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Antimicrobial potential of some medicinal plants in Saudi Arabia and Jazan Region

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REVIEW ARTICLE

Because of its climate diversity, the Kingdom of Saudi Arabia (KSA) has a diverse range of plants traditionally used to treat some infections. Current Knowledge of many Saudi medicinal plants that are useful in preventing infections by pharmacological means is presented in this study. The databases of Science Direct, Scopus, PubMed, Elsevier, Springer, and relevant research publications were consulted for all information. It demonstrates the effective plant part with its family, the solvents used for extraction, the tested pathogenic microbes, and the antimicrobial effect indicated by inhibition zones and/or minimum inhibitory concentrations. This review highlights the significance of ethnobotanical uses of medicinal plants against various pathogens. The study reported 79 medicinal plant species belonging to 26 families of which 90% are Dicot and 10% are Monocot. Most of the reported medicinal species (13%) belong to *Asteraceae.* Among studied bacterial pathogens*,* most of the documented ethnobotanical research focused on the effects of different plant extracts against *Staphylococcus aureus* (30%) while *Candida albicans* represented the most studied fungi (69%). Data analysis was conducted to show how to use these results in the future, however, more investigation is still required to confirm the safety and therapeutic use of many of these plants using phytochemical and toxicological analyses.

Keywords: medicinal plants**,** antibacterial, antifungal, ethnobotanical, phytochemical

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INTRODUCTION

Microorganisms generally cause infectious diseases. Since Scottish chemist and Nobel winner Alexander Fleming discovered penicillin in 1928, antibiotics have been used to treat pathogenic microbes (Bennett & Chung, 2001). However, they require a lot of funding and ongoing research to track down microbial genomic alterations. A prominent challenge within the realm of antibiotics is the emergence of antibiotic resistance, where bacteria can adapt and become impervious to once-effective antibiotics (Larsson & Flach, 2022). The situation is still worsening despite all the efforts to stop antibiotic resistance nationally and worldwide. According to the Centers for Disease Control and Prevention's 2019 report in the United States, there were over 2.8 million antibiotic-resistant illnesses annually, which led to over 35,000 deaths. Thus, it is imperative to create new and effective antibacterial substances with novel mechanisms of action or as substitutes for antibiotics. (Chen et al., 2021).

Therefore, the extraction of natural products from medicinal plants that are safer, free from side effects, and genetically improved continually is of interest to all scientists, drug manufacturers, decision-makers, health institutions as well as political affairs and pharmaceutical business owners. Alkaloids, terpenoids, phenols, flavonoids, sterols, and other hydrocarbons, in addition to aromatic structures with non-toxic antibacterial and antifungal properties, are among the active, essential therapeutic components detected in medicinal plants (Mayekar et al., 2021).

Saudi Arabia's flora is rich in medicinal plants distributed in biodiversity areas with highly effective genetic resources and pharmaceutical values. Jazan region is situated in the Southwestern of Saudi Arabia. Its distinct topography is like that of the tropical regions. Because of this, there are now native medicinal plants that are highly recognized at the pharmaceutical level. According to El-Shabasy (El-Shabasy, 2016) there are 306 medicinal plants under 61 families in KSA and Jazan flora. This review highlights the antimicrobial values of the most important medicinal plants in KSA and Jazan Region and represents the most studied parts and solvents used for plant extraction. Moreover, this work focuses on the microorganisms revealed to be sensitive using the plant extractions.

MATERIALS AND METHODS

Scientific databases including Pubmed, ScienceDirect, and Google Scholar were searched for relevant material on Saudi medicinal plants. The literature and several studies published in relevant fields, such as antimicrobial analyses of diverse plant extracts, were consulted for this paper. Some of the papers could be accessed directly, however, others could only cite using references from other sources. Keywords, like medicinal plants, KSA, Jazan, and antimicrobial were used to obtain such information.

RESULTS

Dicotyledonous families

Most medicinal plants in KSA and Jazan region belong to twenty-six families. They are arranged according to the family in successive tables.

***Amaranthaceae* family:** It was a common family like *Ephorbiaceae* which included 6 species; *Achyranthes aspera* L. was recognized as showing an antibacterial effect against uncommon pathogenic microorganism; *Trichophyton rubrum* with an inhibition zone of 20 mm using leaves methanol extract at a concentration of 500 µg/ml (Londonkar et al., 2011). *Aerva* of*javanica* (Burm.f.) Juss. ex Schult ethyl acetate extract (10 mg/ml) showed antibacterial activity against both pathogenic bacteria; *Staphylococcus aureus* and *Pseudomonas aeruginosa* with inhibition zones of 16 and 14 mm respectively (Mufti et al., 2012). *Amaranthus* genus expressed its antibacterial activity with 3 species; *A*. *spinosus* L. and *Amaranthus blitum* subsp*. blitum* showed antimicrobial activities against the same pathogenic bacteria and fungi using the same organic solvent for leaves with different inhibition zones **(**Iqbal et al., 2012; Amabye, 2016**)**. *A. caudatus* L. was effective on three pathogenic bacteria; *S. aureus, Bacillus subtilis,* and *P. aeruginosa* with a minimum inhibitory concentration of 10 mg/ml for all the tested microbes using ethanolic extract (Jimoh et al., 2020)**.** The methanolic extract (500 mg/ml) of the aerial parts of *Bassia muricata* (L.) Asch. showed antibacterial activity against three other pathogenic bacteria; *Enterococcus faecalis, S. aureus, and Staphylococcus epidermidis* with IZ of 10.5-11.5 mm (Sadeek & Abdallah, 2018) (Table 1).

