Chapter 12

Use of Herbal Plants against Bacterial Pathogens

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ABSTRACT

The widely spread outbreaks of bacterial infections have drawn global concern with the discovery of antibiotics which are unfortunately leading to severe resistance against serious pathogenic agents. Though, herbal plants occupy traditional importance in the perspective of handling medicinal operations. These naturally occurring plants are comprised of versatile biomolecules acting as excellent biological weapons to combat multiple bacterial infections. Thus, the antimicrobial potential hidden in different plant extracts can alternatively serve the purpose of fatal drugs with a more appropriate and safer application. The current chapter is focused on the antibacterial use of many herbal plants with the phytochemical investigation of effective ingredients. In the early years, various plant phenolics with the addition of alkaloids, saponins, and terpenoids have been proven to achieve noteworthy antibacterial significance, largely adopting various mechanisms of anti-biofilm formation, cellular membrane disruption, microbial metabolic activities inhibition, and anti-quorum sensing. To enhance their more suitable applications against a wide range of health-risking bacteria, further inventions in the field of omics with the synergistic investigations of pharmacological attributes would be in demand to recognize developmental pathways of novel antibacterial remedies.

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INTRODUCTION

The bacterial pathogenic attack is a serious threat on a worldwide scale leading to an amplified mortality rate due to multiple bacterial infections mainly including colorectal cancer, whereas others may include inflammatory and irritable bowel infections as the foremost health risks (Jones et al., 2008; Sell and Dolan, 2018). The reason for the frequent bacterial outbreaks may involve the intoxication of foodstuff by multifarious food-borne pathogens including the most commonly occurring: *Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, *Mycobacterium tuberculosis, Salmonella typhimurium,* and *Listeria monocytogenes* (Chen et al., 2017). To counter the current situation, worldwide scientists aim and struggle to design and synthesize effective drugs to act against challenging pathogens. With the current perspective, medicinal plants have been gaining the supreme attention of scientists due to their therapeutic importance hidden in their diverse molecules. History also exposed that these biomolecules had been employed as powerful sources of medicine by man even when no other authentic resource was available (Petrovska, 2012; Stéphane et al., 2021). Since medicinal era, the utilization of medicinal/herbal plants reveals a significant pool towards the discovery of novel antibiotics (Atanasov et al., 2015). The exploration of antibiotics against multivariate bacterial infections leads to the reduction of human mortality rate on a worldwide scale. The earliest discovery of penicillin in the year 1928 by Fleming discloses the vast application of other sulphonamide drugs as the advent source of modern antibiotics (Davies and Davies, 2010). Being used during the early 1940s, Penicillin opened great advancements in antibiotic developments, and the 1950s was marked as the "golden era" for the synthesis of novel drugs. These antibiotics have been considered lifesaving drugs for mankind (Conly and Johnston, 2005; Butler and Paterson, 2020).

However, inappropriate and extensive use of antibiotics has resulted in the emergence of resistance to varied antibiotics, making their application ineffective against certain diseases (Baym et al., 2015). Even the WHO has highlighted the serious emerging concern towards antimicrobial resistance (WHO, 2021). Thus, the demand for the development of such antimicrobial compounds or sources has increased which can cut down the indiscriminate use of antibiotics safely without creating any resistance (Tortorella et al., 2018). The current demand has forced researchers to focus on the isolation and identification of effective antimicrobials from plants and declared the consideration of 50% of pharmaceuticals as derivatives of natural compounds (Chavan et al., 2018). In this pursuit, herbal/medicinal plants have been proven as powerful resources with limitless effects of antimicrobial compounds and agents with versatile uses (Nascimento et al., 2000). These herbal plant-based antimicrobial compounds can be not only used alone but their antimicrobial action can be even more enhanced by combining these with other antimicrobial agents (Bazzaz et al., 2018). Still, many medicinal plants are unexplored so worldwide researchers and scientists are trying to sequester the knowledge of the antimicrobial activity of various herbal plants (Savoia, 2012). The special feature of most herbal plants is that their multiple parts can be utilized for essential therapeutic applications, also acting as precursors of various other drugs. Moreover, the majority of medicinal plants include vegetables with economic importance as well (Silalahi et al., 2014). These vegetables impart their role in toxicity reduction besides their other benefits (Lin et al., 2016; Ma et al., 2019). It is very well understood that plants can adopt various inducible and innate mechanisms to combat pathogenic attacks involving the release of barrier compounds, antimicrobial peptides, and amines as well as divergent vital secondary metabolites (Benko-Iseppon et al., 2010; Rodriguez et al., 2019). Some of the naturally extracted compounds have nonantibiotic properties having adequate antimicrobial effect (Yuan et al., 2016; Lee et al., 2017). About 30,000 to 70,000 different plant species have been used in the field of medicine (Javed et al., 2015). Their variable parts including leaves, shoots, roots and even the flowers can act as astonishing medicines for the cure of multiple bacterial pathogens (Abdallah et al., 2023). These herbal extracts have a better mode of action when encountering both types of gram-positive and gram-negative bacteria. Though their application as oil extracts, powder form, distillation, and decoction are frequently used in medicinal products. However, the employment of their phytochemical extracts is the most effective way against bacterial infections (Kumar et al., 2019). Moreover, antibacterial activity may vary with the type of phytochemical extracts made as different ingredients get active with the phytochemical properties (Chen et al., 2021). These plant extracts specifically gain entry into the cell wall of bacteria and prevent their growth ultimately decreasing the number of pathogenic cells.

The drug-resistant bacteria are the major cause of increasing the mortality rate in humans. Amongst bacterial pathogens, worldwide infections of pneumonia and lung organs are caused by *Pseudomonas aeruginosa* which form colonies in many organs like lungs, kidneys, and even in the urinary tract failing the body functions. Sudden attacks of *Escherichia coli* in soft tissues may lead to skin, joint, and bone infections as well as pneumonia, meningitis, gastroenteritis, and urinary tract infections (Todar, 2007). *Bacillus subtilis* has been considered one of the dominant pathogens of humans (Alfiki et al., 2022; Stülke et al., 2023).

Herbal Plants with Antibacterial Action

Among the worldwide plants, the most examined herbal species typically used against bacterial action include the following:

***Alchornea cordifolia* (Schumach. and Thonn.) Müll.Arg. (Christma Bush)**

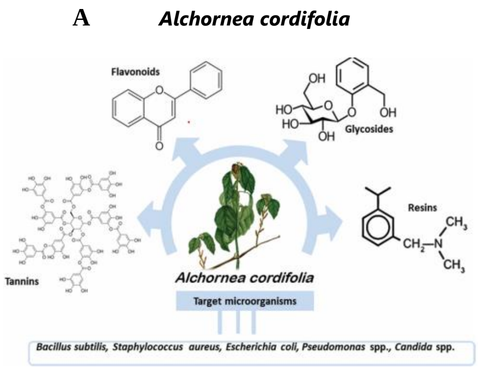
It is a perennial dioecious shruby plant with the common name of Christmas bush and belongs to the family of Euphorbiaceae. It is a naturally grown vegetation of African countries such as Kenya, Senegal, Tanzania, Ghana, and the Democratic Republic of Congo. The leaf stalks are frequently used in the form of infusions for the management of multiple intestinal and respiratory complications while compressed leaves are used for the cure of typical wounds (Mambe et al., 2016). However, the bark of the roots and leaves is applicable as an antidote to snake poison which may cause leprosy. In addition to these applications, different plant parts are comprised of various phenolics including steroid glycosides, terpenoids, flavonoids, saponins, tannins, alkaloids, and carbohydrates. Different plant extracts especially ethanolic extracts are highly significant for antibacterial and antifungal actions (Mavar-Mangar et al., 2007). According to Owusu et al. (2021), both ethanolic and aqueous extracts of *A. cordifolia* were shown to be effective against *S. aureus,* while they observed the highest antibacterial action of ethanolic extract against *E. coli.* Some other investigations (Ebi, 2001; Igbeneghu et al., 2007) explored the antibacterial properties of its methanolic extracts to be remarkable against *E. coli*, *P. aeruginosa,* and *B. subtilis* (Fig. 1) (Table 1).

***Allium sativum* L. (Garlic)**

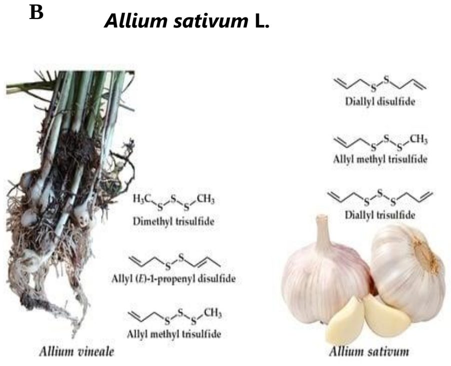
Allicin containing the well-known ayurvedic plant *Allium sativum* L. (commonly called garlic) has been widely used for the treatment of pathogenic bacterial isolates (*Staphylococcus*, *Pseudomonas,* and *Streptococcus*) of lung infections (Reiter et al., 2017). Garlic extracts are reported as strong antibacterial agents for the ailment of *Aggregatibacter actinomycetemcomitans*, *Porphyromonas gingivalis,* and *Streptococcus mutans* by Hoglund et al. (2020). The prominent ingredients against bacterial organisms include ajoenes, allicin, diallyl polysulfides, and vinyldithiins which are considered hydrophobic biomolecules showing the antibiofilm formation for the control of the gram-positive and negative types of bacteria (Nakamoto et al., 2020) (Fig. 1) (Table 1).

