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Hend Al-Jaber
Biomedical Research Center (BRC), Qatar University, P.O. Box 2713, Doha, Qatar

Lubna Abu-Rub
Department of Biomedical Sciences, College of Health Sciences, Qatar University, Doha, Qatar

Hasna H Kunhipurayil
Department of Biomedical Sciences, College of Health Sciences, Qatar University, Doha, Qatar

Nahla O Eltai
Biomedical Research Center (BRC), Qatar University, P.O. Box 2713, Doha, Qatar

Rasha S Abo El Alaa
Biomedical Research Center (BRC), Qatar University, P.O. Box 2713, Doha, Qatar

Layla Al-Mansoori
[1] Biomedical Research Center (BRC), Qatar University, P.O. Box 2713, Doha, Qatar
[2] Department of Biomedical Sciences, College of Health Sciences, Qatar University, Doha, Qatar

Corresponding Author:
Layla Al-Mansoori
[1] Biomedical Research Center (BRC), Qatar University, P.O. Box 2713, Doha, Qatar
[2] Department of Biomedical Sciences, College of Health Sciences, Qatar University, Doha, Qatar

Medicinal properties of Qatari wetland plants: A review

Hend Al-Jaber, Lubna Abu-Rub, Hasna H Kunhipurayil, Nahla O Eltai, Rasha S Abo El Alaa and Layla Al-Mansoori

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Abstract
For over 60,000 years, human dependence on herbal remedies has been a cornerstone of traditional medicine. However, recent times have witnessed escalating concerns about the sustainability of these practices, especially regarding their impact on local culture, biodiversity, and environmental integrity. This issue is particularly pronounced in Qatar, where wetlands play a vital role yet remain insufficiently studied. A comprehensive literature review aimed at identifying wetland plant species traditionally used by the people of Qatar revealed 17 such species from six families, predominantly from the Amaranthaceae family. These plants, thriving in diverse habitats, exhibit promising therapeutic properties, including anti-cancer, anti-diabetic, anti-inflammatory, and anti-microbial activities. Noteworthy is that over 50% of the examined plants possess both antioxidant and anti-inflammatory attributes. Despite their potential, less than 30% of these plants have been explored for their anti-cancer potential. Conservation efforts are imperative to safeguard these unique wetland ecosystems, and further research is essential to validate and unlock the full therapeutic potential of these plants for the development of potent, plant-based drugs.

Keywords: Wetland plants, Qatar, coast, medicine, therapy, Sabkha

Introduction
The plant kingdom has provided a vast array of medicinal plants used in various forms throughout history. Evidence of the use of herbal therapies dates back 60,000 years [1]. Arabs and Indians had trade relations that introduced many new medicinal plants, which helped to introduce many new true, valuable medicinal plants to pharmacotherapy. This has continued in all pharmacopeias around the world until today, such as curcumin, pepper, saffron, ginger, coffee, aloe, henbane, senna, strychnos and deadly nightshade [2, 3]. Medicinal plants were initially used in simple forms but later became part of drug compounds. Despite the loose integration between herbal medicine industries and primary health care systems, the global herbal medicine market is significant and in Qatar as in the Middle East region, herbal medicine is an important source for disease treatment, and people use it to treat various ailments [4, 5].

Wetlands are regions often near the ground surfaces with low water levels. Throughout the water saturation period and the growing season, wetlands are covered with a range of various active plants. These plants are called “kidneys of the Earth,” as they are considered one of the most valuable and important ecosystems [6, 7]. People who live near wetlands harvest wetland plants for various reasons, including food, construction materials, and medicine [8-10]. Wetland plants grow in various wetland environments, including saltwater and freshwater, and are known for tolerating anaerobic conditions [11]. They are diverse in their ecological tolerances, adaptations, and life history strategies. Wetland plants are the most visible component of wetland ecosystems including macrophytes, hydrophytes, and aquatic plants. They serve as the base of the food chain and influence the overall diversity of the wetland community by providing habitat for other taxonomic groups. Wetland plants also improve water quality by taking up contaminants from the water. In Qatar, wetlands are extensively distributed across the country, yet they have received little ethnobotanical attention. The current review paper focuses of the wetland plants known in Qatar, their distribution, use and evidence based therapeutic efficacy.

Qatar is a peninsula located on the north-south axis of the Arabian Peninsula alongside the center of the eastern coastline of Saudi Arabia. The coastline is estimated to be 700 km long, attributed to the variable nature of its coastline (Fig. 1).

The coastline comprises several jetties and is characterized by spikes, bays, and undulations. In 1970, Claude Cavelier conducted the most detailed study on Qatar geology. He reported that Qatar's land reflected 20% of quaternary and recent deposits and 80% of tertiary deposits [12]. The Qatari land demonstrates the environment of its location, where it is warm and humid. It is categorized to be dry or semi-dry, besides high sealine. The land is commonly rocky desert (87.86%), salt marshes and depressions (2.44%), sabkha (6.06%), and sand dunes (3.12%). This environment greatly influences the Qatari flora's biodiversity, that limits the number of wild plants [12, 13]. Along with the environmental changes, the remarkable expansion in the country's infrastructure has threatened Qatar's wildlife [14-16]. Therefore, the need was urgent to document/record the wild plants in Qatar addressing possible discovery (IES) of medicinal plants [17]. Herbal medicine remains a central healthcare approach in Qatar, deeply rooted in both traditional Arabic and Islamic medicine, constituting a cornerstone of "folk medicine." These methods encompass a range of physical treatments, including the use of herbs, tonics, dressings, dietary adjustments, cauterization, and cupping. Moreover, there is a spiritual aspect, with treatments guided by the Qur'an and prayers often enclosed in leather amulets [18].

This review will primarily focus on wetland plants categorized into three groups: seawater, coastal, and sabkhas. Sabkha land consists of salt-encrusted flats, underlaid by sand, silt, or clay soil. Coastal sabkha is created through the accumulation of marine remains, influenced by different tidal forces (Fig. 1). The selection of plants for this study was based on a previous screening process [12].

