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Halophytes and Soil Salinity in Qatar

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النباتات الملحية وعلاقتها بملوحة التربة في قطر

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تحتل الأراضي المالحة حوالي ٦٪ من مساحة قطر، وتنمو الكثير من النباتات الملحية على السواحل وداخل البلاد حيث تتوفر المياه المالحة بصورة دائمة أو موقتة. وهذه النباتات لها أشكال وأنماط نمو متنوعة، أهمها الشجيرات القصيرة العصارية، والتي يعيش كل منها في بيئة ذات مواصفات خاصة:

Anabasis setifera, Arthrocnemum glaucum, Atriplex leucoclada, Cornulaca aucheri, Halocnemum strobilaceum, Halopeplis perfoliata, Heliotropium bacciferum, Limonium axillare, Salicornia europaea, Salsola baryosma, Salsola cyclophylla, Salsola marina, Seidlitzia rosmarinus, Suaeda aegyptiaca, Suaeda vermiculata and Zygophyllum qatarense.

وأعشاب المناطق الرطبة المالحة ذات الكثبان الرملية الصغيرة *Aeluropus lagopoides, Sporobolus spicatus, Cyperus conglomeratus* وقصب وحلفاء المياه الراكدة : *Phragmites australis, Sporobolus arabicus.* وحوليات السبخات : *Cressa cretica, Frankenia pulvurulenta, Zygophyllum simplex.* والشجيرات البحرية : *Avicennia marina.* وشجيرات البرك المائية متباينة الملوحة : *Tamarix ramossissima.* وأشجار النخيل التي تتحمل درجات مختلفة من الملوحة: *Phoenix dactylifera.*

ومن بين أكثر المجتمعات النباتية الملحية في قطر ما يلي: مجتمعات المناطق الداخلية الرطبة، مجتمعات المناطق الداخلية المسطحة المالحة، مجتمعات القرم الساحلي، مجتمعات المستنقعات الساحلية المنخفضة، مجتمعات المستنقعات الساحلية المرتفعة، مجتمعات السواحل الرملية الملحية، ومجتمعات السواحل الرملية - الصخرية الملحية.

Key Words : *Desert, Coastal Halophytes, Inland Halophytes, Soil Salinity, Qatar.*

ABSTRACT

Saline soils cover approximately 6% of the land in Qatar. Halophytes are common along the coastal areas and inland salt flats and wetlands, where saline water is available in their natural habitats permanently or periodically. The prevailing plants are mostly perennials including dwarf succulent shrubs (*Anabasis setifera, Arthrocnemum glaucum, Atriplex leucoclada, Cornulaca aucheri, Halocnemum strobilaceum, Halopeplis perfoliata, Heliotropium bacciferum, Limonium axillare, Salicornia europaea, Salsola baryosma, Salsola cyclophylla, Salsola marina, Seidlitzia rosmarinus, Suaeda aegyptiaca, Suaeda vermiculata and Zygophyllum qatarense*), followed by tussock forming grasses (*Aeluropus lagopoides and Sporobolus spicatus*), sedges (*Cyperus conglomeratus and Sporobolus arabicus*), reeds (*Phragmites australis*), annuals (*Cressa cretica, Frankenia pulvurulenta and Zygophyllum simplex*), and shrubs and trees (*Avicennia marina, Phoenix dactylifera and Tamarix ramossissima*). There are seven common halophytic communities found in Qatar: the inland wetland halophytes, the inland salt flat halophytes, the coastal mangrove halophytes, the coastal low marsh halophytes, the coastal high marsh halophytes, the coastal sandy shore halophytes and the coastal sandy-rocky shore halophytes.

Introduction

Halophytes are those plants that are able to grow under saline conditions. Thus, they are restricted to the more saline soils and thrive in coastal areas, salt marshes and wetlands [1, 2].

