



A Brief Review on Indian Medicinal Plants with Antibacterial Activity

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Abstract

India is a rich country in terms of its flora and fauna. Various plants are used locally for their medicinal properties. Bacterial infections are the most common diseases in today's time which can even lead to mortality. These infections were previously treated by chemical drugs (antibiotics) but due to emergence of resistant bacteria towards various antibiotics and other therapeutic agents, there is need to find different potent compounds to inhibit the bacteria. These medicinal plants consist of various phytoconstituents like phenolic compounds, lipids, essential oils etc., which are responsible for the plant's pharmacology. This review focuses on eleven such medicinal plants for their antibacterial activities. The eleven plants taken were *Anchusa strigose*, *Ocimum sanctum*, *Cinnamomum zeylanicum*, *Acacia nilotica*, *Solanum nigrum*, *Oxystelma esculentum*, *Citrullus colocynthis*, *Ageratina Adenophora*, *Alkanna tinctoria*, *Viola odorata* and *Argemone mexicana*. The activity was tested by the use of antibacterial assay. MIC value of their extracts were tested towards both gram-positive and gram-negative bacteria. Various different extracts of these plants showed different range of antibacterial activity.

Keywords – Antibacterial activity, Antibiotics, Drug resistance, E. coli, Indian medicinal plants, Phytoconstituents, S. aureus.

Introduction

Ayurveda is one of the major ancient healing methods, which is well established in India. In traditional medicine, herbs are commonly used, and their therapeutic ability is well known [1]. For millennia, ancient medical medicine has been recognized in many regions of the world for the management of different human diseases. 80 percent of the worldwide population relies on medicinal plants and the usage of plants as medicinal agents in India persists an essential element of the conventional medicinal method. Medicinal herbs fulfil the healthcare requirements of about 80percent of the worldwide people, mainly millions of citizens in developed countries' large rural areas; over 65% of the world's population [2]. As per the WHO, the safest source for the number of medicines will be the medicinal plants. Phytomedicine, as in the context of the ayurvedic

and Unani method of drugs, may be seen for the management of various diseases or it may be the basis for the production of a medication, a simple blueprint for the production of a drug [3].

Several species of plants have long been used by the native Nepalese people as conventional medicines, namely communicable disease care, but there has been a shortage of evidence on their in vitro and in vivo efficacy [4].

The management of multiple bacterial diseases has been reshaped with the application of antibiotics. Their excessive use, however, has contributed to a troubling rise in microbes' resistance to antibiotics [5]. The key explanation for this is that investigators are concentrating their efforts on plant-derived chemicals and are optimistic of producing stronger drugs towards MDR pathogenic bacteria [6]. Utilizing antibiotic tolerance modifiers from plants is one of the approaches to minimize resistance to antibiotics. In these procedures, the basic oil derived from such plants is also included.

Numerous experiments have established metabolites that are powerful medicines among medicinal herbs [7]. Plant-origin medicines have immense medicinal ability. They are successful in combating communicable diseases thus minimizing several of the adverse effects often related to chemical antibiotics at the same time [8].

Medicinal Phytoconstituents

In medicines, nutraceuticals and cosmetics, medicinal plants are discovering their purpose. Plant species in the pharmaceutical sector are often considered for the large variety of compounds found in plants that have been utilized to cure infectious and chronic illnesses [9]. Usually, the effective therapeutic benefits in plant materials derive from the variations of by-products in the plant that are produced by them. These substances are often secondary metabolites in plants, like hormones, alkaloids, and phenol compounds, and tannins, which are produced and processed in particular sections of the plant or in all parts of plants. Through representing intrinsic compounds, hormones, ligands, neurotransmitters or signal transduction molecules, the secondary products of the plant can exert their impact and therefore have desirable therapeutic impact on mankind because of similarity in their possible target sites [10]. Herbal medicines are an abundant origin of antibacterial products with a broad range of components and numerous plant volatile oils [11]. In particular, essential oil is found throughout the whole sections of the plant, but due to its strong phytoconstituent content, it is primarily derived from the leaves. Its antibacterial function is also accountable for the lipids found in plants.

Pathogenic bacteria's

Among the deadliest infections and common outbreaks of human society have been caused by microorganisms [12]. The 3 major sources of mortality in humans were TB, pneumonia, and diarrhoea in the early span of the 20th Century. As a consequence of the existence of resistant plasmid, which is used as a therapeutic component, bacteria are capable of spreading and develop tolerance to antibiotics [13]. In general, because of the high lipid content, the cell walls of Gram-negative bacteria are more complicated than Gram-positive bacteria and act as a

barrier membrane, making them less sensitive to antimicrobial agents as compared to Gram-positive bacteria [14].