***Apiaceae* family:** *Anethum graveolens* L. showed antibacterial activity against *Bacillus cereus, S. aureus*, and *P. aerogenosa* with similar inhibition zone (18 mm) using methanol extract for the whole plant (Said-Al Ahl et al., 2015) while *Eryngium foetidum* L. leaves extracted with ethyl acetate solvent (50 mg/ml) were effective against *P.aeruginosa* and *Cadida albicans* with IZ 28 mm and 18mm and MIC 3.12 µg/ml and 1.56 µg/ml, respectively (Lingaraju et al., 2016). Seeds of *Foeniculum vulgare* Mill. and *Coriandrum sativum* L. were extracted using ethanol solvents to exhibit their antibacterial activity against only one microorganism; *B*. subtilis with IZ of 17 and 10 mm respectively (Kačániová et al, 2020; Naaz et al., 2022). Moreover, the ethanolic extracts of the aerial parts of *Ducrosia ismaelis* Asch. showed the antimicrobial activity against *S. aureus* and *C. albicans* with MIC 0.07 and 0.31 µg/ml respectively. (Mothana et al., 2020) (Table 2).

***Apocynaceae* family:** Flowers of *Adenium obesum* (Forssk.) Roem. & Schult. had powerful negative impacts on *S. aureus* and *C. albicans* by using methanol extract. Inhibition zones were 24.54 mm for bacteria and 23.40 for fungi. *Calotropis procera* (Aiton) W.T.Aiton had different effects from plant parts. Whole plant material had antifungal activity against *C. albicans* by using methanol extract while leaves had antibacterial activity against *S. aureus*, *Klebsiella pneumonia*, and *E. coli* by using ethanol extract with different IZs and MICs *(Saddiq et al., 2022)*. By using Ag-nanoparticles of *Cynanchum acutum* L. whole plant, there was antibacterial activity against *B. subtilis* and *S. aureus* with IZs of 24 and 23 mm respectively (Soliman et al., 2023). *Leptadenia pyrotechnica* (Forssk.) Decne. fruits methanolic extract had antibacterial activity against *S. aureus and S. epidermidis* with IZ 16 and 14 mm. (Munazir et al., 2012) (Table 3).

***Asteraceae* family:** It had the most medicinal plant in both the KSA and Jazan region. Leaves of *Ambrosia maritima* L. exhibited antibacterial activity when methanol extract was used. The action was against *E. coli* and *S. aureus with inhibition zones 14 and 12.7 mm, respectively (Said et al., 2018)*. *Calendula arvensis* L. inhibited only *E. coli* with IZ 30 mm through ethanol flower extract. *Conyza* genus had two species with different antimicrobial activities: *C. bonariensis* (L.) Cronquist and *Pluchea dioscoridis* (L.) DC. *(a new synonym of* *Conyza dioscoridis* (L.) Desf.) with antibacterial and antifungal activities respectively **(**Ismail, 2013; Girma & Jiru, 2021). *Echinops spinosissimus* subsp*. spinosissimus* exhibited antibacterial activity on a non-common pathogenic bacterial species; *Listeria monocytogenes,* a highly resistant microorganism, with 25 mm IZ. *Euryops arabicus* Steud. ex Jaub. & Spach showed 0.65 µg/ml minimum inhibitory concentration (MIC) against *S. aureus* and an inhibition zone of about 12 mm using ethanol solvents and essential oil, respectively (Mothana et al., 2011, Gouda et al., 2014). *Pulicaria undulata* subsp. *undulate* was an endemic plant in the Jazan region having antibacterial activity against *S. aureus and E. coli* with IZ of 18 and 20 mm respectively using methanol extract of aerial parts (El-Kamali & Mahgoub, 2009). *Psiadia punctulata* Vatke used non-common organic extract for whole plant material that was called dichloromethane as an antimicrobial agent; *S.* aureus and *C.albicans* with MIC 180 and 130 µg/ml respectively (Dal Piaz et al., 2018). *Achillea fragrantissima* (Forssk.) Sch.Bip. had antibacterial activity against Methicillin-resistant *Staphylococcus aureus* (MRSA) and *P. aeruginosa* with MIC 256 and 512 µg/ml respectively by using methanol extract of whole plant material (Almuhanna et al., 2023) (Table 4).

Table 1. Antimicrobial activity of *Amaranthaceae* in KSA and Jazan region

No.	Scientific name	Part used	Solvent	Microorganism	IZ (mm)	MIC µg/ml	Ref.
1	*Achyranthes aspera* L	leaves	methanol extracts	*T. rubrum*	20	625	(Londonkar *et al.*, 2011)
2	*Aerva javanica* (Burm.f.) Juss. ex Schult.	whole	methanol	*E. coli* *P.aeruginosa*	18, 14	-	(Mufti et al., 2012)
3	*Amaranthus caudatus* L.	whole	ethanol extract	*S. aureus,* *B. subtilis* *P. aeruginosa*	-	1000 For all	(Jimoh et al., 2020)
4	*Amaranthus spinosus* L.	leaves	methanol extract	*S. aureus,* *E. coli* *F. solani* *R. oligosporus*	24 16 17 9.0	179 398 436 302	(Amabye, 2016)
5	*Amaranthus blitum* subsp. *blitum*	leaves	methanol extract	*S. aureus* *E. coli,* *Fussarium solani,* *Rhizopus oligosporus*	24mm, 16mm, 17mm, 19mm	-	(Iqbal et al., 2012)
6	*Bassia muricata* (L.) Asch.	aerial parts	methanol extract	*E. faecalis* *S. aureus* *S. epidermidis*	11.5 11.0 10.5	-	(Sadeek & Abdallah, 2018)