Qatari people still believe in herbal medicine and consider it an essential source of health and treatment [19]. In Doha, 46 therapists who use herbal medicine in their practice have been identified, 25 women and 21 men. Despite the limited capacity of producing herbal medicines and the availability of modern medications, people in Qatar are still frequently using herbal medicines to treat many diseases such as Diabetes, Gastroenteritis and colic, Cardiovascular, Rheumatism, Bronchial-pulmonary and Dermatological [18, 20]. Due to the increased demand for traditional medicines worldwide, efforts are needed to standardize Traditional Medicine systems to integrate them into public health care. The quality of the provided medication and the efficacy, safety, and dosage lack the criteria needed to support herbal/traditional medicines worldwide. Also, adverse effects and treatment schemes are not standardized and comprehensively documented [21, 22].

Fig 1: Schematic map of the State of Qatar showing the distribution of different wetland areas in Qatar

In Qatar, a cluster of plant species primarily thrives in wetland regions. These plants, which come from six distinct families, include seawater, coastal, and sabkha (as listed in Table 1).

Each area has its own set of plant species from different families, for instance, Cymodoceaceae and Hydrocharitaceae family plants in the seawater region, Poaceae Family plants in the Sabkha region, and Amaranthaceae family plants primarily found in the coastal area (Figure 2).

Table 1: List of Wet land plants reported in Qatar [12].

Family & Scientific name	Local name	Habitat	Location in Qatar	Number of Medicinal Applications investigated
Acanthaceae *Avicennia marina*	Qurm, Shoura	Muddy tidal zone	Jazirat Bin Ghanim (Al-khor)	5 "Anti-Diabetic, Anti-Oxidant, Anti-Cancer, Anti-Bacterial, Anti-Inflammatory" [12].
Amaranthaceae *Arthocnemum macrostachyum*	Ajram, glaucous glasswort, Hamadh, Qulaam, Shinaan	Salt marsh	Near Mesaieed, Jazirat Bin Ghanim (Al Khor)	4 "Anti-Oxidant, Anti-Cancer, Anti-Bacterial, Anti-Inflammatory" [12].
Anabasis setifera	Hamdal arnab, Himd-Shaaran, Salsola setifera, shuaairan	In dunes (sabkha)	Doha, Jazirat Umm Tays, barrier island at northern tip of Qatar, east from Ruwais	5 "Anti-Bacterial, Anti-Oxidant, Anti-Cancer, Anti-Inflammatory, Anti-Microbial" [12].
Halocnemum strobilaceum	Hadhadi, hamd, jointed glasswort, Sabat	Salt marsh	Jazirat Bin Ghanim (Al Khor)	2 "Anti-Oxidant, Anti-Microbial" [12].
Halopeplis perfoliate	Al Kheriza beach plant, inab al bahr, khureiza, Khurreyz, string of beads	Beach	Jazirat Bin Ghanim (Al Khor) Umm Tays Island in Madinat Al Shamal area, and near Zubara archeological site	5 "Anti-Bacterial, Anti-Oxidant, Anti-Cancer, Anti-Diabetic, Anti-Microbial" [12]
Salicornia	Glasswort	Various zones of	Jazirat Bin Ghanim (Al Khor)	5 "Anti-Bacterial, Anti-

europaea		intertidal salt marshes		Inflammatory, Anti-Oxidant, Anti-Cancer, Anti-Microbial" [12].
Salsola imbricata	Hamd Zeohyr, Khereit	Salty wasteland	Abu Hamour area. Doha Al Markhiya streets in West Bay, Ras Laffan, Jazirat Bin Ghanim (Al Khor)	4 "Anti-Bacterial, Anti-Inflammatory, Anti-Oxidant, Anti-Microbial" [12].
Salsola soda	Opposite-leaved saltwort, Persian seablite, Suaeda heteroptera, Suaeda iranshahrii var. arabica, Suaeda maritima	Sand of littoral	Umm Tays Island in Madinat Al Shamal area, Al Khor.	2 "Anti-Bacterial, Anti-Oxidant" [12]
Seidlizia Rosmarinus	Julman, Salsola rosmarinus, shenan, Suaeda rosmarinus	On dunes near Sealine Beach	Mesaieed	1 "Anti-Microbial" [12]
Suaeda aegyptiaca	Egyptean sea blite, guluman, hamd, Hatallus, ikhreet, juliman, seablite, Suaeda baccata, Suaeda hortensis, suweid	Depressions with high water table and coastal areas	Beach near Umm Bab in south-western, Ras Laffan, Salwa Road near Karaana, south-west from Doha	3 "Anti-Oxidant, Anti-Cancer, Anti-Microbial" [12]
Suaeda vermiculata	Seablite, Suaeda friticosa, suwaid	Seablite beach	Umm Tays Island in Madinat Al Shamal area, Al Istiqlal and Al Markhiya streets in West Bay, Jazirat Bin Ghanim (Al Khor).	5 "Anti-Inflammatory, Anti-Bacterial, Anti-Oxidant, Anti-Diabetic, Anti-Microbial" [12].
Cymodoceaceae *Halodule uninervis*	A'shab bahriya, Hasheesh bahri, narrowleaf seagrass	Marine in shallow depths	Seagrass at shallow depth Al-Shamal	4 "Anti-Bacterial, Anti-Oxidant, Anti-Cancer, Anti-Microbial" [12].
Hydrocharitaceae *Halophila ovalis*	Ashab bahriya, Dugong Grass, Hasheesh bahri, Paddle weed, Sea Wrack, Spoon seagrass	Perennial seagrass (marine in shallow depth)	At shallow depth Al-khor	5 "Anti-Inflammatory, Anti-Bacterial, Anti-Oxidant, Anti-Diabetic, Anti-Microbial" [12].
Halophila stipulacea	Ashab bahriya, Broadleaf seagrass, Hasheesh bahri	Salt marsh	Al Khor	
Plumbaginaceae *Limonum axillare*	Qataf, Sea Lavender, shelail	Coastline with saline shelly soil	Al-khor, Jazirat Umm Tays, Ras Laffan farms etc.	4 "Anti-Bacterial, Anti-Oxidant, Anti-Cancer, Anti-Microbial" [12].
Poaceae *Aeluropus lagopoides*	Aeluropus villosis, ikrish, Kameela	Near leaking water pipes, in sand	Al Shamal Street in area of West Bay, Abu Samra, Jazirat Bin Ghanim (Al Khor)	3 "Anti-Bacterial, Anti-Inflammatory, Anti-Oxidant" [12].
Sporobolus ioclados	Nejma, pan dropseed, rashad, sakham	Water treatment plant	South from Fuwairit. Northern Qatar, Al Khor,	4 "Anti-Bacterial, Anti-Oxidant, Anti-Diabetic, Anti-Microbial" [12].