***Andrographis paniculata* (Burm.f.) (Nees)**

Nees; scientific name: *Andrographis paniculata* (Burm.f.) is popular among ethnic communities for the curative use of infectious diseases of the urinary and upper respiratory systems. 14-Deoxy-11, 12-didehydroandrographolide has been declared as an antibacterial ingredient, to be active in inhibiting around 92% of *P. aeruginosa* growth by the study of Majumdar et al. (2020). The said bioactive plant compound could lessen the synthesis of extracellular polymeric elements which leads to lower levels of pyocyanin and protease production. Rasool et al. (2018) documented that the same plant extract possesses an excellent effect against the *E. coli* organism (Fig. 1) (Table 1).



(El-Saadony et al., 2021).



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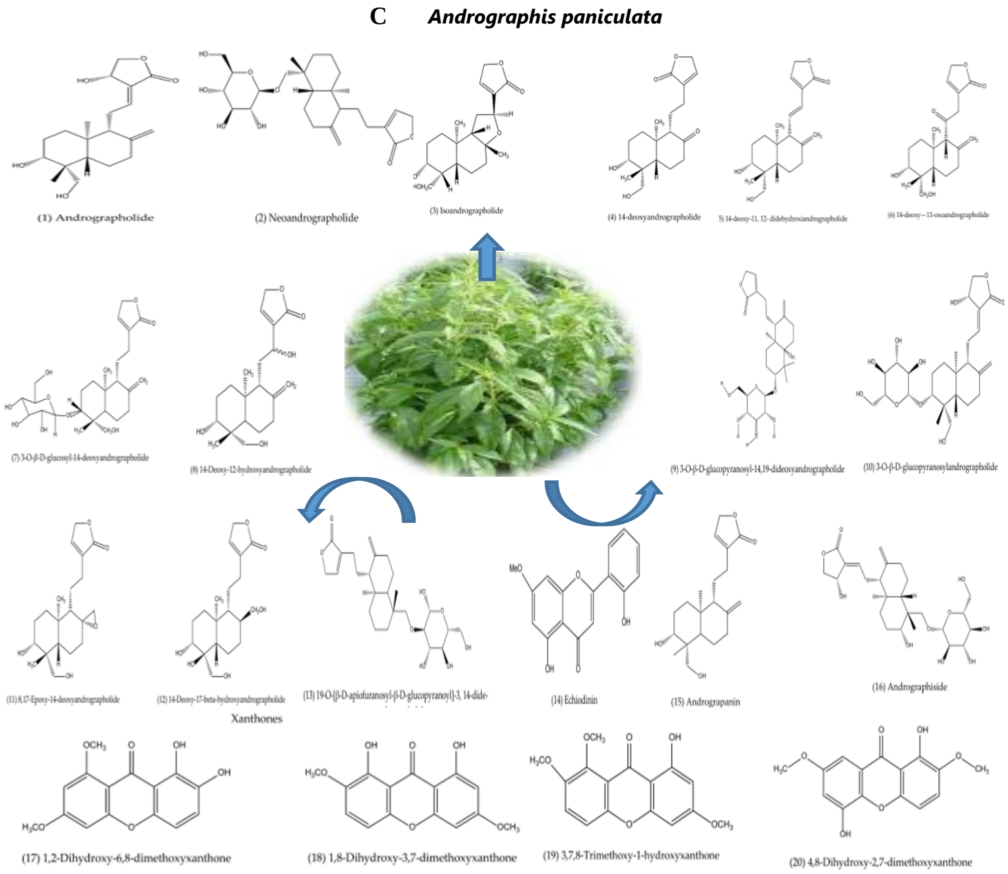


(Hossain et al., 2021).

Fig. 1: Active ingredients of herbal plants used against microbial action.

Azadirachta indica A. Juss (Neem)

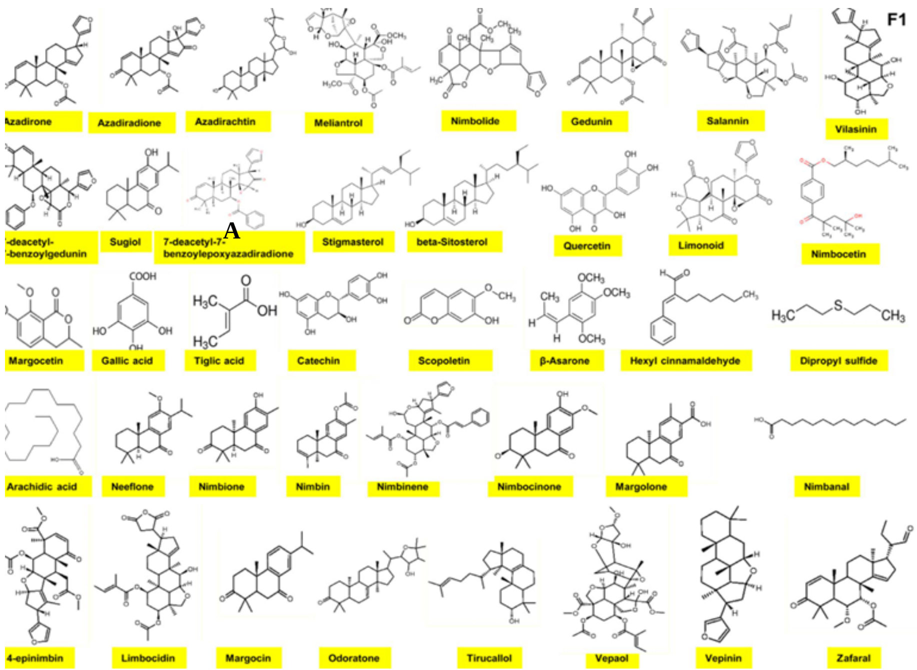
Neem (*Azadirachta indica* A. Juss) is one of the traditionally used plants that are most appropriately used against *Helicobacter pylori* for the treatment of not only dermatological ailments but also for the control of gastrointestinal and urogenital infections. Its oil has robust antibacterial action, particularly at the MIC range of 25–50 µg/mL and in the MBC range of 40–70 µg/mL (Blum et al., 2019). According to Mustafa (2016), its leaf extract could strongly inhibit the cultivation of *Enterococcus faecalis* (Fig. 2) (Table 1).

Calotropis gigantea (L.) Dryand. (Crown flower, Giant milkweed)

Dryand [*Calotropis gigantea* (L.)] plant possesses noteworthy significance in the medicinal control of dermal, arthritic, oral, and gastrointestinal infections in India. The antimicrobial potential is hidden in its aqueous leafy extract which has been proven as a strong antimicrobial agent against varying pathogenic isolates of *S. aureus*, *K. pneumoniae*, *B. cereus*, *P. aeruginosa*, *Micrococcus luteus*, and *E. coli*. (Kumar et al., 2010). In an important article based on the investigation of its antimicrobial biomolecules, quercetin-3-O-rutinoside has been disclosed as a predominating naturally occurring phytochemical in the plant extract, exhibiting remarkable bioactive potential against gram-positive bacteria (*B. subtilis* and *S. aureus*) in contrast to gram-negative (*Salmonella enteritidis* and *P. aeruginosa*) species (Nenaah, 2013). However, research by Bhat and Sharma (2013) publicized cardiac glycosides, asclepin, calactin, cymarin, and calotropin as active biomolecules of the plant (Fig. 2) (Table 1).

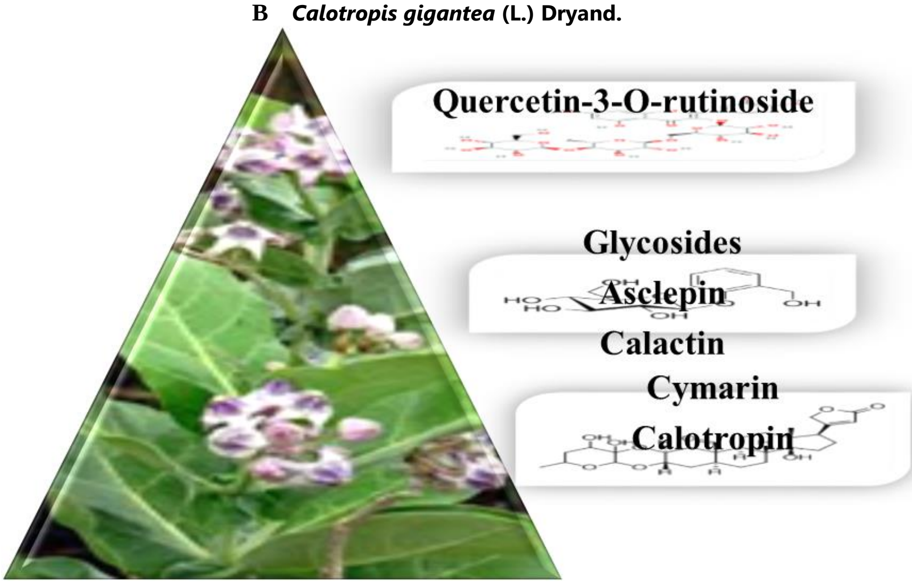
Fig. 2: Active ingredients of herbal plants used against microbial action.