Table 2. Antimicrobial activity of *Apiaceae* in KSA and Jazan region

No.	Scientific name	Part used	Solvent	Microorganism	IZ (mm)	MIC µg/ml	Ref.
1	*Coriandrum sativum* L.	seeds	Essential oil	*B. subtilis*	10.69	-	Kačániová et al, 2020
2	*Ducrosia ismaelis* Asch.	aerial part	ethanol	*S. aureus* *C. albicans*	-	70 310	(Mothana et al., 2020)
3	*Eryngium foetidum* L.	leaves	ethyl acetate	*P. aeruginosa* *C. albicans*	28 18	3.12 1.56	Lingaraju, et al. 2016)
4	*Foeniculum vulgare* Mill.	seeds	ethanol	*B. subtilis*	17	-	(Naaz et al., 2022)
5	*Anethum graveolens* L.	whole	Essential oil	*B. cereus* *S. aureus* *P. aerogenosa*	18 for all	1 3.5 2.5	(Said-Al Ahl et al., 2015)

Table 3. Antimicrobial activity of *Apocynaceae* in KSA and Jazan region

No.	Scientific name	Part used	Solvent	Microorganism	IZ (mm)	MIC µg/ml	Ref.
1	*Adenium obesum* (Forssk.) Roem. & Schult.	flowers	methanol	*S. aureus* *C. albicans*	24.54, 23.40	-	(Kalva & Raghunandan., 2019)
2	*Calotropis procera* (Aiton) W.T.Aiton (Jazan)	whole	Methanol	*C. albicans*	30	40	(Nenaah, 2013)
		leaves	Ethanol	*S. aureus,* *K.pneumonia,* *E. coli*	18.66 21.26 21.93	0.60-1.50	(Saddiq et al., 2022)
3	*Cynanchum acutum* L.	whole	*Silver-Latex Nanoparticles*	*B. subtilis* *S. aureus*	24 23	-	(Soliman et al., 2023)
4	*Leptadenia pyrotechnica* (Forssk.)Decne.	fruits	Methanol	*S. aureus* *S.epidermidis*	16 14	-	(Munazir et al., 2012)

Table 4. Antimicrobial activity of *Asteraceae* in KSA and Jazan region

No.	Scientific name	Part used	Solvent	Microorganism	IZ (mm)	MIC µg/ml	Ref.
1	*Achillea fragrantissima* (Forssk.) Sch.Bip.	whole	methanol extract	*MRSA* *P. aeruginosa*	-	256, 512	(Almuhanna et al., 2023)
2	*Ambrosia maritima* L.	leaves	methanol	*E. coli, S. aureus*	14.0 and 12.7 mm	-	(Said et al., 2018)
3	*Calendula arvensis* L.	flowers	ethanol	*E. coli*	30	-	Jamal et al., 2015
4	*Conyza bonariensis* (L.) Cronquist	leaves	chloroform	*C. albicans*	32.6	190	(Girma & Jiru, 2021)
5	*Echinops spinosissimus* subsp. *spinosissimus*	whole	ethanol	*Listeria monocytogenes*	25	-	(Al Masoudi & Hashim, 2023)
6	*Euryops arabicus* Steud. ex Jaub. & Spach	aerial parts	ethanol	*S. aureus* *B. Subtilis*	12 -	650 320	(Mothana et al., 2011, (Gouda et al., 2014))
7	*Pluchea dioscoridis* (L.) DC.	roots	ethanol	*B. subtilis*	-	100	(Zalabani & Hetta, 2013)
8	*Psiadia punctulata* Vatke	whole	dichloromethane	*S. aureus* *C.albicans*	-	180 130	(Dal Piaz et al., 2018)
9	*Pulicaria undulata* subsp. *Undulata* (Jazan)	aerial part	methanol	*S. aureus* *E. coli*	18 20	25 100	(El-Kamali & Mahjoub, 2009)

***Fabaceae* family:** It includes 5 species; *Acacia arabica* was reported to inhibit three pathogenic bacteria; *B. cereus, B. subtilis,* and *E. coli* using acetone solvent bark extract. Inhibition zones (IZ) ranged from 27-31 mm. (Lawrence et al., 2015). *Alhagi graecorum* Boiss antibacterial activity was examined against different bacteria. The ethanolic extract (10 mg/ml) showed the highest antibacterial activity against the same pathogenic bacteria with inhibition zones of about 9 mm. (Shaker et al., 2022). Pradeepa et al. (2012) used different concentrations (80, 60, 40, 20, 10 mg/ml) of *methanolic extract of Delonix elata* (L.) Gamble leaves 17.6 and 18.4 mm zones appeared against *B. subtilis* and *K. pneumonia* respectively. *Retama raetam* (Forssk.) was another species that belonged to the *Fabaceae* family that had antibacterial activity against two pathogens; *S. aureus* with 15.2 IZ and (MRSA) with 18.3 IZ when the aqueous extract of the aerial parts was used (Hammouche-Mokrane et al., 2017). Regarding the last species; *Albizia lebbeck* (L.) Benth, ethanolic extract showed no inhibitory effect on all the tested organisms. However, the ethyl acetate extract (400 mg/ml) was found to be effective against *P. aeruginosa* (20mm), *Proteus mirabilis* (10 mm), *K. pneumoniae* (15mm), *E. coli* (12mm), *Shigella spp*. (17mm) and *Salmonella typhi* (10mm) (Sheyin et al., 2015). (Table 5).

***Euphorbiaceae* family:** This family which scored 6.41%, contains five species; Two plant species in the Jazan region had antibacterial activities. Among these, *Acalypha indica* leaves were extracted using two different organic solvents. The extracts were effective against *S. aureus* and *S. epidermidis*; methanol showed inhibition zones larger than ethyl acetate (Govindarajan et al., 2008). Another species belonging to the Jazan region is *Euphorbia cuneata* Vahl. which had antibacterial activity against the same pathogens from a previous neighbor plant with more inhibition zones by using acetone and methanol extracts for aerial parts (Soliman et al., 2021). On the other hand, the *Chrozophora* genus is represented by two species; *C. plicata* (Vahl) A.Juss. ex Spreng. with antibacterial activity against *S. aureus* and *S. typhi* with the same inhibition zone of 17 mm. The organic solvent extract was chloroform for the whole plant (Yasir et al., 2017), while *Chrozophora oblongifolia* (Delile) A.Juss. ex Spreng. had a negative effect except for pathogenic bacteria; *S. aureus* with inhibition zone of 23.33 mm when using methanol extract at a concentration of 50 mg/ml for both bark and roots (Kamel et al., 2019). *Euphorbia terracina* L. had antibacterial activity against only one species; *S. aureus* with IZ 10 mm by using petroleum ether for the whole plant (El-Amier et al., 2016) (Table 6).