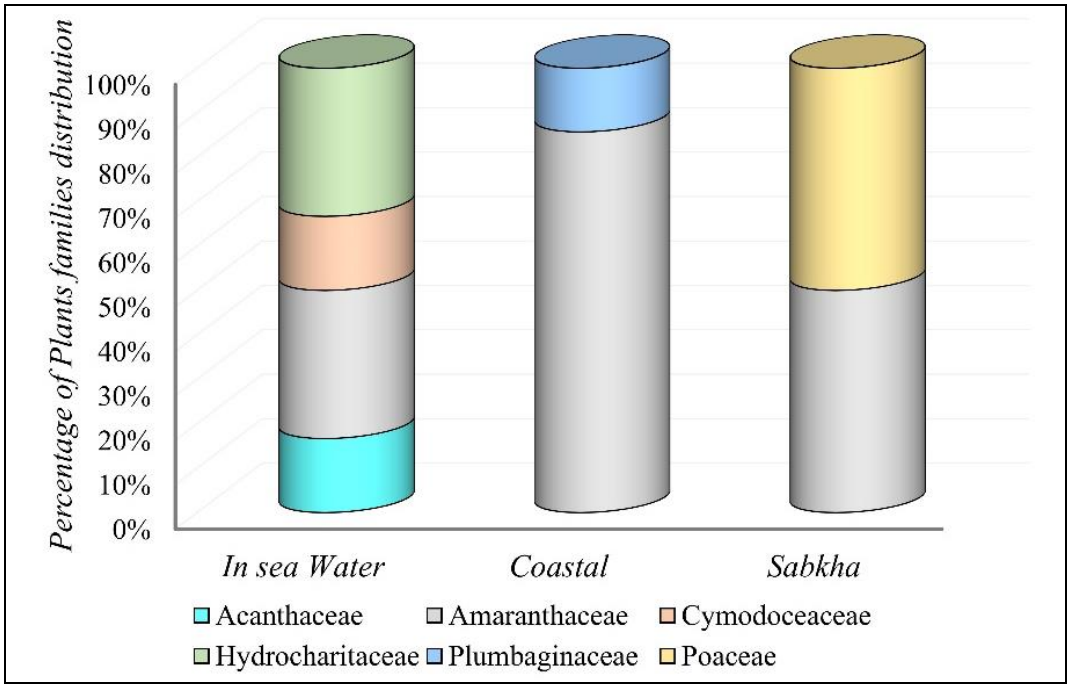

Fig 2: Distribution of plant families across the different wetland regions in Qatar

Evidence-based medicinal efficacy of wetland plants

Throughout the world, various populations have been using traditional medicines for both therapeutic and preventive purposes to maintain good health. However, many of the therapeutic applications of these plants remain unknown, and some have caused serious side effects, sometimes resulting in death due to issues such as overdose, toxicity, or severe allergic reactions [23]. Consequently, several studies have focused on investigating the potential therapeutic uses of plant extracts to identify compounds that could be used to treat specific diseases. Additionally, other studies have been conducted to optimize the use of these traditional medicines

and to explore any hazardous compounds that could potentially harm people.

The medicinal applications that are most commonly investigated for plant extracts include their ability to act as anti-microbial, anti-oxidant, anti-cancer, anti-inflammatory, and anti-diabetic agents. This literature review utilized a systematic methodology to locate, choose, and assess pertinent research on the medicinal qualities and application of wetland plants in Qatar. An extensive exploration was conducted across electronic databases, including PubMed, Science Direct, and Google Scholar. The search was confined to academic articles, research papers, books, and relevant publications. The search terms employed were "wetland plant," "Qatar," "coast," "medicine," "therapy," and "sabkha," and Boolean operators ("AND," "OR") were employed to refine search outcomes. Specific inclusion criteria were established to ensure that the selected studies aligned with the precise goals of this review. Studies were included if they:

1. Addressed alternative medicine interventions.
2. Focused on Qatari wetland plants.
3. Investigated folk medicine practices in Qatar.
4. Were published in English.

The exclusion criteria comprised studies that did not meet these specifications, duplicate publications, conference abstracts, and sources that were not peer-reviewed.

Upon reviewing the wetland plants found in Qatar to assess their therapeutic applications, it was found that some of the plants had been extensively studied for most of these applications, while others had minimal studies. For example, *Seidlizia Rosmarinus* had only been investigated for its anti-microbial efficacy, while *Halophila stipulacea* had not been studied at all (Table 1). Additionally, more than 70% of the studies focus on the plants' anti-oxidant, anti-bcterial and anti-inflammatory effect, however, very few plants (less than 30%) were investigated for their potentitioal anti-diabetic effect (Figure 3).