A ***Azadirachta indica* A. Juss**



(Gupta et al., 2017).

B ***Calotropis gigantea* (L.) Dryand.**



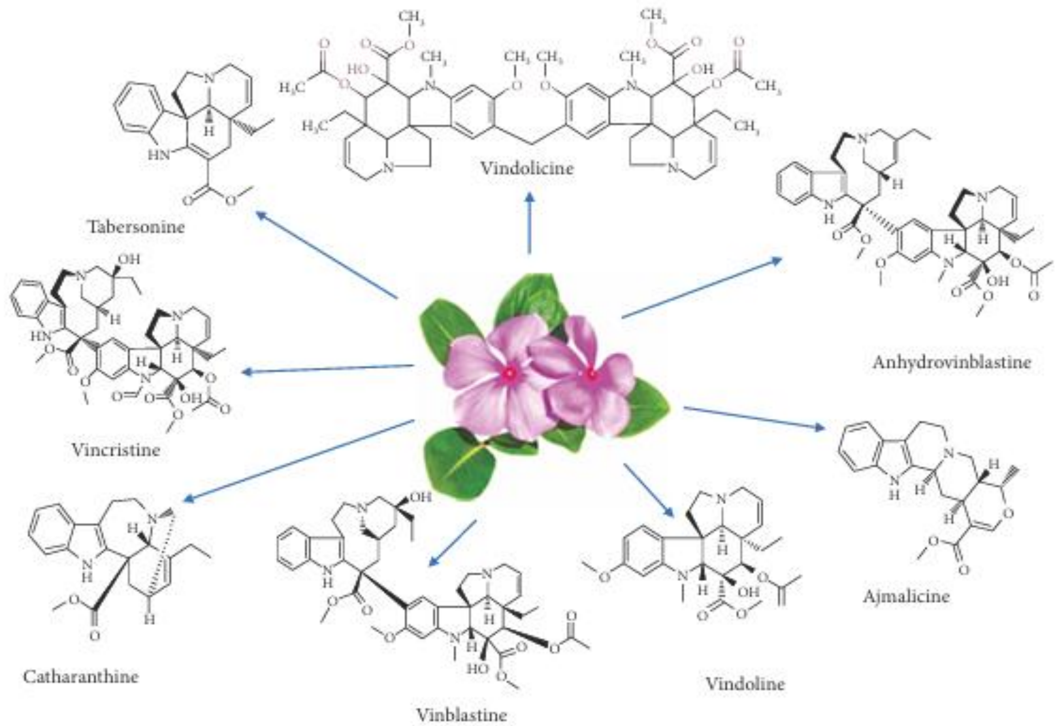
Catharanthus roseus (L.) G. Don (Jasmine)

This plant is native to Madagascar and is commonly called bright eyes. The screening of its antibacterial activity by the well diffusion method revealed powerful action against *Bacillus licheniformis* (Naz et al., 2015). Whereas, 100 mg/mL of its alcoholic extract had a magnificent effect against the famous strains of *S. aureus* and *E. coli* (Khalil, 2012). In addition to these findings, Rani et al. (2017) further reported that an alcoholic extract of canthaxanthin is more suitable for the antibacterial action than other extracts such as ether, petroleum, aqueous, and chloroform. This makes sense that the large number of phytomolecules get solubilized in alcoholic extract and show antibacterial efficacy as compared to other extracts (Fig. 3) (Table 1).

Coccinia grandis (L.) Voigt (Ivy Gourd)

The antibacterial action has been shown by various protease inhibitors of *Coccinia grandis* extract. These protease inhibitors were reported to potentially inhibit the growth of bacterial pathogens including *B. subtilis*, *K. pneumoniae*, *S. aureus*, *E. coli,* and *Proteus vulgaris* (Satheesh and Murugan, 2011). Different research presented that alcoholic and aqueous fruit extracts had an outstanding role in combating the negative effects of *E. faecalis*, *S. aureus*, *P. aeruginosa* and *E. coli* when checked with disc diffusion methodology, associated with erythromycin comparison (Sakharkar and Chauhan, 2017) (Table 1).

A ***Catharanthus roseus*** **(L.) G. Don**



(Kandiah and Chandrasekaran, 2021).

Fig. 3: Active ingredients of herbal plants used against microbial action.

B ***Curcuma caesia*** **Roxb**

Croton bonplandianum Baill (Ban tulsi)

This plant is famous for curing many wound infections. The freshly collected latex of the plant presented the maximum inhibitory activity against the growth of the Enterobacteriaceae family. Among these, *Enterobacter aerogenes* with 26 mm, *E. faecalis* with 30 mm, and *E. coli* with 32 mm inhibitory zones have been found. Similarly, benzene and ethanol extracts from its leaves could fight the battle against *S. aureus* as well as showing an inhibitory zone of 20 mm. However, maximum inhibitory action has been revealed by chloroform extracts specifically against *E. coli* strains having 21 mm of inhibition zones when compared with the effects of other extracts (Vennila and Udayakumar, 2015) (Table 1).

Curcuma sp.

Camphor, epicurzerenone, and eucalyptol are verified as predominant bioactive chemicals found in the crucial oily extract of *Curcuma caesia* Roxb. Its oil had robust effectiveness against *B. cereus* and *B. subtilis* (Paw et al., 2020). A polyphenolic complex called curcumin of the *Curcuma longa* L. plant which is commonly called turmeric has enriched antibacterial properties. Curcumin has been reported to produce lipid peroxidation in the bacterial strains of *E. coli* and *S. aureus*. Whereas in *S. aureus* strains curcumin triggered the redox homeostasis which led to generating the kynurenine trail causing microbial DNA damage as a result of oxidative stress there (Adeyemi et al., 2020) (Fig. 3) (Table 1).

Cuscuta reflexa Roxb. (Giant dodder)

The most commonly found parasitic weed, *Cuscuta reflexa*, is famous for having therapeutic and Ayurvedic properties due to which this weed is greatly used in medicine (Saini et al., 2015). However, the ethanolic extract of *C. reflexa* when screened against *P aeruginosa*, *B subtilis*, and *E coli*, was found to be most effective against *E. coli* and *B. subtilis* (Mishra and Dixit, 2019; Ali et al., 2023). Others have reported the antibacterial action of *C. reflexa* against *Salmonella typhimurium* (Manore et al., 2012), *Proteus vulgaris*, *E. coli*, *Xanthomonas campestris*, *Paracoccus denitrificans* and *Klebsiella pneumonia* (Islam et al., 2015) (Table 1).

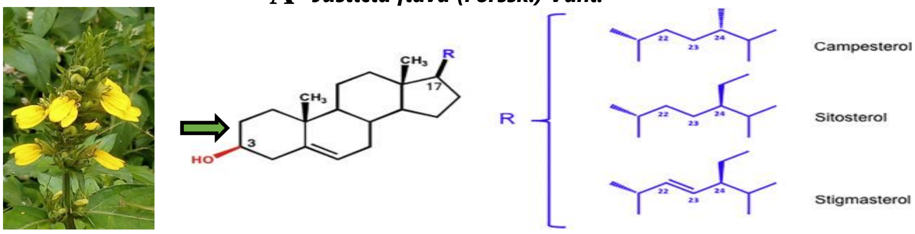
Fagonia cretica L. (Virgin's Mantle)

Likewise, *Fagonia cretica* belonging to Zygophyllaceae is popular for promptly treating many adverse and prevalent diseases (Qureshi et al., 2016). Ali et al. (2023) documented the outstanding role of *F. arabica* specifically in the form of its ethanolic and aqueous extracts against *P. aeruginosa* and *B. subtilus*. According to Ali et al. (2023), the ethanolic extract of *S. chirata* acts as a suitable antibacterial agent against *P. aeruginosa*, *E. coli,* and *B. subtilus*. The extract of *F. arabica* made with dichloromethane is highly efficient in controlling the *E coli* pathogens (Syed et al., 2013) (Table 1).