Convolvulaceae* family:** *Convolvulus arvensis* L. was recognized as the unique plant species that could be effective against the most aggressive pathogenic bacteria; *S. pneumonia* besides *S. aureus* using ethanol solvent with (IZ 12.35 mm & MIC 28.62 µg/ml) and (IZ 17.49 mm & MIC 37.41 µg/ml), respectively (Salamatullah, 2022). *Convolvulus fatmensis* had an antibacterial effect against only one pathogenic bacteria; *S. aureus with IZ 13 mm when all whole plant material was used (Kunze Benmerache, 2013).** Similarly, *Convolvulus pilosellifolius* Desr. faced had shown activity against one pathogenic bacteria; *P. aeruginosa* using ethanol solvent of aerial parts with IZ 20 mm (Al-Rifai et al., 2017). Whole plant of *Cressa cretica* L. exhibited antibacterial activity against *K. pneumonia* and *E. coli* with IZ 31 and 26 mm respectively (Sunita et al., 2011) (Table 7).

Two families with tri-genera: There were two families with three plant species. *Solanaceae* included three medicinal plants; *Datura innoxia* Mill., *Datura metel* L., and *Hyoscyamus muticus* L. that showed antibacterial activities against; *E. coli, B. subtilis,* and *P. aeruginosa,* respectively. (Elsharkawy et al., 2018; Arage et al., 2022; George & Mathur, 2022) (Tables 6-8). The other is *Lamiaceae* which includes three medicinal plant species within two genera: *Lantana* and *Ocimum* sp. They resembled that the active ingredients appeared in leaves which affected different pathogenic bacteria using different organic solvents (Kaya et al., 2008; Naz & Bano, 2013; Vidhya et al., 2020) (Table 8).

Families with di-genera: There were 9 families with only two plant species: *Malvaceae, Boraginaceae, Papaveraceae, Capparaceae, Cucurbitaceae, Cleomaceae, Bruscaceae, Brassicaceae, and Myrtaceae*. All had antibacterial activities except *Boraginaceae, Cucurbitaceae,* while *Bruscaceae* had extra antifungal effects when using different plant parts and solvents. *Salmonella enterica* first appeared as a sensitive microorganism by induction of the *Capparaceae* family. A significant inhibition zone (68mm) was recorded against *C. albicans* using the methanolic extract of *Citrullus colocynthis* L. (Table 9).

Families with mono-genera: Subsequently, the rest of the dicot families have only one genus. The families were eight; *Meliaceae, Ranunculaceae, Acanthaceae, Polygonaceae, Zygophyllaceae, Urticaceae, Resedaceae,* and *Portulaceae*. *Proteus merabilis* was

Table 5. Antimicrobial activity of *Fabaceae* in KSA and Jazan region

No.	Scientific name	Part used	Solvent	Microorganism	IZ (mm)	MIC µg/ml	Ref.
1	*Albizia lebbeck* (L.) Benth.	leaves	methanol	*Salmonella typhii* *P.aeruginosa .Escherichia coli*	23 22 22	-	(Bobby *et al*., 2012)
2	*Alhagi graecorum* Boiss.	whole	ethanol extracts	*S.aureus* *E. coli* *P. aeruginosa*	9.3 9.2 9	-	(Shaker et al., 2022)
3	*Delonix elata* (L.) Gamble	leaves	methanol	*B. subtilis* *K.pneumonia*	17.6 18.4	-	(Pradeepa et al, 2012)
4	*Retama raetam* (Forssk.) Webb & Berthel.	aerial parts	aqueous	*S. aureus* *MRSA*	15.2 18.3	500 500	(Hammouche-Mokrane et al., 2017)
5	*Acacia arabica L*	bark	acetone	*B. cereus* *B. subtilis* *E. coli*	27.65 27.65 31	-	(Lawrence et al., 2015.)

Table 6. Antimicrobial activity of *Euphorbiaceae* in KSA and Jazan region

No.	Scientific name	Part used	Solvent	Microorganism	IZ (mm)	MIC µg/ml	Ref.
1	*Acalypha indica* L. (Jazan)	leaves	Methanol	*S. aureus* *S. epidermidis*	15.8, 14	-	(Govindarajan et al., 2008)
2	*Chrozophora plicata* (Vahl) A.Juss. ex Spreng.	whole	chloroform	*S. aureus* *S. typhi*	17	-	(Yasir et al., 2017)
3	*Chrozophora oblongifolia* (Delile) A.Juss. ex Spreng.	Root &bark	methanol	*S. aureus*	23.33	-	(Kamel et al., 2019)
4	*Euphorbia cuneata* Vahl (Jazan)	aerial parts	Acetone methanol	*S. aureus* *S. epidermidis*	27.5 20	6250 -	(Soliman et al., 2021)
5	*Euphorbia terracina* L	whole	petroleum ether	*S. aureus*	10	-	(El-Amier et al., 2016)