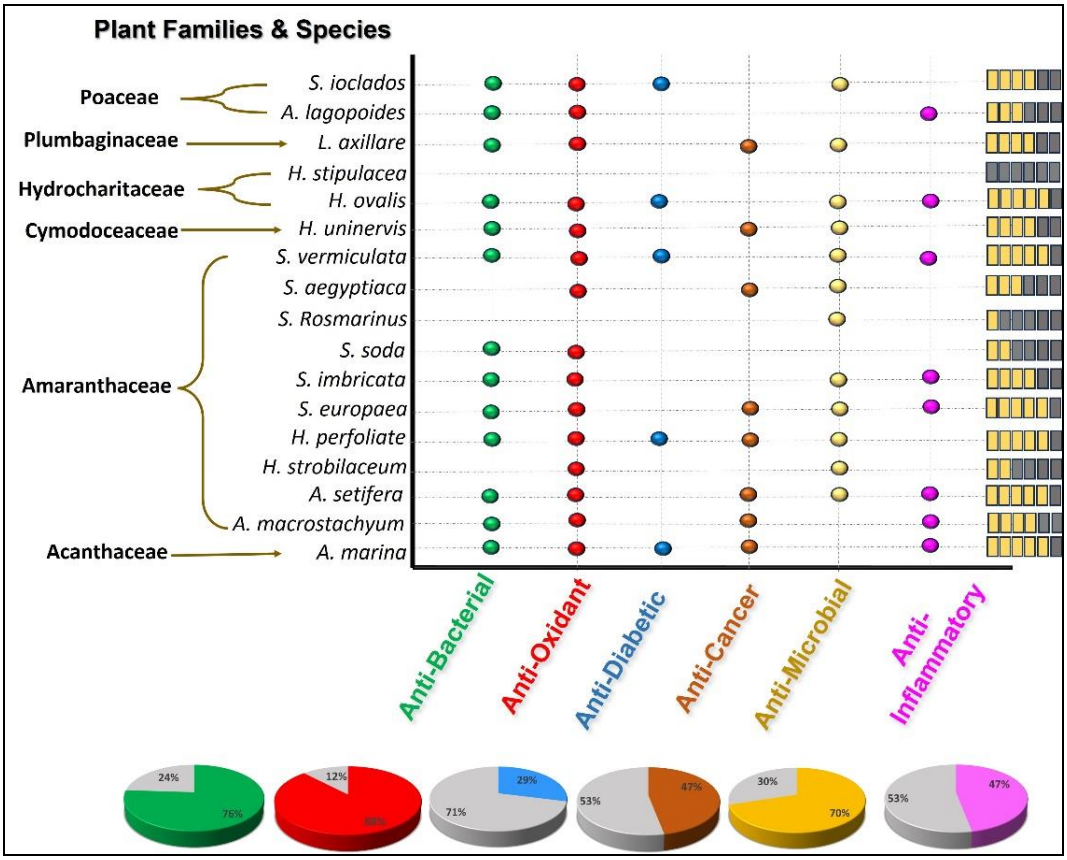

Fig 3: Diverse medicinal therapeutic applications explored for wetland plants in Qatar. On the left, the names of wetland plant families and species are listed. On the right, yellow-labeled boxes represent the number of medicinal applications per plant. The pie chart at the bottom displays the percentage of each plant investigated for specific therapeutic efficacy

Herbs and medicinal plants comprise a diverse range of biologically active compounds, such as alkaloids, terpenoids, flavonoids, nitrogen-containing compounds, phenolics, and more. These compounds can potentially serve as precursors for the synthesis of allopathic drugs [24, 25].However, the extraction of bioactive constituents from plants has always posed a challenge for researchers [25, 26].Since the target compounds may vary in polarity and thermal stability, the suitability of the extraction methods must be carefully considered. Extraction procedures play a critical role in the extraction outcomes and the subsequent assays conducted in the study of medicinal plants. Solvent type and polarity can affect the quality, quantity, extraction velocity, inhibitory compounds, toxicity, other biological activities, and biosafety of the extract [27, 28]. Different solvents are utilized for this purpose, including water, alcohol (ethanol and methanol), hexane, and ethyl-acetate. In the search for studies exploring the medicinal properties of the reported wetland plants, most of the reviewed studies utilized water extracts and showed anti-inflammatory effects, while compounds with anti-microbial impacts were mainly obtained through ethanolic extracts (Figure 4).

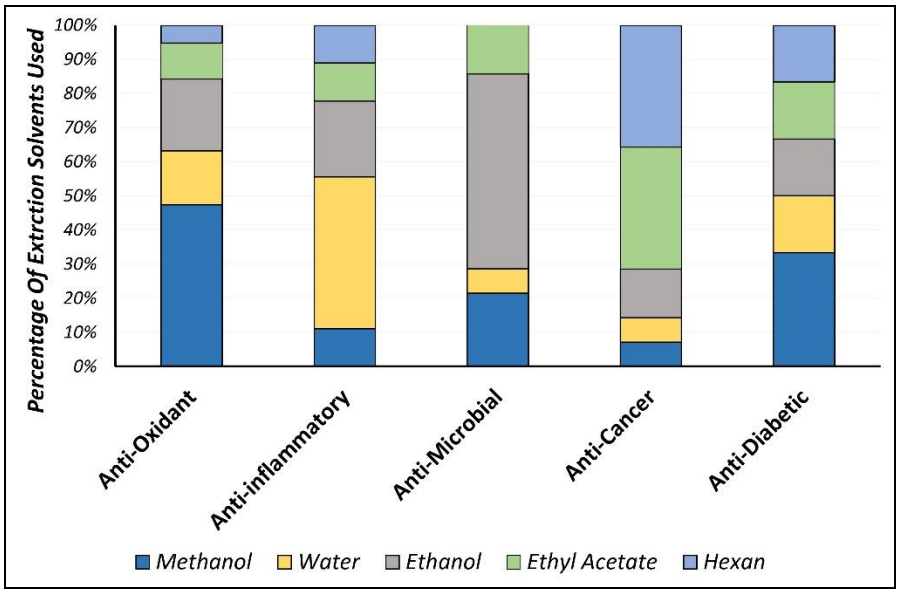

Fig 4: Different solvents used to obtain plant extracts of the wetland plants in Qatar

In the subsequent section, we present studies investigating the various potential medicinal applications of the wetland plants found in Qatar.

Acanthaceae Family

Avicennia marina: is a mangrove species belonging to the family Acanthaceae, occurring in the intertidal zones of estuarine areas and tropical zones. *Avicennia marina* is a Qatari flora found in Al khor, Purple Island, AL Dhakira, and Ruwais. The characteristics of this species possess smooth light-grey bark of thin, stiff, and brittle flakes. The leaves are thick and long, with small, mattered hairs on the surface. Moreover**,** the *Avicennia marina* species has aerial roots that help absorb oxygen and can tolerate high salinity [29].

A previous *In vitro* study conducted on different concentrations of methanolic extract of *Avicenna marina* demonstrated a dose-dependent antioxidant activity [30], and another study showed an anti-fungal activity of the roots, seeds, and fruits ethanolic extract of *Avicenna marina* against a group of microbes such as *Candida albicans* and *Aspergillus fumigatus*[31]. Moreover, the same study has also observed that the chloroform, ethylacetate, and ethanol extract of roots of the *Avicennia marina* exhibited antibacterial effects against both *S. aureus* and *E. coli* [31].