Halophytes are common along the coastal belt of the Arabian Peninsula. High degree of similarity of halophyte species exists among the countries located along the western shorelines of the Arabian Gulf. Halophytes are equally found in the inland parts of most of the Arabian Peninsula, in areas where water is available, especially in the vicinity of farms with poor drainage, and in wastewater dumping sites. Similarly, halophytes are common in wet and moist areas in Qatar, commonly found along the coastal areas and inland salt flats and wetlands.

Information concerning different floristic and ecological aspects of halophytes found in a number of local research works was consulted during the course of this study [3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19].

In the present study habitat characteristics and species composition of halophytic communities were surveyed in Qatar.

Both halophyte and nonhalophytic plants absorb salts across their roots but it is their tolerance to high internal salt levels that distinguishes these two groups. High internal sodium (Na) and chloride (Cl) levels can be toxic to plants as they can compromise enzyme function and disrupt metabolic processes. This condition is detrimental to less tolerant plants but halophytes have achieved several means by which they can reduce this toxicity. One example of such an adaptation is the storage of NaCl in the vacuoles within the plant cells. By sequestering NaCl in this organelle, this reduces the cytoplasmic NaCl levels and consequently reducing the toxicity and possible damage of the cellular machinery (i.e. enzymes). Halophyte may rely upon more than one of several mechanisms to cope with high soil salinity.

Sodium and chloride are the major ions that accumulate in halophytes and these thought to be responsible for establishing succulence. High internal NaCl levels are compensated by high water storage. It is believed that as soil salinity rises, the succulence of the plant becomes greater as both water and salt absorption increases. In certain halophytes, as in *Anabasis setifera* and *Limonium axillare*, salt is absorbed across roots and can accumulate to high levels within the tissues of the plant. Rather than absorb additional water to compensate for the salt stress, *Limonium axillare* possesses glands on the leaves which secrete the excess salt to the outside of the leaf, mainly Na and Cl. These structures are located in the epidermal layer on both the upper and lower sides of the leaves. These salt crystals drop to the soil or are washed off by dew, rain or wind. Excess salt is converted to crystals in case of *Anabasis setifera*, which lie in the chlorenchyma tissue [4].

Materials and Methods

To determine the nature of relationship, which exist between the species and their habitats the known halophytic communities in Qatar were surveyed. Soil samples collected form different communities were analyzed detailing soil texture, soil salinity and pH of the top 0-20 cm. Further ecological information concerning each community included habitat type, community type, species list, life forms and percentage of vegetation cover.

Plant identification was based on prior knowledge of the flora of the Arabian Peninsula, supported by the herbarium specimens at the University of Qatar and various regional publications [11, 15]. Classification of plant life forms was based on the Raunkiaer's system [20].

Soil samples of the representative communities were analyzed in the Ecology Laboratory of the Department of Biological Sciences, University of Qatar. Soil mechanical analysis was conducted in accordance with the standard soil sieve method. Soil salinity and pH was evaluated by using saturated soil extract. Soils were soaked in distilled water for 24 hours before filtration through two layers of filter paper using a suction pump. The filtrate was used to evaluate salinity (ECE) by a conductivity bridge and to determine the pH by a pH meter.

Climatic Conditions and Water Resources

Doha City, which is located more or less in the mid eastern coastline, shows two extremes during the year: a very hot and humid during June and August, and comparatively cool and pleasant from November to March. The average annual rainfall is 81 mm, the average maximum temperature is 31°C, the average minimum temperature is 22°C, the absolute maximum temperature is 47°C, the absolute minimum temperature is 1°C. The average morning relative humidity is 71 %, where as the average afternoon relative humidity is 43 %. Wind blown dust is more common in the southern region. However, Qatar is occasionally affected by sandstorms that originate in United Arab Emirates and Saudi Arabia during summer time [11].