Table 7. Antimicrobial activity of *Convolvulaceae* in KSA and Jazan region

No.	Scientific name	Part used	Solvent	Microorganism	IZ (mm)	MIC µg/ml	Ref.
1	*Convolvulus arvensis* L	leaves	ethanol	*S. aureus* *S. pneumoniae*	21.35 17.49	28.62 37.41	(Salamatullah, 2022)
2	*Convolvulus fatmensis* Kunze	whole	chloroform	*S. aureus*	13	-	(Kunze Benmerache, 2013)
3	*Convolvulus pilosellifolius* Desr.	aerial parts	Ethanol	*P. aeruginosa*	20	-	(Al-Rifai et al., 2017)
4	*Cressa cretica* L.	whole	methanol	*K. pneumoniae* *E. coli*	31 26	-	(Sunita et al., 2011)

Table 8. Antimicrobial activity of dicotyledonous families with tri-genera

No.	Scientific name	Family	Part used	Solvent	Microorganism	IZ (mm)	MIC µg/ml	Ref.
1	*Lantana camara* L	*Lamiaceae*	leaves	methanol	*S. aureus* *P. aeruginosa* *B. subtilis*	22 21 17	-	(Naz & Bano, 2013)
2	*Ocimum americanum* L		leaves	ethyl acetate	*B cereus* *C.penfrigens* *K. pneumonia*	17 16 14	-	(Vidhya et al., 2020)
3	*Ocimum basilicum* L.		leaves	Methanol	*S. aureus* *L. monocytogenes* *P. aeruginosa*	15 15 13	-	(Kaya et al., 2008)
4	*Datura innoxia* Mill.	*Solanaceae*	leaves	ethanol	*E. coli*	20	-	(George & Mathur, 2022)
5	*Datura metel* L		whole	methanol	*B. subtilis*	15.33	-	(Arage et al., 2022)
6	*Hyoscyamus muticus* L.		Aerial part	methanol	*P. aeruginosa*	12	-	(Eman et al., 2018)

Table 9. Antimicrobial activity of dicotyledonous families with di-genera

No.	Scientific name	Family	Part used	Solvent	Microorganism	IZ (mm)	MIC µg/ml	Ref.
1	*Alkanna orientalis* subsp. *integrifolia* (Post) Mouterde ex Charpin & Greuter	*Boraginaceae*	leaves flowers	ethyl acetate	*S. aureus* *M. smegmatis*	-	> 75-80	(Bame et al., 2013)
2	*Arnebia hispidissima* (Sieber ex Lehm.) A.DC.		whole	Petrolium ether	*K. pneumoniae* *B. thuringiensis*	14 13	-	(Jain et al., 2003)
3	*Diplotaxis acris* (Forssk.) Boiss.	*Brassicaceae*	flowers	ethanol	*E coli*	16	-	(Oueslati et al., 2021)
4	*Lepidium sativum* L.		whole	methanol	*S. aureus* *S. mutans* *P. aeruginosa*	19 18 17	-	(Akrayi & Tawfeeq, 2012
5	*Commiphora africana* L.	*Burseraceae*	leaves	Ethanol	*C. albicans* *S. aureus*	23 18	-	(Idris & Usman, 2019)
6	*Commiphora guidottii* Chiov. ex Guid.		whole	methanol	*C. albicans* *S. aureus*	20.15 21	-	(Alhussaini et al., 2015)
7	*Capparis cartilagniea* Decne	*Capparaceae*	aerial parts	methanol	*S. enterica*	-	10.42	(Rahimifard et al., 2015)
8	*Capparis spinosa* L.		leaves	methanol	*C. albicans* *E. coli*	-	156.25 625	(AlMousa et al., 2022)
9	*Cleome brachycarpa* Vahl ex Dc.	*Cleomaceae*	flowers	ethanol	*S. typhi*		8000	(Joukar et al., 2023)
10	*Cleome viscosa* L		leaves	Methanol	*S. aureus*	28	-	(Swaminathan, 2017)
11	*Citrullus colocynthis* L.	*Cucurbitaceae*	arial parts, fruits	ethanol methanol	*Proteus mirabilis* *E. coli* *C. albicans*	16 18 68	-	(Bnyan et al., 2013) (Neelam, 2020)
12	*Cucumis prophetarum* L.		roots	methanol	*E. coli* *S. aureus*	15 14.6	-	(Galma et al., 2021)
13	*Abutilon pannosum* (G.Forst.) Schltdl. (Jazan)	*Malvaceae*	leaves	Methanol	*S. pneumoniae* *S. typhi*	14, 13	-	(Duggirala et al., 2017)
				Petroleum ether	*P. aeruginosa*	14	-	
14	*Hibiscus micranthus* L. f. (Jazan)		leaves	methanol	*S.aureus*	22	2500	(Begashaw et al., 2017)
15	*Eucalyptus camaldulensis* Dehnh.	*Myrtaceae*	leaves	ethanol	*K.pneumoniae* *S.aureus*	35 30	500 1000	(Asiaei et al., 2018)
16	*Eucalyptus dives* L		aerial parts	ethanol	*S. pneumoniae*	13.67	-	(Miguel et al., 2018)
17	*Argemone Mexicana* L.	*Papaveraceae*	fruit	Ethyl acetate	*S. typhi* *N.gonorrhoeae*	13 13	-	(Jaiswal et al., 2023)
18	*Argemone ochroleuca* Sweet		whole	methanol	*M. luteus,* *E. aerogenes,* *B. subtilis*	33.6 24 24	-	(Alamri & Moustafa, 2010)

reported as a sensitive microorganism using extracts of the *Acanthaceae* family (Table 10).

Monocotyledonous families: Among *Amaryllidaceae, Asphodelaceae, Poaceae, and Zingiberaceae*; *Poaceae* is the most common family reported to contain medicinal plants with antibacterial activities. Rhizome and stalk were new parts inserted in this investigation. *Poaceae* species Ag-nanoparticles were also detected for their antibacterial activity (Alabdallah & Kotb, 2023) (Table 11).