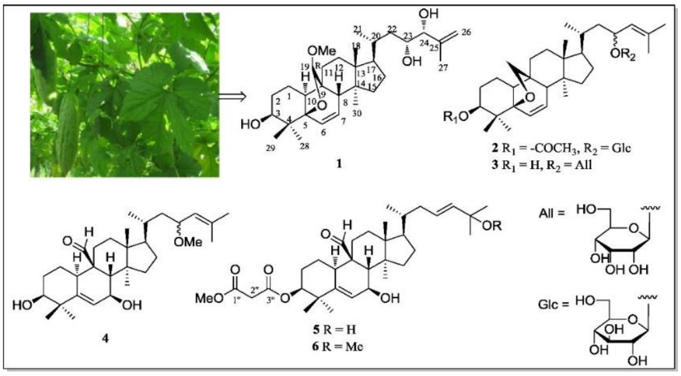
Justicia flava **(Forssk.) Vahl. (Water-willow and shrimp plant)**

This plant belongs to the family Acanthaceae and is commonly disturbed in varying habitats of semi-shaded and sunny regions with an array of soil categories. It has been reported as a common flora of Africa and its leafy extracts have excellent activity against typical strains of *Pseudomonas aeruginosa* ATCC 4853, *Escherichia coli* ATCC 25922, and *Staphylococcus aureus* ATCC25923 (Agyare et al., 2013). It's being employed as a traditional medicine to cure disorders of dysentery, diarrhea, epilepsy, fever, cough, and skin problems (Agyare et al., 2009; Asante-Kwatia et al., 2023). On the other hand, Corrêa and Alcantara (2012), reported the pharmacological importance of *J. flava*. Adding to these, some other scientists disclosed various steroids comprising the active ingredients of sitosterol, campesterol, and stigmasterol for controlling bacterial infections (Amborabé et al., 2002; Rajakumar and Shivanna, 2009) (Fig. 4) (Table 1).

A ***Justicia flava (Forssk.) Vahl.***

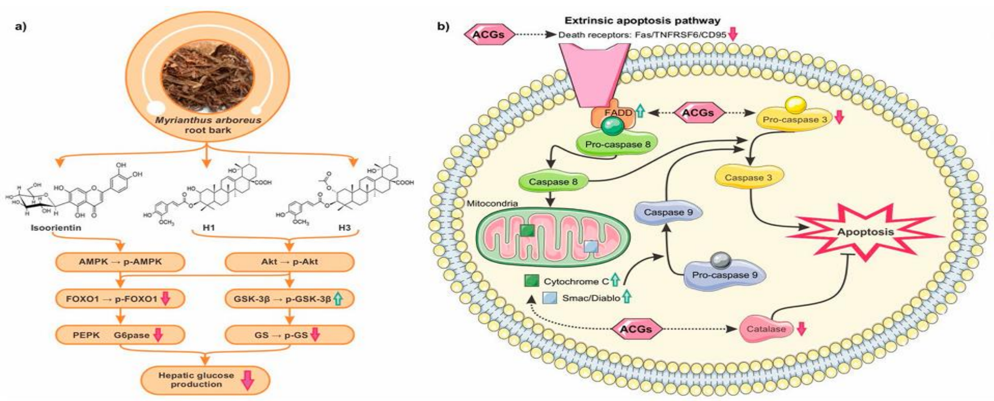


B ***Momordica charantia*** **L.**



(Zhao et al., 2014)

C ***Myrianthus arboreus*** **P. Beauv.**



(García-Pérez et al., 2023).

D ***Viola odorata*** **L**

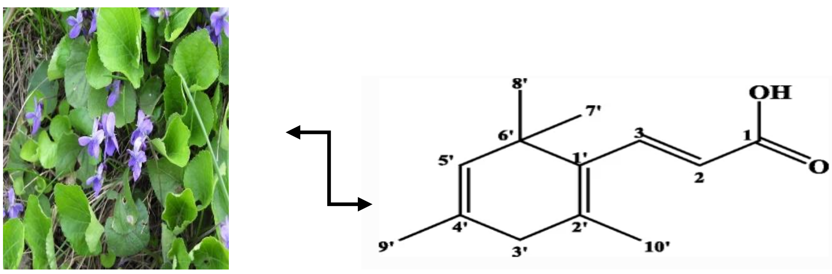


Fig. 4: Active ingredients of herbal plants used against microbial action; A new derivative of ionone (3-(2′,4′,6′,6′-tetramethylcyclohexa-1′,4′-dienyl)acrylic acid) from aerial parts of *Viola odorata* Linn. and its antibacterial role against respiratory pathogens (Gautam et al., 2017).

Table 1: Mechanism of actions against target pathogens using active ingredients from various sources of herbal plants.

Sr. No.	Herbal plant	Source	Active ingredients	Mechanism of action with target pathogens			References
1.	*Alchornea cordifolia*	Leaf stalks/ leaves, Root barks	Steroid glycosides, terpenoids, flavonoids, saponins, tannins, alkaloids, carbohydrates	Aqueous extract ↓ *S. aureus*	Ethanolic extract ↓ *S. aureus*	Methanolic extract ↓ *E coli,* *P. aeruginosa* *B. subtilis*	(Mambe et al., 2016) (Mavar-Mangar et al., 2007) (Owusu et al., 2021) (Ebi, 2001) (Igbeneghu et al., 2007)
2.	*Allium sativum* L.	Bulb	Ajoenes, allicin, diallyl polysulfides, vinyldithiins	*Aggregatibacter actinomycetemcomitans*, *Porphyromonas gingivalis* and *Streptococcus mutans*			(Reiter et al., 2017) (Hoglund et al., 2020); (Nakamoto et al., 2020);
3.	*Andrographis paniculata* (Burm.f.)	Leaves	14-Deoxy-11, 12-didehydroandro grapholide	Methanolic extract ↓ *P. aeruginosa,* *E coli,* *Mycobacterium tuberculosis*, *Enterococcus faecalis*, *Staphylococcus aureus*			(Mishra et al., 2013) (Majumdar et al., 2020) (Rasool et al., 2018)
4.	*Azadirachta indica* A. Juss	Leavesseeds, bark, stems	Isoprenoids (e.g., terpenoids containing limonoid structures) and non-isoprenoids (e.g., tannins)	Aqueous extract ↓ *Bacillus anthracis,* *Enterococcus faecalis,* *E coli,* *Klebsiella pneumoniae,* *Helicobacter pylori,* *Pseudomonas aeruginosa,* *Salmonella spp.* *S. aureus,* *Streptococcus mutans,* *Vibrio parahaemolyticus*	Ethanolic extract ↓ *Klebsiella pneumoniae,* *Helicobacter pylori,* *Bacillus subtilis,* *Enterococcus faecalis,* *E coli,* *Lactobacillus acidophilus,* *Listeria monocytogenes,* *Pseudomonas aeruginosa,* *Porphyromonas gingivalus,* *Staphylococcus aureus,* *Salmonella spp.* *Staphylococcus epidermidis,* *Streptococcus mutans*	Methanolic extract ↓ *Helicobacter pylori,* *Klebsiella pneumoniae,* *Alcaligenes faecalis,* *E coli,* *Pseudomonas aeruginosa,* *Pseudomonas gingivalis,* *Salmonella spp.* *Salmonella typhi,* *Shigella spp.* *Staphylococcus aureus,* *Streptococcus viridans*	(Blum et al., 2019) (Mustafa, 2016) (Saleem et al., 2018) (Wylie and Merrell, 2022)
5.	*Calotropis gigantea* (L.)	Leaves	Quercetin-3-O-rutinoside, Glycosides, Asclepin, Calactin, Cymarin, Calotropin	Aqueous extract ↓ *S. aureus*, *K. pneumoniae*, *Bacillus cereus*, *P. aeruginosa*, *Micrococcus luteus,* *E. coli,* *Salmonella enteritidis,* *B. subtilis*			(Kumar et al., 2010). (Nenaah, 2013) (Bhat and Sharma, 2013)
6.	*Catharanthus roseus* (L.) G. Don	N/A	Canthaxanthin	Alcoholic extracts ↓ *Bacillus licheniformis,* *S. aureus,* *E. coli*			(Naz et al., 2015) (Khalil, 2012) (Rani et al., 2017)
7.	*Coccinia grandis* (L.)	N/A	Protease inhibitors	Aqueous + Alcoholic extracts ↓ *B. subtilis*, *K. pneumoniae*, *S. aureus*, *E. coli,* *Proteus vulgaris*, *E. faecalis*, *S. aureus*, *P. aeruginosa*			(Satheesh and Murugan, 2011) (Sakharkar and Chauhan, 2017)
8.	*Croton bonplandianum* Baill	N/A	N/A	N/A *Enterobacter aerogenes* *E. faecalis E. coli*	Benzene + Ethanolic extracts ↓ *S. aureus*		(Vennila and Udayakumar, 2015)
9.	*Curcuma sp.* *Curcuma caesia* Roxb	Crucial oil	Epicurzerenone, Eucalyptol, Curcumin, Kynurenine	*B. cereus*, *B. subtilis*, *E. coli* and *S. aureus*			(Paw et al., 2020) (Adeyemi et al., 2020)