Hydro-alcoholic *Avicenna marina* extracts significantly impacted lessening inflammatory markers and improving joint lesions in rheumatoid arthritis model rats [32]. The anti-cacner effect was studied for the *Avicenna marina* methnolic extract, which was found to have a notable cytotoxic effect on the hepatocellular carcinoma cancer cell line (HepG2), indicating an anticancer activity [33]. Besides, another study has also revealed that hexane extract of *Avicenna marina* presented a high cell inhibitory effect on hepatocellular and breast cancer cell lines [34]. Decisively, the *in-vivo* study on the extracts of *Avicenna marina* and *Rhizophora Mucronata* in combination or alone has explored the antioxidant and antidiabetic effects on streptozotocin induced diabetic rats [35].

Amaranthaceae Family

***Arthocnemum macrostachyum*:** is a flowering plant species belonging to the family Amaranthaceae. It is native to the Mediterranean and the Red Sea coastal areas. It is also a Qatar flora in Mesaieed, Al Khor, Al Shamal, and Al Thakira. This species is much branched and grows in clumps, having horizontal woody stems that root at the nodes and succulent green stems [36]. An investigation was conducted on *Arthrocnemum macrostachyum* to explore its antifungal, antibacterial, and anti-inflammatory properties. The findings revealed that the methanol, chloroform, and hexane extracts displayed potential antifungal activity, while only the methanol extract exhibited possible antibacterial activity. Furthermore, the study highlighted that the methanol and chloroform extracts demonstrated anti-inflammatory activity, particularly by inhibiting albumin denaturation [37]. Although the anti-cancer effect of *Arthrocnemum macrostachyum* has not been investigated scientifically, studies have assessed the anti-cancer and antidiabetic potential of *Arthrocnemum indicum*, a member of the Arthrocnemum class. In one study, *Arthrocnemum indicum* exhibited anti-cancer activity against mouse colorectal cancer cells, demonstrating its potential as an anti-cancer agent [38]. Additionally, another study reported the possible anti-diabetic effect of *Arthrocnemum indicum* [39], while the anti-diabetic activity of *Arthrocnemum macrostachyum* has not been thoroughly explored yet.

***Anabasis setifera*:** Species belongs to the family Amaranthaceae, native being Egypt to India. The common names include Hamd al arnab, Himd-Shaaran, Salsola setifera, and Shuaairan. It is a Qatar flora found in West Bay, Ruwais, Al Khor, Salwa Road, Simaisma, Dukhan, and the Central coastal area. This plant is a subshrub or shrub that grows mainly in subtropical areas [40]. A study discovered that a derivative of oleanane triterpene saponin (from *Anabasis setifera*) possesses a remarkable ability to inhibit cyclooxygenase 1 and 2 activities, suggesting its anti-inflammatory potential [41]. Additionally, another study demonstrated the good anti-oxidant effects of the total phenolic and flavonoid methanol extraction of *Anabasis setifera* [42]. However, there is a scarcity of literature examining the potential anti-bacterial, anti-microbial, anti-cancer, and anti-diabetic effects of *Anabasis setifera* plant species.

***Halocnemum strobilaceum*:** *Halocnemum strobilaceum* is a flowering plant species that belongs to the family Amaranthaceae, which is native to the Red Sea and Mediterranean Sea. The Qatar flora of *Halocnemum strobilaceum* are found in Al Khor and Al Thakira Regions.

The branches of the species are considerably more erectile; stems are woody, erect, and succulent with rounded buds [43]. According to a previous study, *Halocnemum strobilaceum's* high proline content contributes to its effective antioxidant enzyme activity, reducing damage caused by oxygen free radicals to cell plasma membranes [44]. Another study discovered that the phenolic extract of this species exhibited antibacterial properties by inhibiting the growth of pathogenic bacteria, namely *Vibrio aestuarianus* and *Vibrio carchariae* [45]. In 2018, a study evaluated the effect of *Halocnemum strobilaceum* extracts on α-glucosidase and found that they did not exhibit significant inhibition at the tested concentration [46]. Therefore, further extensive research is needed to determine if this plant possesses any anti-diabetic properties. Additionally, the literature lacks clear identification of evaluations to estimate this species' anti-inflammatory, ant-icancer, and anti-microbial effects.

***Halopeplis perfoliata*:** *Halopeplis perfoliata* is a species that belongs to the family Chenopodiaceae. The common name includes a string of beads, Al Kheriza beach plant, inab al bahr, khureiza, and Khurreyz. The species is widely distributed across Mediterranean and tropical areas. Moreover, the Qatar flora of *halopeplis perfoliate* is found in Zubara, Safliya Island, Al shamal, and Al khor regions [47]. The available literature on *Halopeplis perfoliate* species is notably limited. Consequently, there is a lack of scientific research examining the ant-ioxidant, anti-inflammatory, anti-cancer, anti-diabetic, anti-microbial, and anti-bacterial activities of this species in the literature review.

***Salicornia europaea*:** *Salicornia europaea* is a halophytic annual dicot flowering plant in the family Amaranthaceae, and the common name is Glasswort. This plant is relatively small and occurs in jointed stems and leaves that are small and scale-like feature [48]. The typical distribution lies in Europe and North America. It is also a Qatar Flora found in Fuwairit and Al khor regions [49]. In one study, the ethyl acetate extract of *Salicornia europaea* demonstrated anti-inflammatory and anti-oxidant effects by inhibiting several proinflammatory mediators and oxidative stress markers. The central bioactive compound observed was Irilin B [50]. Likewise, another study found that the ethyl acetate fraction had a high content of total polyphenols, resulting in a wide range of anti-bacterial activities against gram-positive bacteria [51]. In a study evaluating anti-cancer activity, flavonoids in ethyl acetate extraction of *Salicornia europaea* demonstrated maximum cell inhibition in human breast adenocarcinoma cell lines (MCF7) compared to tannins and coumarins in methanolic extraction, indicating potential anti-cancer action [52]. Furthermore, a study reported that hexane extraction could be a potential bioactive and anti-microbial agent (*Candida albicans*, *C. parapsilosis*) for medicinal and cosmetics applications [53]. Although research studies on anti-diabetic activity were not well defined, the isolation of polysaccharides from *Salicornia europaea* promised to exhibit a remarkable anti-diabetic effect on streptozotocin-induced diabetic rats [54].