DISCUSSION

From the current results, we can deduce that 92%of the reported medicinal plants were occupied in KSA and 8% in Jazan where dicot plants were 90% (Figures 1, 2). Moreover, *Asteraceae* ranked as the first distributed family with the highest number of medicinal plants (13%) (Figure 3). Besides, the tested pathogenic bacteria represented a higher percentage in experiments than pathogenic fungi because they are more aggressive, mutant, and resistant than any other microorganisms (Figure 4). This study reported that there is a focus on leaf extract than any other plant part. This may refer to the metabolite content which remarkably occurred in the part of photosynthetic processes (Figure 5). Furthermore, the study revealed that methanol was the most suitable solvent for plant extraction procedures. This could be due to its polarity and stereo-chemical structures (Truong et al., 2019) (Figure 6). *S. aureus* was recognized as the highest tested bacteria (30%) as it is the causative of a variety of infections, from minor to serious, some of which are fatal (Linz et al., 2023). (Figure 7) while *C. albicans* was the most studied fungi (Figure 8).

CONCLUSION

Considering how many medicinal plants have not yet been studied for their phytochemical compositions, the future of medicinal plants is bright. This review reflects that the Kingdom of Saudi Arabia is rich in medicinal plants. It has demonstrated the effectiveness of these plants as an alternative therapy in combating the emergence and spread of multidrug-resistant bacteria. Nonetheless, focusing on the chemical constituents of medicinal plants is still needed.

Table 10. Antimicrobial activity of dicotyledonous families with Mono- genera

No.	Scientific name	Family	Part used	Solvent	Microorganism	IZ (mm)	MIC µg/ml	Ref.
1	*Ecbolium viride* (Forssk.)	*Acanthaceae*	Root	ethyl acetate	*P. merabilis* *B. subtilis*	21 20	-	(Cecilia et al., 2012)
2	*Azadirachta indica* A.Juss.	*Meliaceae*	leaves	DMSO	*E. faecalis* *S. mutans* *S. aureus*	18 24 18	-	Agnihotri et al., 2020
3	*Emex spinosa* (L.)	*Polygonaceae*	whole	methanol	*B. subtilis* *C. albicans*	13 10	-	(Ziada et al., 2015) (Corina et al., 2019)
4	*Portulaca oleracea* L	*Portulacaceae*	whole	methanol	*B. subtili* *S. aureus* *E. coli*	21 20 18	-	(Tleubayeva et al., 2021)
5	*Clematis simensis*.Fresen.	*Ranunculaceae*	bark	ethanol	*S. aureus* *S. pyogenes*	20 18	-	(Ayana et al., 2022)
6	*Ochradenus baccatus* Del.	*Resedaceae*	leaves	methanol	*E. coli* *Salmonella* *S. aureus*	-	15.6 20 500	(Khojali et al., 2023)
7	*Forsskalea tenacissima* L	*Urticaceae*	leaves	ethanol	*S. aureus*	10	-	(Aslam, 2018)
8	*Fagonia indica* Burm. (Jazan)	*Zygophyllaceae*	whole	methanol	*B. subtilis* *P. aeruginosa*	15 12	125 250	(Sulieman et al., 2023)

Table 11. Antimicrobial activity of Monocotyledonous families

No.	Scientific name	Family	Part used	Solvent	Microorganism	IZ (mm)	MIC µg/ml	Ref.
1	*Allium baeticum* Boiss.	*Amaryllidaceae*	roots stalks	aqueous extracts	*S.aureus* *P. aeruginosa*	12.10 15.17	-	(Gavanji et al., 2023)
2	*Aloe vera* (L.) Burm.f. (Jazan)	*Asphodelaceae*	leaves	ethanol extract	*E.coli,* *E. faecalis* *S. aureus*	24 21 24	-	(Athiban et al., 2012)
3	*Cymbopogon schoenanthus* subsp. *proxis* (Hochst. ex A.Rich.) Maire & Weiller	*Poaceae*	whole	methanol	*S. aureus* *K. pneumonia*	22 21	-	(Mokhtar et al., 2023)
4	*Cynodon dactylon* L.	*Poaceae*	leaves	methanol	*S. typhi* *S. aureus*	14 14	-	(Gideon et al., 2017)
5	*Dactyloctenuium aegyptium* L.	*Poaceae*	whole	AgNPs aqueous	*S.aureus*	15.17	-	(Ti et al., 2023)
6	*Hyphaene thebaica* L.	*Poaceae*	leaves	nano-AgNPs	*S.aureus*	18	1.5	(Alabdallah & Kotb, 2023)
7	*Alpinia galanga* (L.) Willd.	*Zingiberaceae*	rhizomes	aqueous extracts	*E. coli,* *B. subtilis*	0.8 1.13	-	(Rini et al., 2018)
8	*Curcuma longa* L.	*Zingiberaceae*	whole	DMSO	*S. pyogenes*	-	31.25	(Adamczak et al., 2020)

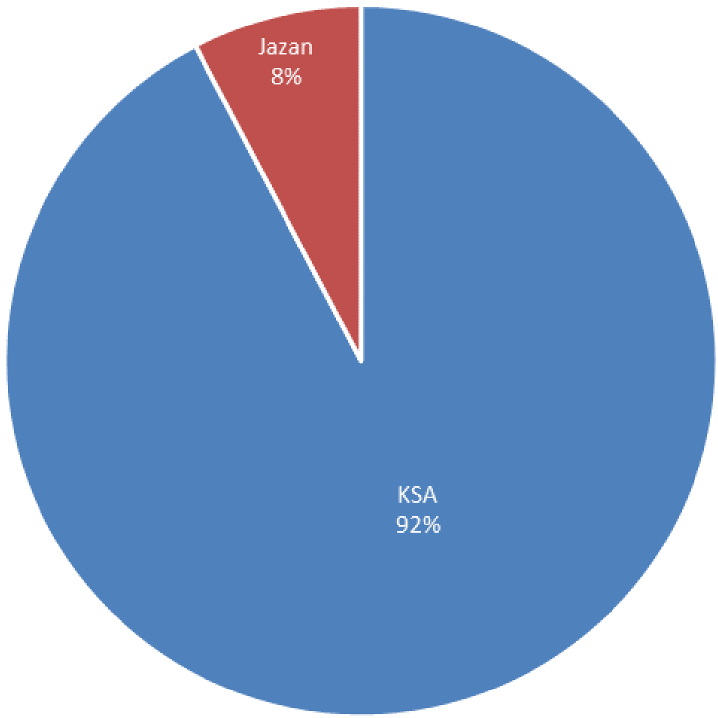

Figure 1. Distribution of reported medicinal plant families in KSA and Jazan region.