A gram-positive, coccal bacteria, *Staphylococcus aureus* is a facultative anaerobic. Infections of *S aureus* are progressively recorded worldwide [15]. Infections related to *S aureus* often put a heavy and growing pressure on the capital of medical services. In the small intestine of humans and livestock, *Escherichia coli* is usually found. Many *E coli* types are innocuous, although O157:H7 is a crucial concern, since this strain induces extreme diarrhoea, including death, leading to kidney failure and other serious complications [16].

Drug resistance in bacteria

Bacterial diseases which are resistant to antibiotics are now common on the world [17]. The WHO released its first ever checklist of 'threat bacteria' immune to antibiotics in February 2017, representing the largest danger to global health. 1st important concerned microbes include –

Carbapenem-resistant - *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and extended spectrum betalactamase (ESBL) producing Enterobacteriaceae pathogens.

Most concerned second-level microbes include –

- Methicillin-resistant – *S. aureus*
- Fluoroquinolone-resistant - *Campylobacter* spp., and *Salmonellae*
- Cephalosporin and Fluoroquinolone-resistant - *Neisseria gonorrhoeae*
- Clarithromycin-resistant – *H. pylori*
- Vancomycin-resistant - *Enterococcus faecium*

All such priority infections are invulnerable to several antibiotics and also have an in-built capacity to withstand therapy and to transmit genetic material that often renders some resistance of bacteria to drugs. Over the past twenty years, the development of new medicines has steadily declined, offering less opportunities to combat these drug-resistant microbes [18]. This opposition is causing a serious health risk.

Medicinal plants

- *Anchusa strigosa*

Chemical constituents - Pyrrolizidine alkaloids, Four triterpenes i.e., beta-amyrin, oleanolic acid, beta-sitosterol glucoside [19] and crataegolic acid, tetra-, penta-, hexa-, hepta-, octa- and decanoic acid [20].

Pharmacological activities - Antimicrobial, gastric protective effect, antidiabetic and hypotensive.

- *Acacia nilotica*

Chemical constituents - Volatile essential oils, alkaloids, resins, phenols, steroids, phenolic glycosides, tannins, oleosins, and terpenes [21], ellagic acid, gallic acid, leucocyanidin, isoquercetin, rutin, glucopyranoside, and kaempferol-7-diglucoside.

Pharmacological activities - Emollient, astringent, anthelmintic, styptic, diuretic, emetic, expectorant, aphrodisiac, antihemorrhagic, nutritive, antileprotic, wound ulcers, leukoderma, seminal weakness, and skin diseases [22]. Bark of *A. nilotica* has been used for treating diarrhoea, haemorrhages, tuberculosis, colds, and leprosy.

- *Argemone mexicana*

Chemical constituents - Coptisine, Sanguinarine, cheilanthifolined, isorhamentin 3-glycoside, horsanguinarine, and protopine.

Pharmacological activities - Antiviral, antifungal, carcinogenic activities, and antibacterial [23].

- *Cinnamomum zeylanicum*

Chemical constituents - Cinnamon bark contains catechins, procyanidins [24], essential oils, like cinnamyl acetate, α -terpineol, *trans*-cinnamaldehyde, L-borneol, eugenol, caryophyllene oxide, E-nerolidol, α -cubebene, b-caryophyllene, L-bornyl acetate, terpinolene, and α -thujene [25].

Pharmacological activities - Antiviral, larvicidal properties, bactericidal, and antifungal.

- *Ocimum sanctum*

Chemical constituents - Leaves - fatty acid derivatives, volatile oil (0.7%), flavonoids, phenolics, terpenoids, and neolignans.

Seeds - β -sitosterol, fixed oil (18–22%), polysaccharides, and mucilage in the unsaponifiable matter [26].

Pharmacological activities - Radiation protective, wound healing, antidiabetic, antioxidant, anti-inflammatory, antifertility, antimicrobial, antistress, anticancer, and immunomodulatory properties.

- *Solanum nigrum*

Chemical constituents - Nicotinic acid, Riboflavin, β -sitosterol, diosgenine, solasonine, solamargine, α and β - solanigrine, β -carotene, and solasodine.

Pharmacological activities – CNS depressant, diuretic, antibacterial, vasodilation and hypotensive properties [27].

- *Oxystelma esculentum*

Chemical constituents - Flavonoids, cardenolides, triterpenoids, sterols, and phenolics.

Pharmacological activities - Antibacterial and anti-ulcer properties [28].

- *Citrullus colocynthis*

Chemical constituents - Elaterin, dihydroelatericin B, elatericin B, choline, triterpenoids, 1, 11-undecanediol monoacetate, hepatacosan 1-ol, citrullonal, α -elaterin 2-D-glucopyranoside, and nonylhexadecanoate.

Pharmacological activities - Antibacterial and anti-inflammatory and activities [29].