***Salsola imbricata*:** species belongs to the family Amaranthaceae. Common name for the *Salsola imbricata* includes Hamd Zeohyr and khereith. This plant is a perennial halophytic shrub which is native in arid regions of Arabian Peninsula and in deserts, North Africa, and southwestern Asia. It is a salt tolerant plant and has a winged fruit structure. This plant is a Qatar flora found in Abu Hamour, Dar Al salam, Fuwairit, Ras Laffan, West Bay, Al Khor, Duhkan, and Salwa Road [55]. A previous study demonstrated that the phenolic and flavonoid components of *Salsola imbricata* species exhibited anti-microbial, anti-oxidant, and anti-diabetic effects [56]. Another study revealed that the methanol extract from the bark showed potential anti-bacterial activity against Bacillus subtilis, while the chloroform extract of bark exhibited anti-microbial activity against *Aspergillus Niger* [57]. Moreover, the ethanolic leaf extracts of this species were found to regulate inflammation, oxidative stress, and anti-apoptosis in hepatic inflammations, indicating potential anti-inflammatory and antioxidant effects [58]. A similar investigation reported anti-inflammatory and antioxidant effects in inflammatory bowel disease [59]. However, there is a lack of sufficient evidence in the literature to indicate any potential anticancer effect of this plant species.

***Salsola soda*:** Species belongs to the family Chenopodiaceae, native to southern Europe. *Salsola soda* is a Qatari flora found in Al khor and Al shamal areas. It is a hermaphrodite (both male and female organ) and is more commonly known as the opposite leaved saltwort, the opposite-leaf Russian thistle, or barilla plant. *Salsola soda* is a halophyte, salt-tolerant plant that grows in the seaside and can be irrigated with salt water [60, 61]. A study found that the flavonoids extracted from wild *Salsola soda* demonstrated inhibitory activity on three human recombinant enzymes, including aldose reductase (hAKR1B1), aldose-reductase-like protein (hAKR1B10), and carbonyl reductase 1 (hCBR1), with the compound quercetin 3-O-glucuronopyranoside being the most active, suggesting that *Salsola soda* may have the potential to be used in treating conditions associated with antidiabetic, anti-inflammatory, and anti-cancer activities [62]. Additionally, another study showed that the alkaloid extract from the aerial parts of *Salsola soda* possessed anti-oxidant activities [63]. In a 2018 study, the aqueous extract of *Salsola soda* was found to exhibit rare or no significant anti-fungal activity against several fungal species, including *Alternaria alternata*, *Cladosporium sphaerospermum*, *Fusarium oxysporum*, and *Botrytis cinerea*, while the ethanolic extracts showed inhibitory effects against all the studied fungi, indicating antimicrobial activities [64]. There is insufficient research available in the literature to support the potential anti-inflammatory, anti-bacterial, anti-cancer, and anti-diabetic effects of *Salsola soda* species.

***Seidlizia Rosmarinus*:** *Seidlizia Rosmarinus* is a green desert species that belongs to the family Chenopodiaceae. The common names include Julman, Salsola rosmarinus, shenan, and Suaeda, which is commonly known as ušnān in Arabic. The plant is distributed around the lower Jordan Valley along the Dead Sea, and some of the Middle East regions. It is a Qatari flora typically found in the different areas of Mesaieed. The leaves are fleshy and winged outgrowth; leaf bases are entirely joined at the nodes and contain white hairs, which are tuft dense in the axil of each leaf [65]. A study was conducted to evaluate the anti-oxidant, anti-bacterial, and anti-microbial activities of *Seidlizia rosmarinus* species using both ethanol and aqueous extracts. The results indicated that the ethanol extracts displayed higher anti-oxidant, anti-bacterial, and anti-microbial potentials than the aqueous extracts, suggesting that *Seidlizia rosmarinus* extracts possess these activities [66]. Another *In vitro* study aimed at investigating the anti-cancer effect showed that chloroform and methanol extracts

exhibited cytotoxic effects against hepatocellular cancer cell lines [67].

***Suaeda aegyptiaca*:** *Suaeda aegyptiaca* is a succulent plant species that belongs to the family Amaranthaceae. It is a halophyte species distributed in eastern North Africa and East and West Asia regions. It is a Qatar flora found in Southwestern, Ras Laffan, Doha, Al Markhiya, West Bay, Zubara, and Ruwais regions. In Qatar, the local vernacular names for this species are hamd, guluman, juliman, or ikhreet. The species' shape is wildly variable; stems are erect, branched, and succulent, and the stems are woody at the base [68]. A study has demonstrated that the phenolic fraction of *Suaeda aegyptiaca* displays anti-oxidant activity, indicating that this plant contains naturally occurring compounds with anti-oxidant potential [69]. Similarly, another study found that methanolic extraction can serve as an eco-friendly natural resource for anti-oxidants [70]. In an animal experiment (*in-vivo*) investigating the anti-diabetic effect, it was observed that the extracts of *Suaeda aegyptiaca* had higher concentrations of malondialdehyde (MDA) than the metformin group, suggesting extract composition of better diabeteis therapeutic agent [71]. Additionally, the aqueous extract and crude extracts of the aerial parts of the plant (phenol, terpens, tannins) displayed inhibitory activity against pathogenic microorganisms, indicating potential antimicrobial and antibacterial activities [72]. Furthermore, the methanol extract of *Suaeda aegyptiaca* exhibited antibacterial activity against Gram-positive bacteria (*Staphylococcus aureus* and *S. epidermidis*) and Gram-negative bacteria (*Escherichia coli* and *Pseudomonas aeruginosa*) [73]. Nevertheless, there is a significant knowledge gap in the literature regarding the anti-inflammatory and anti-cancer effects of Suaeda aegyptiaca plant species.