10.	*Cuscuta reflexa* Roxb.	Whole plant	Alkaloids, Oil, Fat glycosides, Carbohydrates, Phenolics, Tannins, Lignin, Saponins, Flavonoids, Terpinoids	Ethanolic extract *E coli, B subtilis, Salmonella typhimurium, Proteus vulgaris, Xanthomonas campestris, Paracoccus denitrificans, Klebsiella pneumonia*	(Saini et al., 2015) (Manore et al., 2012) (Islam et al., 2015) (Noshad et al., 2023) (Dhale, 2022)
11.	*Fagonia cretica* L.	Leaves stem	Gallic acid, Quinic acid, Cyclo-l-leu-l-pro, Vidalenolone, Liquirtigenin, Rosmarinic acid, Cerebronic acid, Succinic acid, cyclo (l-Leu l-Pro), Liquirtigenin	Aqueous + Ethanolic extracts *B. subtilis, E. coli, P. aeruginosa* Methanolic extract *E. coli, Klebsiella pneumoniae, S. carnosus, E. coli S. typhi*	(Qureshi et al., 2016) (Ali et al., 2023) (Syed et al., 2013) (Arsalan et al., 2022) (Tabassum et al., 2022)
12.	*Justicia flava (Forssk.) Vahl.*	Leaves	Sitosterol, Campesterol Stigmasterol	*Pseudomonas aeruginosa ATCC 4853, Escherichia coli ATCC 25922, Staphylococcus aureus ATCC25923*	(Agyare et al., 2013) (Amborabé et al., 2002; (Rajakumar and Shivanna, 2009).
13.	*Momordica charantia* L.	Leaves Fruit	Phenolic, Saponins, Terpenoids	*Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli*	(Mwambete et al., 2009) (Agyare et al., 2014)
14.	*Myrianthus arboreus* P. Beauv.	Leaves Bark	Linoleic acids	*Enterobacter aerogenes, Esrichia coli, Klebsiella pneumoniae, Providencia stuartii, Pseudomonas aeruginosa*	(Agyare et al., 2009) (Seukep et al., 2015)
15.	*Onosma bracteatum* Wall.	Leaves	Alkannin, Ferulic acid, Vanillic acid, Flavonoids	*E coli, S. aureus, P. aeruginosa*	(Rahman et al., 2015) (Kumar et al., 2013) (Yasmin et al., 2018)
16.	*Phyllanthus emblica L.*	Fruit Seeds	1, 2, 3-benzene-triol	*Salmonella enteritidis Salmonella typhi P. aeruginosa, Chromobacterium violaceum, S. aureus, Serratia marcescens*	(Nair et al., 2020) (Patel et al., 2020)
17.	*Swertia chirata Roxb.*	LeavesStem, Roots	Alkaloids, Coumarin, Glycosides, Steroids, Quinones, Flavonoid, Terpenoids	*E. faecalis, P. aeruginosa, S. aureus, K. pneumonia*	(Manjulika et al., 2016) (Khan et al., 2018) (Subedi and Karki, 2018)
18.	*Viola odorata L.*	N/A	Saponins, Terpenes, Tannins, Alkaloids, Flavonoids, Glycosides, Steroids	Ethanolic extracts *B. cereus, E. coli, B. subtilis, K pneumonia, M. luteus.*	(Aslam et al., 2018) (Das et al., 2021)

***Momordica charantia* L. (Bitter melon)**

This plant belonging to the family Cucurbitaceae is available with the common names of bitter melon, bitter cucumber, or bitter gourd in Africa, Asia, and the Amazon. It's highly famous for curing sort of skin diseases. The main components of its leaves and fruits, effective for multiple ailments have been observed to contain phenolic and saponins (Lopes et al., 2020). However, different plant parts have the crucial potential for controlling diabetes, the growth of tumors, anti-viral particles causing severe infections of measles and hepatitis, and other menstrual health issues (Nagasawa et al., 2002). The most prominent bacterial pathogens including *Staphylococcus aureus*, *Pseudomonas aeruginosa,* and *Escherichia coli* could be better controlled by extracts *of M. charantia* (Mwambete et al., 2009). Further investigation by Agyare et al. (2014) revealed that terpenoids present in the plant extract are responsible for inhibiting the non-mevalonate pathway that could indirectly block the synthesis of bacterial cell membranes (Fig. 4) (Table 1).

***Myrianthus arboreus* P. Beauv. (Giant yellow mulberry or Monkey fruit)**

This is one of the essential medicinal plant of the family Cecropiaceae which is included in the emergently growing vegetation of Ghana and the surrounding forests of African zones. Leafy extracts are very effective in various health problems such as diarrhea, dysmenorrhea, dysentery, incipient hernia, boils, and wounds which are caused by bacteria. In case of skin problems, linoleic acids as the chief composition of its oil can better manage the impermeability of skin to water and safely control such bacterial infections (Agyare et al., 2009).As well as, bark and leaf extracts of Myrianthus have been reported to be significantly effective (78.6%) against multiple bacterial strains of *Enterobacter aerogenes*, *Esrichia coli*, *Klebsiella pneumoniae*, *Providencia stuartii* and *Pseudomonas aeruginosa* (Seukep et al., 2015) (Fig. 4 (Table: 1).

***Onosma bracteatum* Wall. (Gaozaban)**

The cell wall of *Onosma bracteatum* (universally known as Gaozaban) comprises effective chemicals including alkannin, ferulic acid, vanillic acid, and essential flavonoids with pharmacologic importance. It is used as the basic ingredient of many Ayurvedic formulations in different parts of world (Rahman et al., 2015)to cure human problems including constipation, chronic diarrhea, dyspepsia, dysentery as well as heart and brain issues (Rao et al., 2003).. The leafy extracts of *O. bracteatum* were reported to be most effective against *E coli*, *S. aureus,* and *P. aeruginosa* by Kumar et al. (2013) and Yasmin et al. (2018). The leaves and stems of this herb can act as a potential drinking constituent (called the Joshanda) for the cure of bronchitis and asthma (Patel et al., 2008) (Table: 1).

***Phyllanthus emblica* L. (Amla)**

Another widely used herbal plant: *Phyllanthus emblica* with the common name of Amla was reported to exhibit the 1, 2, 3-benzene-triol as an active biomolecule which in the form of its fruit extract indicated exceptional antimicrobial effect against *Salmonella* strains of species: *enteritidis* and *typhi* (Nair et al., 2020). The seed extracts of the plant exhibited antibacterial action against *P. aeruginosa, Chromobacterium violaceum*, *S. aureus,* and *Serratia marcescens* (Patel et al., 2020) (Table: 1).

***Swertia chirata* Roxb. (Bitter stick)**

One of the popular members of the family Gentianaceae is *Swertia chirata* which plays a critical role as a traditional medicine to cure digestive issues, fever, loss of appetite, diabetes, and many skin problems due to its bitter toxicity (Aleem and Kabir, 2018). Moreover, ingredients of *S. chirata* exhibited an active role against *E. faecalis*, *P. aeruginosa*, *S. aureus,* and *K. pneumonia* (Manjulika et al., 2016; Khan et al., 2018; Subedi and Karki, 2018) (Table: 1).

***Viola odorata* L. (Sweet voilet)**

Among the herbal medicines, the significance of *Viola odorata* can't be ignored as it is highly effective in various health issues the most common including the common cold, cough, headache, fever, dysuria, constipation, dyspnea, palpitation, epilepsy, insomnia, and multiple skin infections (Feyzabadi et al., 2018). The antibacterial action of *V. odorata* in the form of ethanolic extract has been revealed by Aslam et al. (2018) against the five most dominating pathogenic strains including *B. cereus*, *E. coli*, *B. subtilis*, *K pneumonia*, and *M. luteus.* However, saponins, terpenes, tannins, alkaloids, flavonoids, glycosides, and steroids are declared as potential phytochemicals (Das et al., 2021) (Fig. 4) (Table 1).

Conclusion

Although pathogenic bacteria prevail worldwide, their antibiotic properties persist, imposing a serious threat to the medicinal industry. To control the current scenario, understanding of key mechanisms of bioactive compounds is becoming a major challenge for the scientific community. However, the role of herbal plants in this perspective cannot be ignored which can be the key solution for the development of therapeutic drugs to be effective against multifarious communities of bacteria. As only a considerable amount of phytochemical ingredients have been investigated yet, further efforts for the screening and exploring of the bioactive chemicals along with the recognition of suitable molecular mechanisms are in urgent demand, for the benefit of the global population.

REFERENCES

Abdallah, E. M., Alhatlani, B. Y., de Paula Menezes, R., and Martins, C. H. G. (2023). Back to Nature: Medicinal plants as promising sources for antibacterial drugs in the post-antibiotic era. *Plants*, *12*(17), 3077. 7. https://doi.org/10.3390/plants12173077.

Adeyemi, O. S., Obeme-Imom, J. I., Akpor, B.O., Rotimi, D. Batiha, G. E., and Owolabi, A. (2020). Altered redox status, DNA damage, and modulation of L-tryptophan metabolism contribute to the antimicrobial action of curcumin. *Heliyon*, *6*(3), e03495. https://doi.org/10.1016/j. heliyon.2020.e03495.

Agyare, C., Ansah, A. O., Ossei, P. P. S., Apenteng, J. A., and Boakye, Y. D. (2014). Wound healing and anti-infective properties of *Myrianthus arboreus* and *Alchornea cordifolia*. *Journal of Medicinal Chemistry*, *4*(7), 533-539.

Agyare, C., Asase, A., Lechtenberg, M., Niehues, M., and Deters, A. (2009). An ethnopharmacological survey and *In Vitro* confirmation of ethnopharmacological use of medicinal plants used for wound healing in Bosomtwi-Atwima-Kwanwoma area, Ghana. *Journal of Ethnopharmacology, 125*(3), 393–403. https://doi.org/10.1016/j.jep.2009.07.024.