Qatar according to its geographical location and climate falls within the hot subtropical desert. Because of Qatar's smallness and general flatness there is little differences in the climatic conditions experienced from place to place. The average annual rainfall recorded in three locations from the north to the south are as follows: 107.7mm in Rawdat Al-Faras (north), 104.3mm in Al-Otoriyah (center), and 70.7mm in Abu-Samrah (south). In all these stations rainfall is expected between October and May [7]. More rainfall expected between December and March. Air temperature is slightly different among these stations. It increases slightly proceeding from north to south. Such slight differences in climatic factors from north to south attributed to the flatness and the smallness of the country.

Qatar receives very little rainfall and has no rivers and lakes. Its primary source of fresh water is the ground water. Geological studies showed that Qatar and Saudi Arabia have joint aquifers, and share ground water resources. The salinity in these aquifers increases eastward toward Qatar Peninsula [7].

Large number of water wells found in Qatar [21]. These wells discharge various water quality: fresh, brackish or saline [22]. The quality of these waters in the northern half of the country is compartively better than those of the southern half. Northern waters have on the average total dissolved solids of 400-6000 ppm, whereas the southern waters maintain 3000-6000 ppm [23]. Further, water can be reached at around 30m below the ground surface in the northern half of Qatar, and at 30-80m depth in the southern half of Qatar).

Surface water, on the other hand, is very limited. In a good rainy season, water may be seen in depressions, wadis, and runnels for a while. Such water penetrates the earth surface and/or evaporate to the atmosphere. In spite of its scarcity, such water is essential for the seed germination and the growth of the wild vegetation.

Demand for fresh water is rising constantly for domestic, indistrial and agricultural use. Desalinization plants and ground water provide most of the water.

The land of Qatar is known by its high total dissolved solids (salinity) in the coastal areas and lowland areas. Likewise the total dissolved solids of the underground water is much higher in wells closer to the coastal areas [23]. Total dissolved solids (TDS) of underground water measured all over the country in October 1986 and in April 1988 showed dramatic increase proceeding from inland (1000 ppm) to the coastal areas (8000 ppm). Total dissolved solids of the underground water is relatively low in the north central part of Qatar, and accordingly large number of farms which depend on such water were successfully developed. The second low groundwater total dissolved solid was encountered in the south-central region of Qatar, where second-degree farms were developed. Farming in the coastal areas is not possible because of high soil total dissolved solids. TDS of Well waters changes seasonally corresponding with the water level of the Arabian Gulf.

Since most parts of Qatar are low-leveled flat lands, ground water is accordingly relatively shallow. Groundwater is 15-35 m deep in the north central parts of Qatar, 15-70 m deep in the south central parts of Qatar, and 0-15 m deep along the coastal areas. Generally, the high ratio of salinity in well water is attributed in part to the intrusion of seawater into the underground water as a result of the high consumption of the well water through agricultural practices and industry [11].

Landform

The peninsula of Qatar is located between 24° 27` and 26° 10` north and at 50° 45` and 51° 40` east. It is 180 km long and 85 km wide. It covers an area of 11,437 km2 [7, 11, 24]. Qatar has a number of islands mostly to the east and west of the country. The elevation of Qatar peninsula ranges between sea level and 103m. The landscape is generally flat to undulated, with rocky hills and sand dunes situated in the southern parts of the country. Saline swampy areas are common along the coastal areas and in a few inland areas [7, 11, 15, 25].

Soil

According to the soil classification of the State of Qatar (Fig. 1) saline soils belong to Association-B (equivalent to Solonchack or Solonetz soils), and commonly annexed to the seashores of Qatar and sporadically in inland areas [26]. Such soils locally called Sabkha or Sbakha, varying greyish, brownish or bluish massive soils, having shallow to deep profiles, from 30 to 150- cm depth. Their texture is between calcareous clay loam, sandy clay loam and sandy loam. Salt crusts were observed on soil surfaces, especially in places where the topsoil goes through a prolonged dry period. This soil association covered approximately 70,000 hectare, equivalent to 6% of the Qatari soil [26].