- *Ageratina Adenophora*

Chemical constituents - Germacrene D, ferulic acid, b-farnesene, caryophyllene, bisabolene, epifriedelinol, 9-oxo-ageraphorone, stigmasterol, 9- β -hydroxy-ageraphorone, octacosanoic acid, o-hydroxycinnamic acid, 2- isopropenyl-5-acetyl-6-hydroxybenzo-furan acetate, b-daucosterol, and caffeic acid [30].

Pharmacological activities – Antifungal, antibacterial, antiplasmodial, astringent, antitumor, antifeedant, antioxidant, and anti-HIV.

- *Alkanna tinctoria*

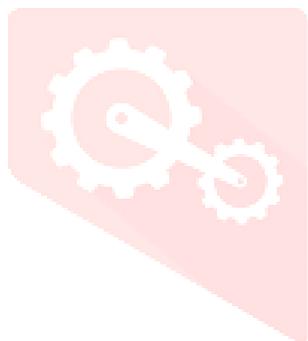
Chemical constituents – Alkannin, dimethylacryl alkannin, angelylalkannin, 5-methoxyangenyalkannin, acetylalkannin, naphthoquinones, alkanfuranol, alkandiol, and arnebifuranone [31].

Pharmacological activities – Emmenagogue, antibacterial, emollient, astringent, and lithotriptic.

- *Viola odorata*

Chemical constituents - Salicylaldehyde, citronellal, spathulenol, 3-hexenol, linalool, 2-hexenal, methyl salicylate, dodecanol, undecanal, tridecane, geraniol, hexadecane, 1,8-ocimene, and heneicosane.

Pharmacological activities - Diuretic, healing, and soothing activity, anti-inflammatory, bronchitis, cystitis, expectorant, rheumatism, and skin conditions.



S. no.	Scientific names	Family	Common names	Plant part
1.	<i>Anchusa strigose</i>	Boraginaceae	Prickly alkanet	Root
2.	<i>Acacia nilotica</i>	Fabaceae	Babool	Leaves
3.	<i>Argemone Mexicana</i>	Papaveraceae	Mexican prickly poppy	Seeds
4.	<i>Cinnamomum zeylanicum</i>	Lauraceae	Cinnamon	Bark
5.	<i>Ocimum sanctum</i>	Lamiaceae	Holy basil	Leaves, seeds
6.	<i>Solanum nigrum</i>	Solanaceae	Black nightshade	Fruit
7.	<i>Oxystelma esculentum</i>	Asclepiadaceae	Rosy milkyweed vine	Leaves
8.	<i>Citrullus colocynthis</i>	Cucurbitaceae	Colocynth	Fruit
9.	<i>Ageratina adenophora</i>	Compositae	Crofton weed, Mexican devil	Leaves, root
10.	<i>Alkanna tinctoria</i>	Boraginaceae	Dyer's alkanet	Leaves, root
11.	<i>Viola odorata</i>	Violaceae	Sweet violet	Flowers and twigs

Determination of antibacterial activity

The antibacterial activity of a compound is assessed by the antimicrobial assay. The potency of the tested compound is evaluated by calculating MIC value.

Antimicrobial assay - Antimicrobial assays are valuable instruments for measuring and screening the inhibitory action towards microbes of numerous substances until their inhibition spectra are formed. The efflux of dye from labelled bacteria was proportionally connected to the compound's antimicrobial activity [32]. In the traditional antimicrobial bioassay for pathogenic *E. coli* O157:H7, *Listeria monocytogenes*, *Salmonella enterica* serovar typhimurium, and *Bacillus cereus*, disk diffusion, spot-on-lawn, and agar well diffusion, assays were conducted. A live-cell-staining, cell-membrane-permeable, green, fluorescent dye, carboxyfluorescein diacetate succinimidyl ester (cFDA-SE) was used to mark the bacteria in the fluorescence-based assay. The dye efflux from labelled bacteria was substantially connected to the compound's antimicrobial function [33].

The most accepted and essential approaches are the broth or agar dilution and disk-diffusion.

i. **Agar disk-diffusion method**

It is the standard tool used in the regular antimicrobial susceptibility monitoring in several medical microbiology labs. By this approach, some fastidious bacterial pathogens like *Neisseria gonorrhoeae*, streptococci, *Haemophilus parainfluenzae*, *Neisseria meningitidis* and *Haemophilus influenzae* have been standardized, utilizing unique culture medium different requirements of incubation and interpretive requirements for zones of inhibition [34]. Agar plates are inoculated with a uniform inoculum of the research microbe in this well-known method. Then, filter sheet discs (approximately 6 mm) are mounted on the agar floor, comprising the test substance at the required amount. In ideal circumstances, the Petri dishes are incubated. The anti-microbial agent typically diffuses into the agar and prevents the growth and development of the test microorganism. The diameter of zone of inhibition is then calculated.

