most of the extracts were devoid of antifungal, except the aqueous extract of leaves of *Indigofera suffruticosa* obtained by infusion. The MIC value of Dermatophyle strains were 2500 mg ml^{-1} against *Trichophyton rubrum* and *Microsporum canis*.

Anand *et al*. [55] tested the medicinal plant extracts of *Curcuma longa, Acalypha indica* and *Anona sqamosa* by Cold percolation method against Dermatophytic isolates. *Curcuma lounga* showed antifungal effect against *Trichophyton rubrum* and *Microsporum gypseum*. These two organisms were found to be resistant towards *Acalypha indica* and *Anona sqamosa*. The other dermatophytes were resistant to all medicinal plants tested.

Kilani *et al*. [56] proposed that the antifungal activity of a herbal decocation used by South western Nigeria traditional healers in the treatment of superficial mycoses and related infectious diseases are effective against clinical isolates of *Candida albicans*, *Trichophyton rubrum* and *Microsporium* sp. *Candida albicans* were highly susceptible, while *Microsporum* sp. were least susceptible. Qualitative detection of some antimicrobial phytochemicals may account for the antifungal efficacy exhibited by the studied decoction.

Padmalatha *et al*. [57] suggested that methanolic extract of root parts of *Achyranthes aspera* shows effect on aflatoxicosis rats at five dose levels. Aflatoxin intoxication in rats significantly elevated the levels of SGPT, SGOT, ALKP and total bilirubin, which indicated acute hepatocellular damage and biliary obstruction. Methanol extracts showed dose dependent decrease in the levels of SGPT, SGOT, ALKP and total bilirubin. Minimum effective dose of extracts was found to be 100mg/ml body weight. Results obtained from histopathological studies also supported hepatoprotective activity against aflatoxin induced hepatotoxicity. Thus the study demonstrates that *Achyranthes aspera* possess anti-hepatotoxic effect against aflatoxin.

Satish *et al*. [58] tested the aqueous extract of 52 plants from different families for their antifungal potential against eight important species of *Aspergillus* such as *Aspergillus candidus*, *Aspergillus columnaris*, *Aspergillus flavipes, Aspergillus flavus*, *Aspergillus fumigatus, Aspergillus niger, Aspergillus ochraceus* and *Aspergillus tamarii* which isolated from sorghum, maize and paddy seed samples. The test fungi were mainly associated with seed biodeterioration during storage. Among fifty-two plants tested, aqueous extract of *Acacia nilotica*, *Achras zapota*, *Datura stramonium*, *Emblica officinalis*, *Eucalyptus globules*, *Lawsonia inermis*, *Mimusops elengi*, *Peltophorum pterocarpum, Polyalthia longifolia*, *Prosopis juliflora*, *Punica granatum* and *Sygigium cumini* have recorded significant antifungal activity against one or the other *Aspergillus* species tested. *Aspergillus flavus* recorded high susceptibility and hence solvent extracts *viz*., petroleum ether, benzene, chloroform, methanol and ethanol extracts of all the twelve plants were tested for their antifungal activity. Among the solvent extracts tested, methanol gave more effective than ethanol, chloroform, benzene and petroleum ether, except for *Polyalthia longifolia*, where petroleum ether extract recorded highly significant antifungal activity than other solvent extracts.

Amer Jamil *et al*. [59] investigated the extracts of some potential medicinal plants such as *Hygrophila auriculata*, *Abrus precatorius*, *Moringa oleifera*, *Withania somnifera*, *Croton tiglium*, *Solanum nigrum* and *Psoralea corylifolia* against pathogenic fungal strains of *Aspergillus tamarii, Rhizopus solani, Mucor mucedo* and *Aspergillus niger*. After extraction the extracts were purified by ammonium sulphate precipitation followed by gel filtration chromatography (Sephadex G-100) by using Tris HCl as an extraction buffer. Antifungal activity of the extracts was determined by disc diffusion assay. Antifungal activity was found lost in many extracts after treatment with trypsin, which shows that the activity was due to proteins or peptides, but not due to some other compounds.

Siva Sakthi *et al*. [60] 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*.

Sekar *et al*. [61] 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 (100mg/ml, 200mg/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.

CONCLUSION

In conclusion, various studies on antimicrobial activity of herbal plant extracts showed that the various solvent extracts showed promising antimicrobial activity against bacterial and fungal human pathogens. The results of various herbal researchers also indicated that scientific studies carried out on medicinal plants having traditional claims of effectiveness might warrant fruitful results. These plants could serve as useful source of new antimicrobial agents.

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