Agyare, C., Bempah, S. B., Boakye, Y. D., Ayande, P. G., Adarkwa-Yiadom, M., and Mensah, K. B. (2013). Evaluation of antimicrobial and wound healing potential of *Justicia flava* and *Lannea welwitschii*. *Evidence-Based Complementary and Alternative Medicine*, *2013*, 632927. https://doi.org/10.1155/2013/632927.

Aleem, A., and Kabir, H. (2018). Review on *Swertia chirata* as traditional uses to its phytochemistry and pharmacological activity. *Journal of Drug Delivery and Therapeutics*, *8*(5-s), 73-78.

Alfiky, A., L'Haridon, F., Abou-Mansour, E., and Weisskopf, L. (2022). Disease inhibiting effect of strain Bacillus subtilis EG21 and its metabolites against potato pathogens *Phytophthora infestans* and *Rhizoctonia solani*. *Phytopathology®*, *112*(10), 2099-2109.

Ali, A., Ali, M., Nisar, Z., Shah, S. M. A., Mustafa, I., Nisar, J., and Asif, R. (2023). Antibacterial Activity of Economically

Important Medicinal Plants in Pakistan Against Different Bacterial Strains. *Bioinformatics and Biology Insights*, *17*, 11779322231189374. https://doi.org/10.1177/11779322231189374.

Amborabé, B. E., Fleurat-Lessard, P., Chollet, J. F., and Roblin, G. (2002). Antifungal effects of salicylic acid and other benzoic acid derivatives towards Eutypa lata: structure-activity relationship. *Plant Physiology and Biochemistry*, *40*(12), 1051-1060.

Arsalan, H. M., Javed, H., and Farheen, N. (2022). Antibacterial activity of some medicinal plants against human pathogens. *International Journal of Natural Medicine and Health Sciences*, *1*(2), 82-88.

Asante-Kwatia, E., Baah, M. K., Forkuo, A. D., Anokwah, D., Nketia, R. I., Gyimah, L., and Mensah, A. Y. (2023). A Study on *Justicia flava* (Forssk.) Vahl.: Pharmacognostic characterization and antiplasmodial and anti-inflammatory properties of the leaves. *The Scientific World Journal*, *2023,* 9133288. https://doi.org/10.1155/2023/9133288.

Aslam, L., Kaur, R., Kapoor, N., and Mahajan, R., (2018). Evaluation of antimicrobial activity of various extracts of *Viola odorata* L. *Horticulral Flora Research Spectrum*, *7*(4), 286-290.

Atanasov, A. G., Waltenberger, B., Pferschy-Wenzig, E. M., Linder, T., Wawrosch, C., Uhrin, P., Temml, V., Lemei, W., Schwaiger, S., Heiss, E., S., Rollinger, J., M., Schuster, D., Breusse, J., M., Bochkovg, V., Mihovilovic, M., D., Bauer, R., Kopp, B., Dirsch, V., M., and Stuppner, H. (2015). Discovery and resupply of pharmacologically active plant-derived natural products: A review. *Biotechnology Advances*, *33*(8), 1582-1614.

Baym, M., Stone, L. K., and Kishony, R. (2016). Multidrug evolutionary strategies to reverse antibiotic resistance. *Science*, *351,* 6268. https://doi.org/10.1126/science.aad3292.

Bazzaz, B. S. F., Khameneh, B., Ostad, M. R. Z., and Hosseinzadeh, H. (2018). *In vitro* evaluation of antibacterial activity of verbascoside, *Lemon verbena* extract, and caffeine in combination with gentamicin against drug-resistant *Staphylococcus aureus* and *Escherichia coli* clinical isolates. *Avicenna Journal of Phytomedicine*, *8*(3), 246-253.

Benko-Iseppon, A. M., Lins Galdino, S., Calsa Jr, T., Akio Kido, E., Tossi, A., Carlos Belarmino, L., and Crovella, S. (2010). Overview on plant antimicrobial peptides. *Current Protein and Peptide Science*, *11*(3), 181-188.

Bhat, K. S., and Sharma, A. (2013). Therapeutic potential of cardiac glycosides of *Calotropis gigantea* for breast cancer. *International Research Journal of Pharmacy, 4*, 164-167. http://dx.doi. org/10.7897/2230-8407.04636.

Blum, F. C. Singh, J., and Merrell, D. S. (2019). *In vitro* activity of neem (*Azadirachta indica*) oil extract against *Helicobacter pylori*. *Journal of Ethnopharmacology, 232*, 236–243. https://doi.org/10.1016/j. jep.2018.12.025.

Butler, M. S., and Paterson, D. L. (2020). Antibiotics in the clinical pipeline in October 2019. *The Journal of Antibiotics*, *73*(6), 329-364.

Chavan, S. S., Damale, M. G., Devanand, B., and Sangshetti, J. N. (2018). Antibacterial and antifungal drugs from natural source: A review of clinical development. *Natural Products in Clinical Trials*, *1*, 114-164.

Chen, K., Wu, W., Hou, X., Yang, Q., and Li, Z. (2021). A review: antimicrobial properties of several medicinal plants widely used in Traditional Chinese Medicine. *Food Quality and Safety*, *5*, https://doi.org/10.1093/fqsafe/fyab020.

Chen, X., Leng, J., Rakesh, K. P., Darshini, N., Shubhavathi, T., Vivek, H. K., Mallesha, N., and Qin, H. L. (2017). Synthesis and molecular docking studies of xanthone attached amino acids as potential antimicrobial and anti-inflammatory agents. *MedChemComm*, *8*(8), 1706-1719.

Conly, J. M., and Johnston, B. L. (2005). Where are all the new antibiotics? The new antibiotic paradox. *Canadian Journal of Infectious Diseases and Medical Microbiology*, *16*, 159-160.

Corrêa, G. M., and Alcântara, A. F. D. C., (2012). Chemical constituents and biological activities of species of Justicia: a review. *Revista Brasileira de farmacognosia*, *22*, 220-238.

Das, M., Mondal, S., Ghosal, S., Banerji, A., Dixit, A. K., and Prasad, P. V. V. (2021). Phyto-pharmacognostic evaluation and HPTLC fingerprinting profile of Gulbanafsha (*Viola odorata* L.) flower. *GSC Biological and Pharmaceutical Sciences*, *14*(1), 183-192.

Davies, J., and Davies, D. (2010). Origins and evolution of antibiotic resistance. *Microbiology and Molecular Biology Reviews*, *74*(3), 417-433.

Dhale, D. A. (2022). Phytochemical screening and antimicrobial activity of *Cuscuta reflexa* Roxb. *GIS Science Journal, 9*(10), 1180-1185.

Ebi, G. C. (2001). Antimicrobial activities of *Alchornea cordifolia*. *Fitoterapia*, *72*(1), 69-72.

El-Saadony, M. T., Zabermawi, N. M., Zabermawi, N. M., Burollus, M. A., Shafi, M. E., Alagawany, M. Nahed Yehia, Ahmed M. Askar, Sara A. Alsafy, Ahmed E. Noreldin, Asmaa F. Khafaga, Kuldeep Dhama, Shaaban S. Elnesr, Hamada A. M. Elwan, Alessandro Di Cerbo, Khaled A. El Tarabily., and Abd El-Hack, M. E. (2021). Nutritional aspects and health benefits of bioactive plant compounds against infectious diseases: a review. *Food Reviews International*, *39*(4), 2138-2160.

Feyzabadi, Z., Ghorbani, F., Vazani, Y., and Zarshenas, M. M. (2017). A critical review on phytochemistry, pharmacology of *Viola odorata* L. and related multipotential products in traditional Persian medicine. *Phytotherapy Research*, *31*(11), 1669-1675.

García-Pérez, M.-E.; Kasangana, P.-B.; Stevanovic, T. (2023). Bioactive Molecules from *Myrianthus arboreus*, Acer rubrum, and Picea mariana Forest Resources. *Molecules*, *28*, 2045. https://doi.org/ 10.3390/molecules28052045

Gautam, S. S., Bithel, N., Kumar, S., Painuly, D., and Singh, J. (2017). A new derivative of ionone from aerial parts of Viola odorata Linn. and its antibacterial role against respiratory pathogens. *Clinical Phytoscience*, *2*, 1-5. DOI 10.1186/s40816-016-0018-3.

Gupta, S. C., Prasad, S., Tyagi, A. K., Kunnumakkara, A. B., and Aggarwal, B. B. (2017). Neem (*Azadirachta indica*): An Indian traditional panacea with modern molecular basis. *Phytomedicine*, *34*, 14-20.

Hoglund, K. B., Barnett, B. K., Watson, S. A., Melgarejo, M. B., and Kang, Y. (2020). Activity of bioactive garlic compounds on the oral microbiome: a literature review. *General Dentistry, 68*(3), 27–33.

Hossain, S., Urbi, Z., Karuniawati, H., Mohiuddin, R. B., Moh Qrimida, A., Allzrag, A. M. M., Ming, L. C., Pagano, E. and Capasso, R. (2021). *Andrographis paniculata* (burm. F.) wall. Ex nees: an updated review of phytochemistry, antimicrobial pharmacology, and clinical safety and efficacy. *Life*, *11*(4), 348. https://doi.org/10.3390/life11040348.