***Suaeda vermiculata*:** is a plant species that belongs to the family Amaranthaceae. This is a halophyte (salt tolerant) plant branched, and woody stem at its base. The common names include Seablite, Suaeda friticosa, suwaid. The distribution is scattered across Africa and the Middle East. Moreover, it is a Qatari flora found in many places, including, Dukhan, Mesaieed, West Bay, Ras Laffan, Al Shamal, and Al Khor regions [74]. The antioxidant activity of *Suaeda vermiculata* species was found to be exhibited by the ethanolic extract and quercetin, an isolated compound, showing significant radical scavenging capacity [56]. Additionally, the study suggested that the flavonoids and phenolic plant constituents in the ethanolic extract also exhibited antimicrobial and anti-inflammatory properties[75]. Another research conducted on *Suaeda vermiculata* revealed that the aqueous ethanolic extract showed cytotoxicity against HepG-2 cell line, indicating its potential anti-cancer properties [76]. Yet, a thorough search of the literature did not uncover any studies investigating the anti-diabetic and anti-bacterial effects of this particular species.

Cymodoceaceae Family

Halodule uninervis: is a seagrass species that belongs to the family Cymodoceaceae. The species is widely distributed in the Indian Ocean and western pacific. Moreover, it is a Qatari flora found in the northern coastal regions of Qatar. It is commonly known as narrowleaf seagrass and a'shab bahriya in English and Arabic, respectively. *Halodule uninervis* is a flowering plant, spreading through a branching rhizome that roots at the node. This species is called a needle seagrass as it produces erect stems and alternately positioned leaves. It is a euryhaline species that can adapt to a wide range of salinities, live entirely submerged, and complete the entire life cycle in submerged undersea conditions [77, 78]. *Halodule uninervis* contains various biocomponents such as phenols, phenylpropanoid, flavonoids, tannins, steroids, alkaloids, nitrogen compounds, fatty acids, quinones, and glycosides that have been studied for their potential biological applications. *In vitro* studies have shown that *Halodule uninervis* has significant cytotoxic effects on A549 lung carcinoma cells, indicating its potential as an apoptosis-inducing agent [79]. Previous research on *Halodule uninervis* leaves (extracted with ethanol and water) has also revealed anti-bacterial properties against *Pseudomonas aeruginosa* and *Staphylococcus aureus* [80], and the flavonoid compounds of this species have demonstrated significant anti-oxidant activity through *In vitro* assays [81]. In addition, an earlier study on *Halodule uninervis* extract from ethanol solvent has reported strong anti-diabetic effects [82]. These studies suggest that *Halodule uninervis* exhibits promising activity against anti-oxidant, anti-bacterial, anti-diabetic, and anti-cancer effects.

Hydrocharitaceae Family

Halophila ovalis: is a seagrass species that belongs to the family Hydrocharitacaea. It is commonly known as paddle weed, spoon grass, or dugong grass. *Halophila ovalis* is a small herbaceous plant that grows in a sea- bed and saltwater environment, widely distributed in tropic and subtropic coasts, and found in Al khor regions in Qatar [82]. The characteristics of their leaves are ovate in outline, occurring on stems that arise from rhizome beneath the sand. It is also described by fast-growing, as the population can expand rapidly and form biomass under appropriate environmental conditions [83]. According to previous research, the purified fraction of sulfated polysaccharides from *Halophila ovalis* demonstrated potential anti-nociceptive and anti-inflammatory effects [84]. Additionally, sulfated polysaccharide extracts were found to possess anti-oxidant and anti-inflammatory properties in HT-29 cell lines [85]. In 2019, a study reported that phenolic extracts from *Halophila ovalis* effectively inhibited the growth of breast cancer cells (MCF-7), indicating potential anti-cancer activity [86]. Furthermore, a previous *In vitro* study using methanol extracts of this species showed significant anti-bacterial effects as well as noticeable anti-oxidant and anti-inflammatory effects [87]. However, the literature lacks comprehensive knowledge on the potential anti-diabetic and anti-microbial effects of *Halophila ovalis* extracts.

***Halophila stipulacea*:** *Halophila stipulacea* is a seagrass species that belongs to the family Hydrocharitaceae. It is a Qatari flora found in Al khor regions**,** typically native to the Indian Ocean, and was gradually spread to the Mediterranean region. It is a dioecious small tropical seagrass; with creeping, branched, and fleshy rhizomes; and roots appearing solitary at every single rhizome node [88, 89]. A study conducted previously revealed that the macromolecular composition and pigment content of *Halophila stipulacea* extracts exhibited anti-oxidant activity by counteracting oxidative stress in human fibroblast cell line WI-38 [90]. In a recent study, the methanol and chloroform extracts of *Halophila stipulacea* demonstrated activity against all tested pathogens (*Staphylococcus aureus* and *Pseudomonas aeruginosa*), suggesting the anti-bacterial activity of *Halophila stipulacea*

extracts [91]. Moreover, using the ethanolic extracts of *Halophila stipulacea*, an eco-friendly anti-bacterial and anti-inflammatory cotton fabric, was produced. The fabric was finished through encapsulation and crosslinking with citric acid, resulting in higher anti-bacterial and anti-inflammatory activities [64]. Hexane and ethyl acetate extracts of *Halophila stipulacea* leaves and stems exhibited a remarkable cytotoxic activity against three cancer cell lines: neuroblastoma (SHSY5Y), colon adenocarcinoma (HCT116), and osteosarcoma (MG-63) cancer cell lines. The polyphenols found in the extracts, particularly flavonoids like luteolin, were identified as the active compounds with anticancer properties. However, the extracts showed no significant effect on lipid reduction in fatty acid-loaded liver cells (HepG2 cell line) [92]. In addition, an aqueous extract of *Halophila stipulacea* demonstrated high activity against filamentous *Aspergillus Niger* fungus, indicating anti-microbial activity [93].