Results

The common halophytes found in Qatar include the following species: *Aeluropus lagopoides, Anabasis setifera, Arthrocnemum glaucum, Avicennia marina, Cressa cretica, Cyperus conglomeratus, Halocnemum strobilaceum, Halopeplis perfoliata, Limonium axillare, Salicornia europaea, Salsola baryosma, Salsola marina, Seidlitzia rosmarinus, Suaeda aegyptiaca, Suaeda vermiculata* and *Zygophyllum qatarense* (Table 1, Figures 2A & 2B). Halophytes are grouped according to their distribution into two categories, inland halophytes and coastal halophytes.

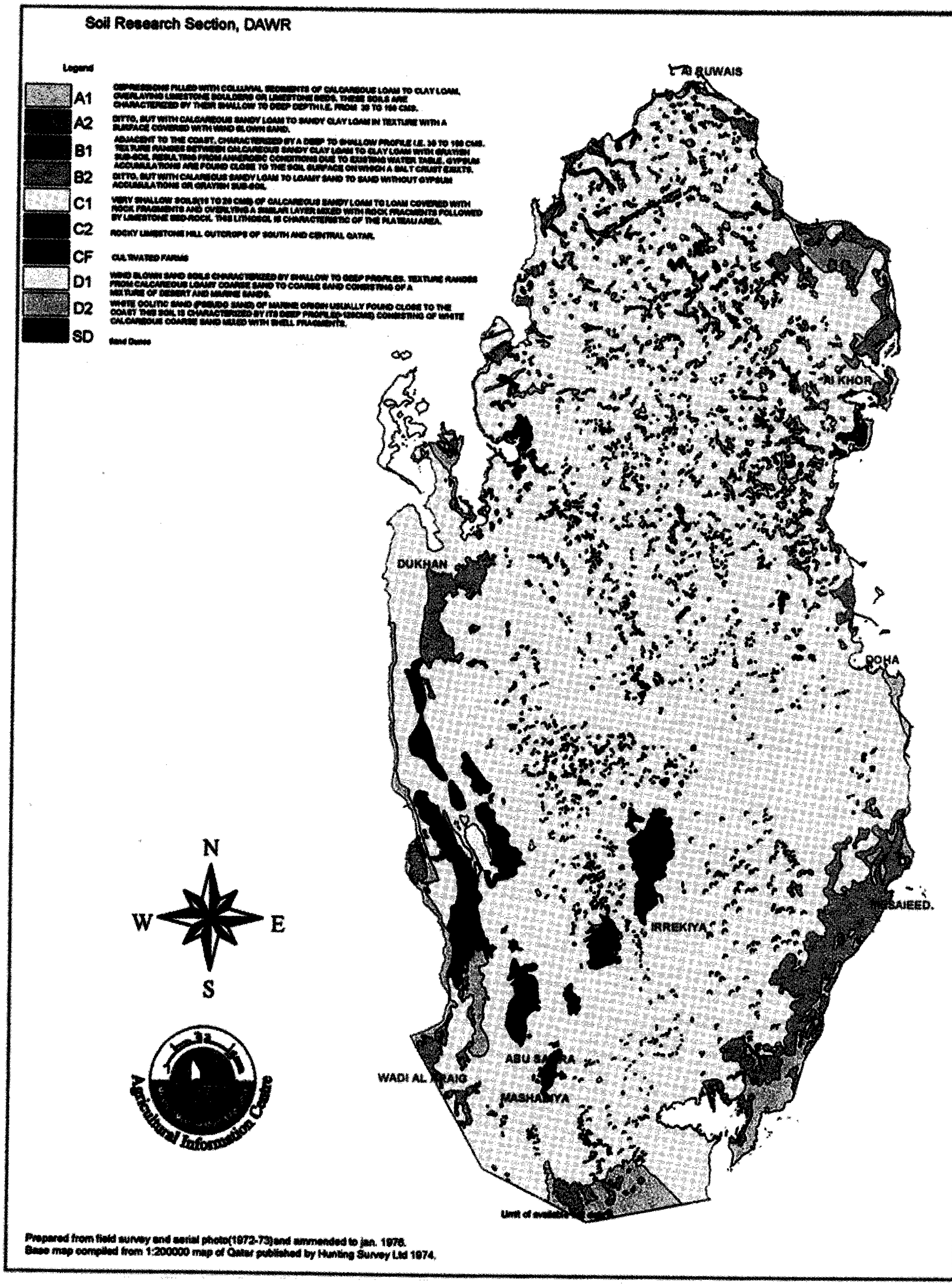

Figure 1. Soil Map of Qatar.