Igbeneghu, O. A., Iwalewa, E. O., and Lamikanra, A. (2007). A study of the *in vivo* activity of the leaf extract of *Alchornea cordifolia* against multiply antibiotic-resistant S. aureus isolate in mice. *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, *21*(1), 67-71.

Islam, R., Rahman, M. S., and Rahman, S. M. (2015). GC-MS analysis and antibacterial activity of *Cuscuta reflexa* against bacterial pathogens. *Asian Pacific Journal of Tropical Disease*, *5*(5), 399-403.

Javed, T., Adnan, M., Tariq, A., Akhtar, B., and Ullah, R., Abd El Salam, N. M. (2015). Antimicrobial activity of three medicinal plants. *African Journal of Traditional Complementary and Alternative Medicines*, *12*(3), 91-96.

Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman, J. L., and Daszak, P. (2008). Global trends in emerging infectious diseases. *Nature*, *451*(7181), 990-993.

Kandiah, M., and Chandrasekaran, K. N. (2021). Green synthesis of silver nanoparticles using *Catharanthus roseus* flower extracts and the determination of their antioxidant, antimicrobial, and photocatalytic activity. *Journal of Nanotechnology*, 2021, 1-18. 5512786. https://doi.org/10.1155/2021/5512786.

Khalil, A. (2012). Antimicrobial activity of ethanol leaf extracts of *Catharanthus roseus* from Saudi Arabia. In *2nd International Conference on Environment Science and Biotechnology,* (Vol. 48, No. 2, pp. 6-11).

Khan, M. A., Zia, M., Arfan, M., Nazir, A., Fatima, N., Naseer, M., Khan, S., A., Ismail, T., Alkahraman, Y., M., S., A., Murtaza, G., and Mannan, A. (2018). Antioxidants, antimicrobial and cytotoxic potential of *Swertia chirata*. *Biomedical Research*, *29*(13), 2722-2726.

Kumar, A., Singh, D., Rehman, H., Sharma, N. R., and Mohan, A. (2019). Antibacterial, antioxidant, cytotoxicity, and qualitative phyto-chemical evaluation of seed extracts of *Nigella sativa* and its silver nanoparticles. *IJPSR, 10*(11), 4922-4931.

Kumar, G., Karthik, L., and Rao, K. V. B. (2010). Antibacterial activity of aqueous extract of *Calotropis gigantea* leaves – an *in-vitro* study. *International Journal of Pharmaceutical Sciences Review and Research*, *4*(2), 141-144.

Kumar, N., Kumar, R., and Kishore, K. (2013). Onosma L.: A review of phytochemistry and ethnopharmacology. *Pharmacognosy Reviews*, *7*(14), 140-151.

Lee, J. H., Kim, Y. G., and Lee, J. (2017). Carvacrol-rich oregano oil and thymol-rich thyme red oil inhibit biofilm formation and the virulence of uropathogenic *Escherichia coli*. *Journal of Applied Microbiology*, *123*(6), 1420–1428.

Lin, L. L., Shan, J. J., Xie, T., Xu, J. Y., Shen, C. S., Di, L. Q., Chen, J., B., and Wang, S. C. (2016). Application of traditional Chinese medical herbs in prevention and treatment of respiratory syncytial virus. *Evidence-Based Complementary and Alternative Medicine*, *2016*, 6082729. http://dx.doi.org/10.1155/2016/6082729.

Lopes, A. P., Galuch, M. B., Petenuci, M. E., Oliveira, J. H., Canesin, E. A., Schneider, V. V. A., and Visentainer, J. V. (2020). Quantification of phenolic compounds in ripe and unripe bitter melons *(Momordica charantia)* and evaluation of the distribution of phenolic compounds in different parts of the fruit by UPLC–MS/MS. *Chemical Papers, 74, 2613-2625.*

Ma, Y., Chen, M., Guo, Y., Liu, J., Chen, W., Guan, M., Wang, Y., Zhao, X., Wang, X., Li, H., Meng, L., Wen, Y., and Wang, Y. (2019). Prevention and treatment of infectious diseases by traditional Chinese medicine: a commentary. *APMIS*, *127*(5), 372-384.

Majumdar, M., Misra, T. K., and Roy, D. N. (2020). *In-vitro* anti-biofilm activity of 14-deoxy 11, 12-didehydroandrographolide from Andrographis paniculata against *Pseudomonas aeruginosa*. *Brazilian Journal of Microbiology*, *51*(1), 15–27. https://dx.doi.org/10.1007% 2Fs42770-019-00169-0.

Mambe, F. T., Voukeng, I. K., Beng, V. P., and Kuete, V. (2016). Antibacterial activities of methanol extracts from *Alchornea cordifolia* and four other Cameroonian plants against MDR phenotypes. *Journal of Taibah University Medical Sciences*, *11*(2), 121-127.

Manjulika, Y., Kumar, K. D., Sanjukta, C., and Geeta, W. (2016). Comparative antibacterial efficacy of *Swertia chirata* and *Colocasia esculenta*. *International Journal of Pharmacognosy and Phytochemical Research*, *8*, 2016-2019.

Manore, D., Pillai, S., Joshi, A., and Punashiya, R. (2012). Preliminary Phytochemical Screening and Antibacterial Activity of Ethyl Acetate Extract of *Cuscuta reflexa* Roxb. *Research Journal of Pharmacy and Technology*, *5*(1), 79-82.

Mavar-Manga, H., Haddad, M., Pieters, L., Baccelli, C., Penge, A., and Quetin-Leclercq, J. (2008). Anti-inflammatory compounds from leaves and root bark of *Alchornea cordifolia* (Schumach. and Thonn.) Müll. Arg. *Journal of Ethnopharmacology*, *115*(1), 25-29.

Mishra, P. K., Singh, R. K., Gupta, A., Chaturvedi, A., Pandey, R., Tiwari, S. P., and Mohapatra, T. M. (2013). Antibacterial activity of *Andrographis paniculata* (Burm. f.) Wall ex Nees leaves against clinical pathogens. *Journal of Pharmacy Research*, *7*(5), 459-462.

Mishra, S., and Dixit, N. (2019). Investigations on the anti-bacterial effect of extract *Cuscuta reflexa*. *Asian Journal of Pharmacy and Pharmacology*, *5*(2), 419-424.

Mustafa, M. (2016). Antibacterial Efficacy of Neem (*Azadirachta indica*) Extract against *Enterococcus faecalis*: An *in vitro* Study. *The Journal of Contemporary Dental Practice, 17*(10), 791–794. https://doi.org/10.5005/jp-journals-10024-1932.

Mwambete, K. D. (2009). The *in vitro* antimicrobial activity of fruit and leaf crude extracts of *Momordica charantia*: A Tanzania medicinal plant. *African Health Sciences*, *9*(1), 34-39.

Nagasawa, H., Watanabe, K., and Inatomi, H. (2002). Effects of bitter melon (*Momordica charantia* L.) or ginger rhizome (*Zingiber offifinale* Rosc) on spontaneous mammary tumorigenesis in SHN mice. *The American Journal of Chinese Medicine*, *30*(02n03), 195-205.

Nakamoto, M., Kunimura, K., Suzuki, J. I., and Kodera, Y. (2020). Antimicrobial properties of hydrophobic compounds in garlic: Allicin, vinyldithiin, ajoene, and diallyl polysulfides. *Experimental and Therapeutic Medicine*, *19*(2), 1550–1553. https://dx.doi. org/10.3892%2Fetm.2019.8388.

Nascimento, G. G., Locatelli, J., Freitas, P. C., and Silva, G. L. (2000). Antibacterial activity of plant extracts and phytochemicals on antibiotic-resistant bacteria. *Brazilian Journal of Microbiology*, *31*, 247-256.

Naz, S., Haq, R., Aslam, F., and Ilyas, S. (2015). Evaluation of antimicrobial activity of extracts of *in-vivo* and *in-vitro-grown Vinca rosea* L. (*Catharanthus roseus*) against pathogens. *Pakistan Journal of Pharmaceutical Sciences*, *28*(3), 849–853.

Nenaah, G. (2013). Antimicrobial activity of *Calotropis procera* Ait. (Asclepiadaceae) and isolation of four flavonoid glycosides as the active constituents. *World Journal of Microbiology and Biotechnology, 29*(7), 1255–1262. https://doi.org/10.1007/s11274-013-1288-2.

Noshad, Q., Ajaib, M., and Kiran, A. (2023). Antioxidant and Antimicrobial Activity of *Cuscuta reflexa* ROXB. and Few Members of Family Convolvulaceae. *Current Trends in OMICS*, *3*(2), 01-14. https://journals.umt.edu.pk/index.php/cto.

Owusu, E., Ahorlu, M. M., Afutu, E., Akumwena, A., and Asare, G. A. (2021). Antimicrobial activity of selected medicinal plants from a sub-Saharan African country against bacterial pathogens from post-operative wound infections. *Medical Sciences*, *9*(2), 23.

Pandey, A. K., Silva, A. S., Varshney, R., Chávez-González, M. L., and Singh, P. (2021). Curcuma-based botanicals as crop protectors: From knowledge to application in food crops. *Current Research in Biotechnology*, *3*, 235-248.