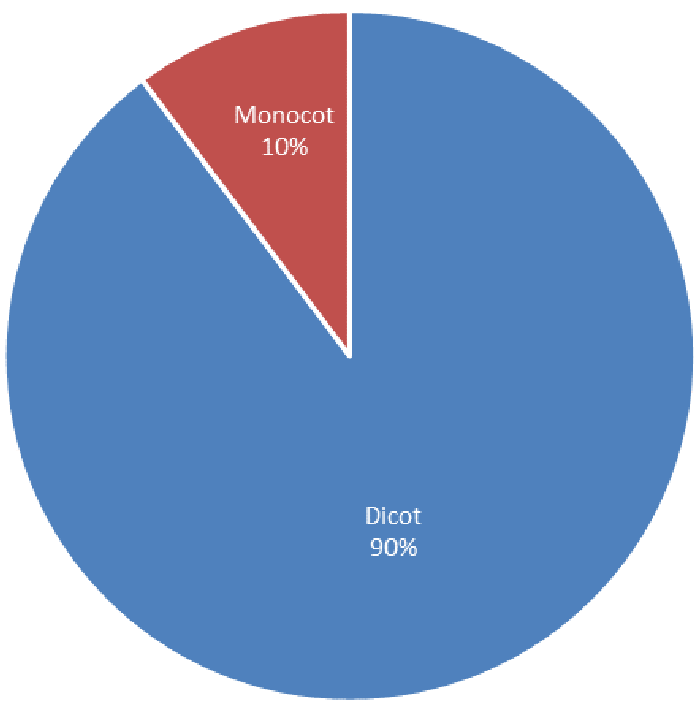

Figure 2. Distribution of species among Dicot and Monocot plant families.

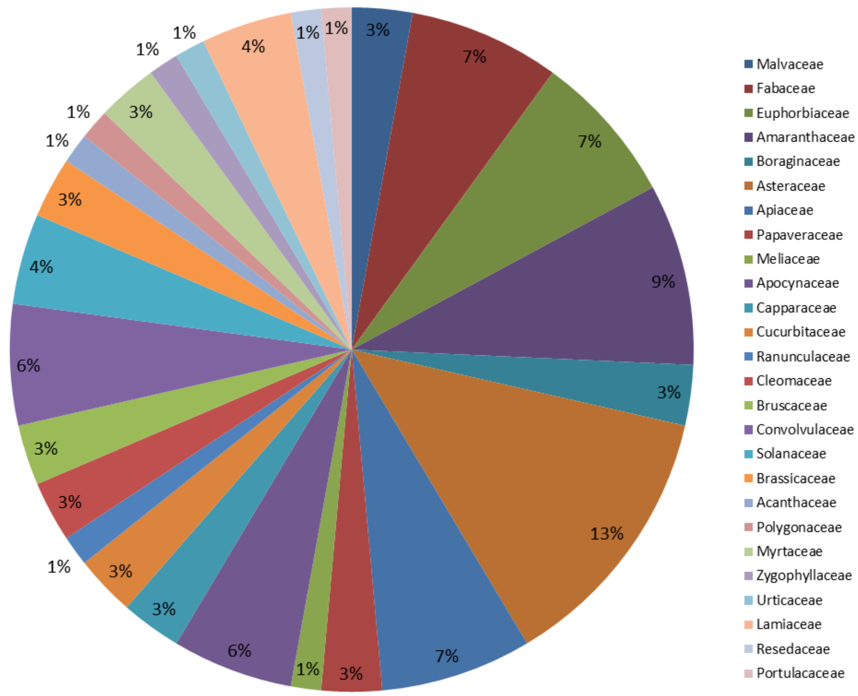

Figure 3. Plant species per family.

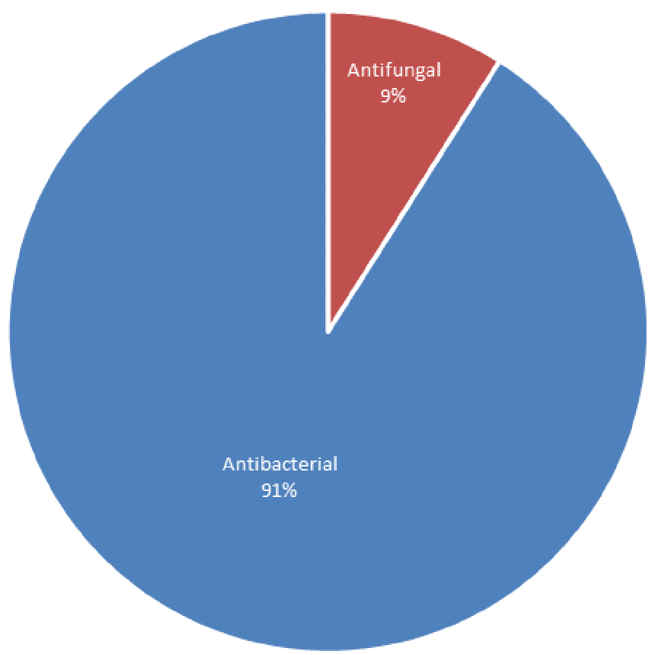

Figure 4. Antimicrobial activity of medicinal plants.