Table 1. Species composition, vegetation cover, soil types and soil salinity of halophytic communities in Qatar.

Halophytic Communities	Species	Cover (%)	Soil Type	Soil Salinity (dS/m)
Inland wetland halophytes	*Aeluropus lagopoides, Cressa cretica, Phragmites australis, Sporobolus arabicus, Tamarix ramossissima, Zygophyllum simplex*	10-30	Sandy	8.8 ± 8.17
Inland salt flat halophytes	*Aeluropus lagopoides, Cyperus conglomeratus, Heliotropium bacciferum, Salsola baryosma, Tamarix ramossissima, Sporobolus arabicus, Zygophyllum qatarense, Anabasis setifera*	5-30	Sandy, Occasionally crusty	61.1 ± 10.2
Coastal mangrove halophytes	*Avicennia marina, Salicornia europaea, Salsola marina.*	50-100	Sandy silty	36.4 ± 20.5
Coastal low marsh halophytes	*Arthrocnemum glaucum, Halocnemum strobilaceum, Salicornia europaea, Salsola marina*	10-60	Sandy-silty	36.4 ± 20.5
Coastal high marsh halophytes	*Aeluropus lagopoides, Anabasis Cressa cretica, Halocnemum setifera, strobilaceum, Halopeplis perfoliata, Limonium axillare*	20-60	Sandy, Occasionally crusty	49.8 ± 2.19

Table 1. Contd.

Halophytic Communities	Species	Cover (%)	Soil Type	Soil Salinity (dS/m)
Coastal Sandy shore halophytes	*Aeluropus lagopoides, Anabasis setifera, Cornulaca aucheri, Cyperus conglomeratus, Heliotropium bacciferum, Limonium axillare, Phoenix dactylifera, Salsola baryosma, Seidlitzia rosmarinus, Sporobolus arabicus, Sporobolus spicatus, Suaeda aegyptiaca, Suaeda vermiculata, Zygophyllum qatarense*	10-40	Sandy	11.8 ± 18.1
Coastal sandy-rocky shore halophytes	*Anabasis setifera, Limonium axillare, Salsola baryosma, Suaeda aegyptiaca, Suaeda vermiculata, Zygophyllum qatarense*	10-20	Sandy-rocky	6.25 ± 4.16

Soil Salinity Classes: None Saline (0-2), Slightly Saline (2-4), Moderately Saline (4-8), Strongly Saline (8-16), Very Strongly Saline (>16 dS/M). After Abrol [27].