ii. **Agar well diffusion method**

For the determination of the antibacterial function of plants or bacterial products, the agar well diffusion approach is commonly used [35]. Likewise, the agar plate surface is inoculated by distributing an amount of the inoculum across the whole plate as a technique utilized in the disk-diffusion process. A hole of 6 to 8 mm is then penetrated aseptically with a sterilised cork borer or a pin, and the antibacterial substance or extract solution amount (20-100 mL) is injected into the well at the appropriate amount. Then, based on the tested microorganism, agar plates are incubated under appropriate situations. The antibacterial agents diffuse and prevents the development of the tested bacterial species in the agar medium.

iii. **Broth dilution method**

Among the most fundamental antimicrobial resistance research techniques is broth micro- or macro-dilution. The method includes the preparation of two-fold anti-microbial agent dilutions (e.g., 1, 2, 4, 8, 16 and 32 mg/mL) in liquid culture media in tubes comprising a sufficient quantity of 2 mL (macro-dilution) or smaller amounts utilizing a 96-well plate of microtitration (microdilution). A bacterial inoculum formulated in the same medium after dilution of the uniform bacterial culture modified to 0.5 McFarland scale is then inoculated for each tube or well. Following well-mixing, depending on the research microorganism, the inoculated tubes or the 96-well microtitration plate are incubated (without agitation) under acceptable conditions.

Minimum inhibitory concentration

The MIC is the minimum quantity of antibacterial agents in microdilution wells or tubes that fully prevents the organism's development as observed by the naked eyes [36]. The minimum concentration of the product that prevents development is reported as the MIC. MICs are classified as the minimum antimicrobial concentration that inhibits the detectable development of a microbe following 24 hours of incubation, and minimum bactericidal concentrations (MBCs) are defined as the minimum antimicrobial concentration that prevents the

production of an organisms in antibiotic-free medium after subculture. MICs are primarily used by microbiology laboratory to validate tolerance, but more commonly as a testing instrument to assess the in vitro behaviour of new antimicrobials, and MIC breakpoints have been calculated using evidence from such experiments [37].

Antibacterial activity of tested plants

S.no.	Plant name	Solvent extract	Active compound	MIC (mg/ml)	
				S. aureus	E. coli
1.	<i>Anchusa strigose</i> [38]	Methanolic	Lipids and flavonoids	1.56	>20
2.	<i>Acacia nilotica</i> [39]	Methanolic	Tannins	40	45
3.	<i>Argemone Mexicana</i> [40]	Chloroform	Alkaloids	2	2
4.	<i>Cinnamomum zeylanicum</i>	Alcoholic	Essential oils	62.5	62.5
5.	<i>Ocimum sanctum</i> [41]	Methanolic	Flavonoids	16.60	33
6.	<i>Solanum nigrum</i> [42]	Chloroform	Polyphenols	86.4	98.2
7.	<i>Oxystelma esculentum</i> [43]	Methanolic	Phenolics	25	50
8.	<i>Citrullus colocynthis</i> [43]	Methanolic	Flavonoids	50	12.5
9.	<i>Ageratina Adenophora</i> [44]	Methanolic	Essential oils	25	-
10.	<i>Alkanna tinctoria</i> [45]	Aqueous	Alkaloids	12.5	25
11.	<i>Viola odorata</i> [46]	Methanol	Volatile oils	-	0.5

Future research and scope

A significant undiscovered reservoir of drugs is plant-based medications, and more discovery of plant antimicrobial agents needs to take place. However, just 10 percent were tested for the exploration of new substances in plants, especially angiosperms [47]. There is also an enormous opportunity from flowering plants for more interesting active substances which will generate new medicines. The path to achievement in the exploration of phytomedicines would be a more integrative strategy with several natural product discovery methods to reach this unknown treasure. For scientists, academics and scientific firms, these plants are most beneficial in carrying out more experiments on the extraction and discovery of active substances that can be developed into antibacterial agent. These plants may also be checked for their other therapeutic properties, aside from antimicrobial function. However, their survival is threatened by the substantial usage of medicinal plants

for drug development projects, so cultivation of medicinal plants must be promoted to ensure potential transparency [48].

Conclusion

The findings collected support the medicinal value of certain plants used in conventional medicine from our evaluation of the testing of multiple plant organisms. Herbal medicines have therapeutic effects attributed to the existence in one or more portions of these plants of numerous complicated chemical compounds of varying compositions, which are contained as secondary plant metabolites. Various amounts of bacterial suppression towards gram-negative and gram-positive bacteria were demonstrated by the eleven plants evaluated for their antibacterial activity. Many of the plant extracts were active against both types of bacteria whereas some of them were active against only one. The extracts of these plants can be a potential source for the production of antibiotics.

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