Patel, K. G., Patel, K. V., and Gandhi, T. R. (2008). Evaluation of the effect of *Onosma bracteatum* Wall. (Boraginaceae) on bronchial hyperreactivity in sensitized guinea pigs. *Iranian Journal of Pharmacology and Therapeutics*, *7*(1), 35-41.

Patel, P., Joshi, C., and Kothari, V. (2020). The Anti-infective potential of hydroalcoholic extract of *Phyllanthus emblica* seeds against selected human pathogenic bacteria. *Infectious Disorders Drug Targets*, *20*(5), 672–692. https://doi.org/10.2174/18715265196661 90821154926.

Paw, M., Gogoi, R., Sarma, N., Pandey, S. K., Borah, A., Begum, T., and Lal, M. (2020). Study of anti-oxidant, anti-inflammatory, genotoxicity, and antimicrobial activities and analysis of different constituents found in rhizome essential oil of *Curcuma caesia* Roxb., collected from North East India. *Current Pharmaceutical Biotechnology*, *21*(5), 403–413. https:// doi.org/10.2174/1389201020666191118121609.

Petrovska, B. B. (2012). Historical review of medicinal plants' usage. *Pharmacognosy Reviews*, 6(11), 1-5. DOI: 10.4103/0973-7847.95849.

Rahman, A., U., Imran, H., Taqvi, S., I., H., Sohail, T., Yakeen, Z., Rehman, Z., U., and Fatima, N., (2015). Pharmacological rationale of dry ripe fruit of *Aegle marmelos* L. as an anti-nociceptive agent in different painful conditions. *Pakistan Journal of Pharmaceutical Sciences*, *28*(2), 515-519.

Rajakumar, N., and Shivanna, M. B. (2009). Ethno-medicinal application of plants in the eastern region of Shimoga district, Karnataka, India. *Journal of Ethnopharmacology*, *126*(1), 64-73.

Rani, J., Kapoor, M., and Kaur, R. (2017). *In-vitro* antibacterial activity and phytochemical screening of crude extracts of *Catharanthus roseus* L. (G.) Don. *Agricultural Science Digest, 37*(2), 106-111.

Rao, C. V., Amresh, S. K. O., Mehrotra, S., and Pushpangadar, P. (2003). Analgesic antiinflammatoty and anti ulcerogenic activity of the unripe fruit of A. marmelos. *Acta Pharmaceutica Turcica*, *45*, 85-91.

Rasool, U. S. P. Parveen, A., Sah, S. K. S. H. (2018). Efficacy of *Andrographis paniculata* against extended-spectrum β-lactamase (ESBL) producing E. coli. *BMC Complementary and Alternative Medicine*, *18*(1), 244. https://doi.org/10.1186/s12906-018-2312-8.

Reiter, J., Levina, N., van der Linden, M., Gruhlke, M., Martin, C., and Slusarenko, A. J. (2017). Diallylthiosulfinate (Allicin), a Volatile Antimicrobial from Garlic (*Allium sativum*), Kills Human Lung Pathogenic Bacteria, Including MDR Strains, as a Vapor. Molecules (Basel, Switzerland). *22*(10), 1711. https://doi.org/10.3390/molecules22101711.

Rodriguez, P. A., Rothballer, M., Chowdhury, S. P., Nussbaumer, T., Gutjahr, C., and Falter-Braun, P. (2019). Systems biology of plant-microbiome interactions. *Molecular Plant*, *12*(6), 804-821.

Saini, P., Mithal, R., and Menghani, E. (2015). A parasitic medicinal plant *Cuscuta reflexa*: an overview. *International Journal of Scientific and Engineering Research*, *6*, (12), 951-959.

Sakharkar, P., and Chauhan, B. (2017). Antibacterial, antioxidant, and cell proliferative properties of *Coccinia grandis* fruits. *Avicenna Journal of Phytomedicine*, *7*(4), 295–307.

Saleem, S., Muhammad, G., Hussain, M. A., and Bukhari, S. N. A. (2018). A comprehensive review of phytochemical profile, bioactives for pharmaceuticals, and pharmacological attributes of *Azadirachta indica*. *Phytotherapy Research*, *32*(7), 1241-1272.

Satheesh, L. S., and Murugan, K. (2011). Antimicrobial activity of protease inhibitor from leaves of *Coccinia grandis* (L.)

Voigt. *Indian Journal of Experimental Biology*, *49*(5), 366–374.

Satyal, P., Craft, J. D., Dosoky, N. S., and Setzer, W. N. (2017). The chemical compositions of the volatile oils of garlic (*Allium sativum*) and wild garlic (*Allium vineale*). *Foods*, *6*(8), 63. doi:10.3390/foods6080063.

Savoia, D. (2012). Plant-derived antimicrobial compounds: alternatives to antibiotics. *Future Microbiology*, *7*(8), 979-990.

Sell, J., and Dolan, B. (2018). Common gastrointestinal infections. *Primary Care: Clinics in Office Practice*, *45*(3), 519-532.

Seukep, J. A., Ngadjui, B., and Kuete, V. (2015). Antibacterial activities of *Fagara macrophylla*, *Canarium schweinfurt*hii, *Myrianthus arboreus*, *Dischistocalyx grandifolius* and *Tragia benthamii* against multi-drug resistant Gram-negative bacteria. *Springerplus, 4*, 567. DOI 10.1186/s40064-015-1375-y.

Silalahi, M., Supriatna, J., and Walujo, E. B. (2015). Local knowledge of medicinal plants in sub-ethnic Batak Simalungun of North Sumatra, Indonesia. *Biodiversitas*, *16*(1), 44-54.

Stéphane, F. F. Y., Jules, B. K. J., Batiha, G. El-S., Ali, I., and Bruno, L. N. (2021). Extraction of Bioactive Compounds from Medicinal Plants and Herbs. In H. A. El-Shemy (Ed), *IntechOpen* (pp 147-158). London, UK, 2021.147 -150. DOI: 10.5772/intechopen.98602.

Stülke, J., Grüppen, A., Bramkamp, M., and Pelzer, S. (2023). *Bacillus subtilis*, a Swiss Army Knife in Science and Biotechnology. Journal of Bacteriology, *205*, e00102-23. https://doi.org/10.1128/jb.00102-23.

Subedi, I., and Karki, T. B. (2018). Phytochemical and Antimicrobial Screening of native plant *Swertia chirayita* (Roxb. ex Fleming) karst from Rasuwa district of Nepal. *Journal of Tropical Life Science*, *8*(2), 260576. doi: 10.11594/jtls.08.02.10.

Syed, F., Jahan, R., Ahmed, A., and Khan, S. (2013). *In vitro* antimicrobial activities of *Glycyrrhiza glabra* and *Fagonia arabica*. *Journal of Medicinal Plant Research*, *7*(10), 2265-70.

Tabassum, T., Rahman, H., Tawab, A., Murad, W., Hameed, H., Shah, S. A. R., Alzahrani, K. J., Banjer, H. J., and Alshiekheid, M. A. (2022). *Fagonia cretica*: identification of compounds in bioactive gradient high performance liquid chromatography fractions against multidrug resistant human gut pathogens. *Tropical Biomedicine, 39*(2), 185-190.

Todar K. Pathogenic E. coli. In: Todar, K, ed. Online Textbook of Bacteriology. University of Wisconsin; 2007. https://www.textbookofbacteriology.net/e. coli_2.html.

Tortorella, E., Tedesco, P., Palma Esposito, F., January, G. G., Fani, R., Jaspars, M., and De Pascale, D. (2018). Antibiotics from deep-sea microorganisms: current discoveries and perspectives. *Marine Drugs*, *16*(10), 355. https://doi.org/10.3390/md16100355.

Vennila, V., and Udayakumar, R. (2015). Antibacterial activity of *Croton bonplandianum* (Bail.) against some bacterial isolates from infected wounds. *British Microbiology Research Journal*, *5*, 83-93. http:// doi.org/10.9734/BMRJ/2015/12620.

World Health Organization (2021) Antimicrobial Resistance. https://www.who.int/health-topics/antimicrobial-resistance (accessed on 14 August 2021).

Wylie, M. R., and Merrell, D. S. (2022). The antimicrobial potential of the neem tree *Azadirachta indica*. *Frontiers in Pharmacology*, *13*, 891535. https://doi.org/10.3389%2Ffphar.2022.891535.

Yasmin, A., Kousar, K., Anjum, N., Farooq, O., and Ghafoor, S. (2018). *In vitro* antibacterial and antifungal activity of different solvent extracts of Onosma bracteatum leave. *Khyber Journal of Medical Sciences*, *11*(3), 451-453.

Yuan, H., Ma, Q., Ye, L., and Piao, G. (2016). The traditional medicine and modern medicine from natural products. *Molecules*, *21*(5), 559-576.

Zhao, G. T., Liu, J. Q., Deng, Y. Y., Li, H. Z., Chen, J. C., Zhang, Z. R., and Qiu, M. H. (2014). Cucurbitane-type triterpenoids from the stems and leaves of *Momordica charantia*. *Fitoterapia*, *95*, 75-82.