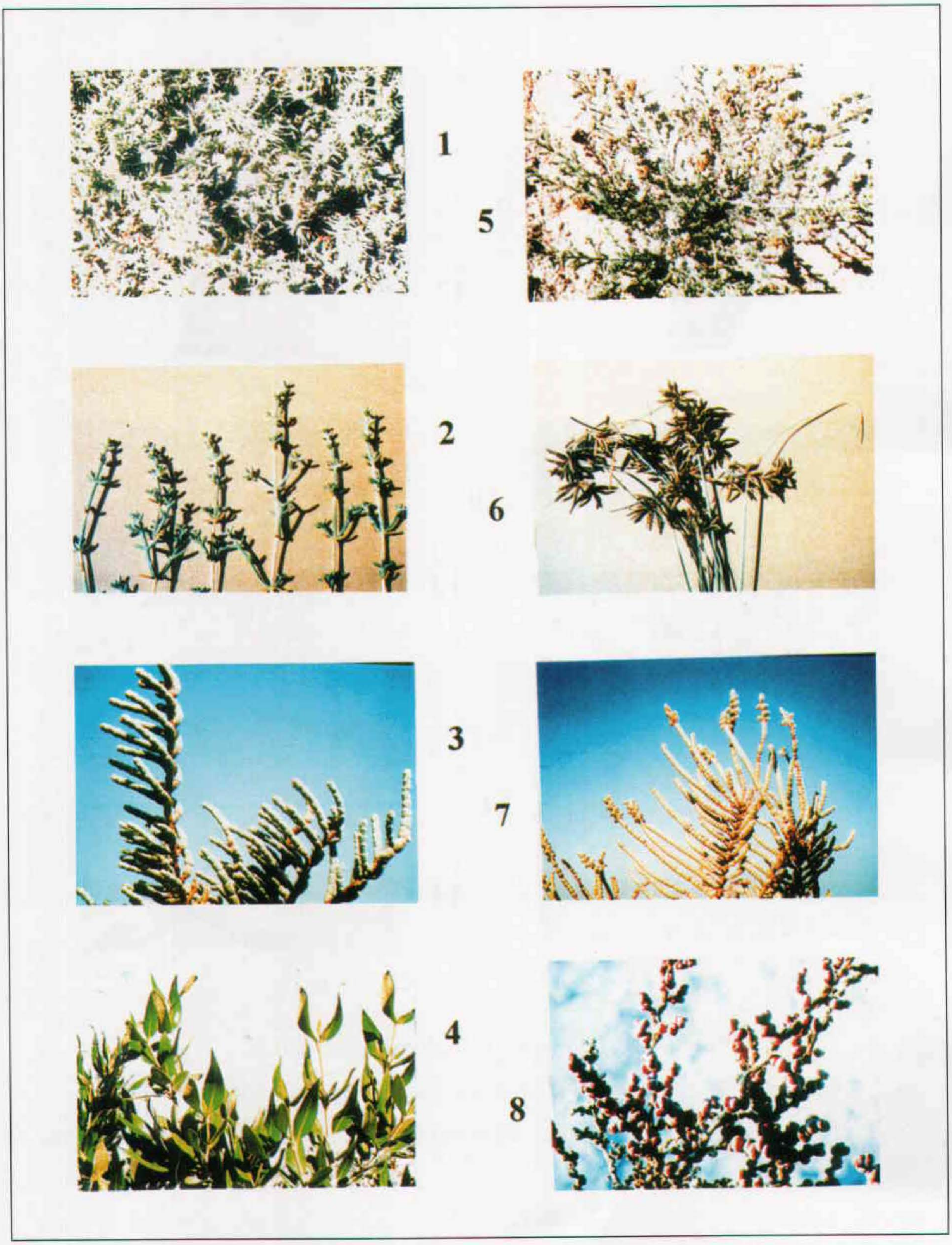

Figure 2A. Common halophytes from Qatar.

(1) *Aeluropus lagopoides*, (2) *Anabasis setifera*, (3) *Arthrocnemum glaucum*, (4) *Avicennia marina*, (5) *Cressa cretica*, (6) *Cyperus conglomeratus*, (7) *Halocnemum strobilaceum* and (8) *Halopeplis perfoliata*.