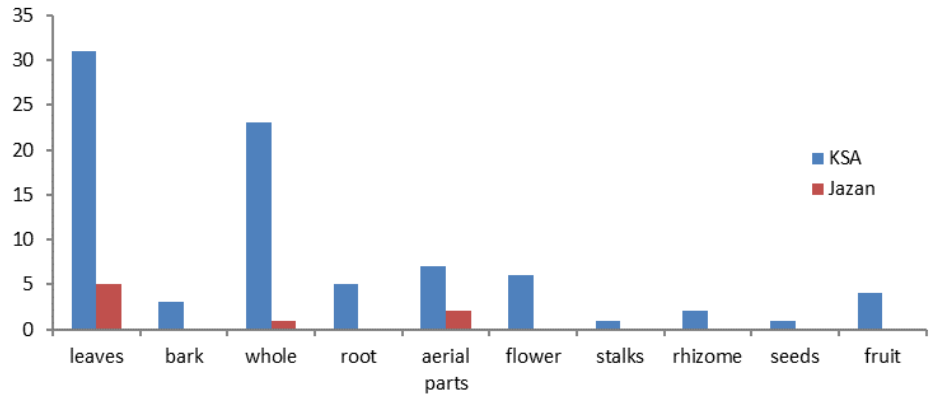

Figure 5. Different parts used for the extraction.

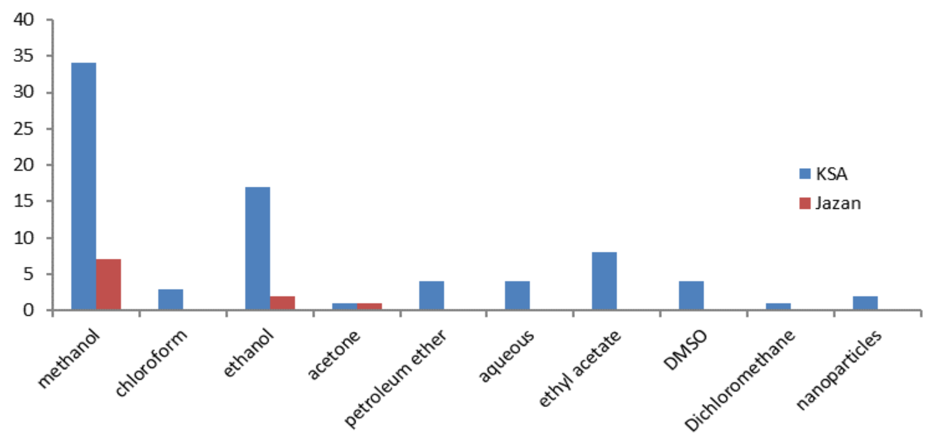

Figure 6. The solvents are used for extraction.

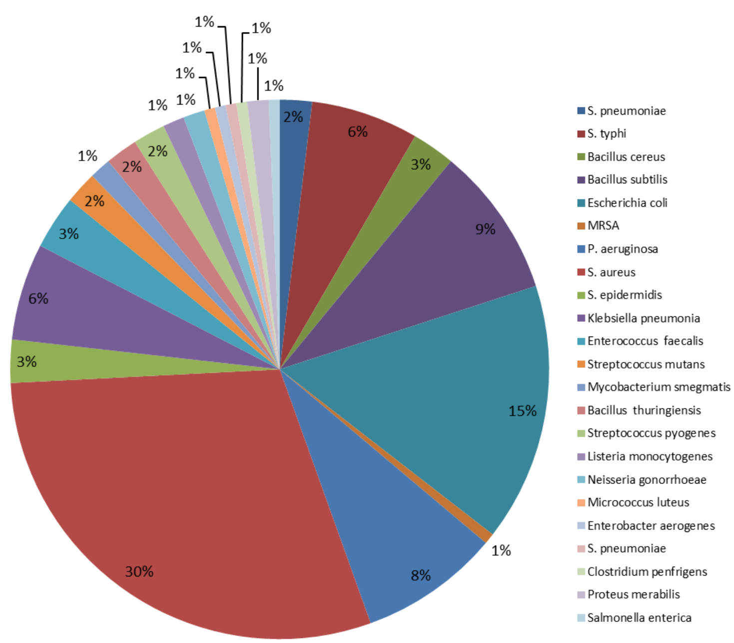

Figure 7. Different pathogenic bacteria were involved in this investigation.

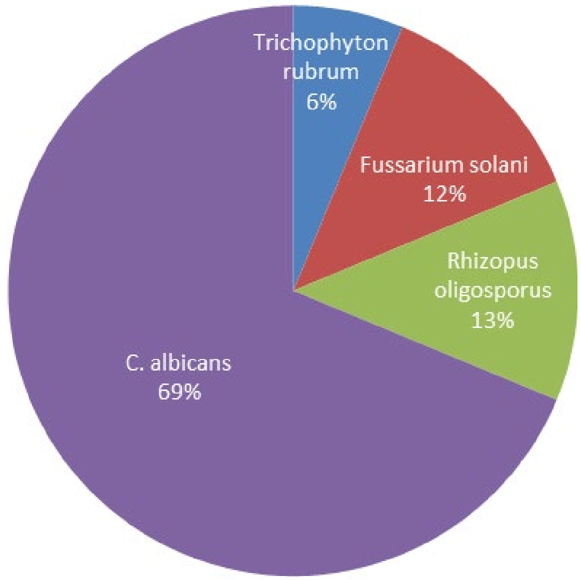

Figure 8. Different pathogenic fungi were involved in this investigation.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available within the article.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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