Plumbaginaceae Family

Limonum axillare: species belongs to the family of Plumbanginaceae. The species' habitat is hypersaline soil and is distributed in the Mediterranean area, especially in Egypt, Arabian Peninsula, Qatar, and Iran. *Limonum axillare* plant is ubiquitous in the saline coasts of Qatar. Qatar, Gataf, and Shleil are the common names of this plant. Moreover, it is a shrubby species with flowering branches; leaves are fleshy having gland secreting salts [94]. A previous study showed that the butanol extracts of *Limonum axillare* displayed anti-fungal activity against *Aspergillus flavus*, *Candida albicans*, and *yeast*, as well as anti-bacterial activity against both Gram-positive and Gram-negative bacteria, indicating its potential as an anti-bacterial and anti-fungal agent [64]. A recent study investigated the anti-diabetic effect of *Limonum axillare*, and the results indicated that both the root ethanolic extract and aerial part of ethanolic extract exhibited anti-diabetic effects [95, 96]. Another group reported that flavonoids, steroids, saponins, and alkaloids in *Limonum axillare* have antioxidant activity [97].

Poaceae Family

***Sporobolus ioclados*:** species belongs to the family Poaceae, and the common names include Njema, Pan dropseed, Rashad, and Sakham. He native lays from Africa to the Indian subcontinent. It is a Qatar flora mainly found in Fuwairit, Al Khor, Qatar University, and the northeastern coast of Qatar. The plant is short-lived and sometimes has a short oblique rhizome, erectile and branched. Leaves are coarse, flat, folded, or involute and sometimes ciliated with tubercle-based hairs [98, 99]. There is a significant lack of comprehensive information available on the *Sporobolus ioclados* species in the existing literature. Consequently, a review of the scientific research to assess the species' any potential medicinal effect reveals a dearth of information. Nonetheless, some studies suggest that the phenolic content of *Sporobolus ioclados* is highly correlated with its anti-oxidant activity [100].

***Aeluropus lagopoides*:** *Aeluropus lagopoides* is a mangrove grass belonging to the family Poaceae, a species of Eurasian and African plant in the grass family. The large habitat of this plant passes through Southeast Europe, North Africa, the Middle East and the Arabian Peninsula, and central Asia. It is a Qatari flora found in West Bay, Abu Samra, Salwa Road, and Al khor regions. Moreover, this plant is a halophyte and a salt-secreting plant having thick waxy cuticle [56].

According to a recent study, *Aeluropus lagopoides* has been found to exhibit anti-diabetic and anti-oxidant activities due to its phenolic and flavonoid contents. However, the same study also revealed that the plant extracts showed no significant anti-bacterial activity and only weak anti-microbial activity against Gram-positive and Gram-negative bacteria, as well as *Candida albicans* [56]. Another study highlighted the potential of the phenolic compounds in *Aeluropus lagopoides*, such as flavonoids, phenolic acids, and tannins, in exhibiting anti-cancer and anti-inflammatory activities [101]. Moreover, in another study, hexane and ethyl acetate extracts from *Aeluropus lagopoides* are known to have a potential anti-cancer effect on the HepG2 cancer cell line [102].

Discussion

The plant kingdom has long served as a significant source of medicinal plants, with herbal therapies dating back 60,000 years. Despite modern medical advancements, herbal medicine remains vital for disease treatment in Qatar and the Middle East, where it continues to be used for various ailments. This review focuses on Qatar's wetland plants, categorized as seawater, coastal, and sabkhas. Despite their potential medicinal value, these wetland plants have received limited attention in ethnobotanical studies. Numerous studies have explored their therapeutic applications, including antimicrobial, antioxidant, anticancer, anti-inflammatory, and antidiabetic properties.

Notably, over 80% of the studies focused on the antioxidant effects, while less than 30% explored their potential as anti-diabetic agents. Given the significant health challenge posed by diabetes in Qatar and worldwide, there is an urgent need to investigate their potential anti-diabetic efficacy. Herbal and medicinal plants offer a valuable resource for drug discovery due to their various biologically active compounds that can serve as precursors for allopathic drugs. However, extracting bioactive constituents remains challenging due to variations in polarity and thermal stability. Most studies in this review used water extracts for their anti-inflammatory effects, while ethanolic extracts were commonly employed to obtain compounds with antimicrobial impacts.

Furthermore, several wetland plants in Qatar, such as *A. marina*, *A. setifera*, *H. perfoliate*, *S. europaea*, *S. vermiculata*, *and H. ovalis*, exhibited multiple therapeutic applications, rendering them promising candidates warranting further investigation for the identification and separation of active components and conducting pre-clinical and clinical trials. Conversely, the scarcity of data for some species like H. stipulacea and S. Rosmarinus highlights the need for more extensive research to harness their medicinal potential.

In conclusion, Qatar's wetland plants offer a rich resource of medicinal plants traditionally used for therapeutic purposes. While their evidence-based medicinal efficacy shows promise, further research is necessary to fully explore their potential. Integrating traditional herbal medicines into public healthcare systems requires standardized quality, efficacy, safety, and dosage, promoting wider use while ensuring patient safety. This review lays the groundwork for future research and emphasizes the importance of preserving wetland ecosystems to safeguard these valuable medicinal plant resources.

Author contribution

Hend Al-Jaber: Draft manuscript preparation, study conception, and design reviewed the final draft of the manuscript.

Lubna Abu-Rub: Literature review, draft manuscript preparation, study conception and design.

Hasna H. Kunhipurayil: Draft manuscript preparation.

Nahla O Eltai: Reviewed and approved the final version of the manuscript.

Rasha S. Abo El Alaa: Revised and approved the final manuscript.

Layla Al-Mansoori: Study conception and design, reviewed and approved the final version of the manuscript.

Abbreviations
Med: Medicinal
AB: Anti-Bacterial
AO: Anti-Oxidant
AD: Anti-Diabetic
AM: Anti-Microbial
AI: Anti-Inflammatory
AC: Anti-Cancer
HepG2: Hepatocellular carcinoma cell line
S. aureus: Staphylococus aureus
MCF7: Breast cancer cell line
C. parapsilosis: Candida parapsilosis
hAKR1B1: Aldose-resuctase-like protein
hAKR1B10: Akdose-reductase-like protein
hCBR1: Carbony1 reductase
MDA: Malondialdehyde
S. epidermidis: Staphylococcus epidermidis
A549: Adenocarcinomic human alveolar basal epithelial cell lines
HT-29: Human colorectal adenocarcinoma cell line
WI-38: Winstar Institute 38 – human fibroblast cell line
SHSY5Y: Neuroblastoma cell line
HCT 116: Human colorectal carcinoma cell line
MG-63: Osteosarcoma cell lines

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