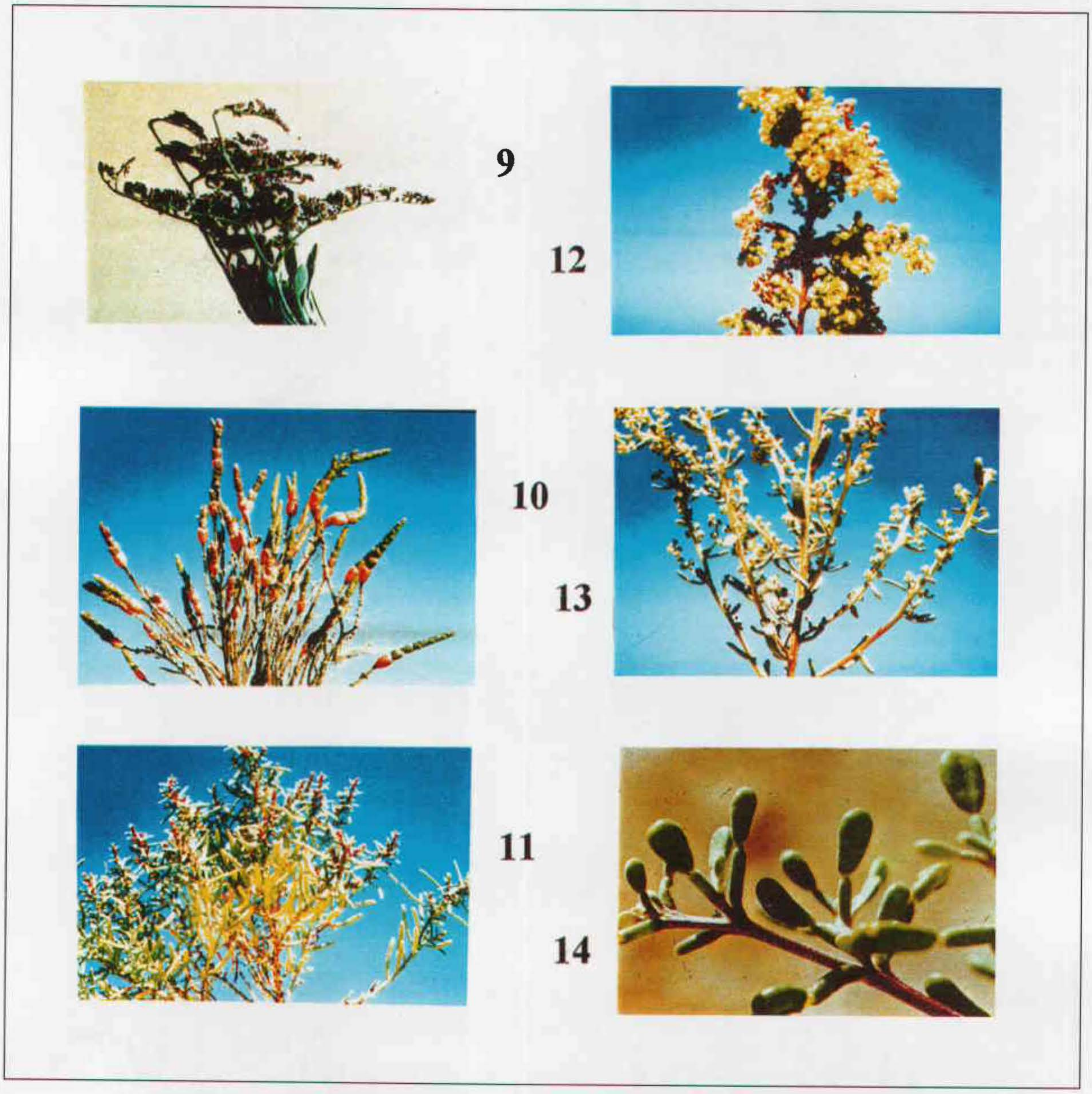

Figure 2B. Common halophytes from Qatar.

(9) *Limonium axillare*, (10) *Salicornia europaea*, (11) *Salsola marina*, (12) *Suaeda aegyptiaca*, (13) *Suaeda vermiculata* and (14) *Zygophyllum qatarense*.

Inland Halophytes

The location of Qatar at the western side of the Arabian Gulf, and being part of the large land mass of the Arabian Peninsula play an essential role in the make up of its flora and vegetation. Inland halophytes live in wetland or salt flat, receiving underground water via seepage. Other groups of halophytes live around the man-made wastewater pools, or in low-leveled unpermeable ground (basins), which retain rain-water for prolonged periods.

The characteristic of each community is highly controlled by the nature of substratum and soil salinity (Table 1). Ecological information concerning inland and coastal halophytic communities are detailed below.

1. Inland Wetland Halophytes

They are commonly located in depressions receiving wastewater from different sources. These depressions are in most cases rocky with little soil, but after a period of time the top layer becomes thicker as a result of litter accumulation and decomposition. In some cases, the color of the topsoil change to olive green. Soil is strongly saline at the top 20 cm (8.83 ± 8.17 dS/m). Such depressions are well suited for the establishment of many annuals, grasses, reeds, sedges and shrubs, such as: *Aeluropus lagopoides, Cressa cretica, Phragmites australis, Sporobolus arabicus, Tamarix ramossissima* and *Zygophyllum simplex.*

2. Inland Salt Flat Halophytes

The soil is 10-150 cm deep, found in lowlands, affected to a certain degree by the shallow underground water and seawater intrusion. Some inland low-level areas show water logging for parts of the year. Sun-baked salt crust, flufy soil or cracks appear on the surface, caused by variable edaphic and environmental factors. Soil is strongly saline at the top 20 cm, recording 61.1 ± 10.2 dS/m. No plants often grow in the core of the salt flats. However, *Aeluropus lagopoides* grass is common along with the sporadically present associate species around the edges of salt flats: *Tamarix ramossissima, Sporobolus arabicus, Zygophyllum qatarense, Anabasis setifera, Cyperus conglomeratus, Salsola baryosma* and *Heliotropium bacciferum*.

Coastal Halophytes

Some salt marshes are among the most productive ecosystems in the world. Few flowering halophytes dominate the intertidal low salt marshes [28].

Salt marshes are affected by a number of factors, which regulate the existence of plant species. These factors include tidal patterns, salinity, drainage, water table, precipitation, soil type, evaporation, temperature, and biota [9, 10, 11, 28, 29, 30].

Coastal vegetation is generally patchy, comprised of mostly dwarf shrubby halophytes, with a few halophytic annuals and a mangrove tree species. Most plants start their active growth between December and

March, when the temperature is mild and they loose some of their foliage in summer. Most plants on wet sites grow from off shoots and rhizomes of older plants.

In certain parts along the shorelines, large areas with loose sandy soil or sandy rocky soil. Plants that occupy such habitats receive their water from various sources: underground seawater, surface and underground fresh water, air humidity and sea water spray. Coastal areas in Qatar vary from place to place. Plants living in coastal salt marshes inundated and drained periodically. On the other hand, palants living on sandy and rocky shore receive ground water mostly.

Five major plant communities were encountered in the coastal areas of Qatar: (1) coastal mangrove halophytes, (2) coastal low salt marsh halophytes, (3) coastal high salt marsh halophytes, (4) coastal sandy halophytes and (5) coastal sandy-rocky halophytes. The study revealed that the width of the coastal communitie vary from stand to stand depending on the local soil type, moisture and elevation. A species could cover a couple of meters in some areas, while stretching over hundreds or even thousands of meters away from the water front in other areas.

Coastal halophytes divided into the following categories

1. Coastal Mangrove Halophytes

Soil under mangrove forests is of silty clay loam type, made of two layers, the top one is white and about 1-2 cm in thickness, and the lower one in olive green colored. Species present in the mangrove intertidal zone are: *Avicennia marina, Salicornia europaea* and *Salsola marina*. Very large mangrove communities were found in Al-Thakhirah and Al-Khor, northeast Qatar, with strongly saline soils (36.4 ± 20.5 dS/m).

2. Coastal Low Marsh Halophytes

Low salt marsh is under frquent inundation by seawater. The soil is usually wet sandy. Species present in this habitat include *Salicornia europaea, Salsola marina, Arthrocnemum glaucum* and *Halocnemum strobilaceum*. Soil is strongly saline (36.4 ± 20.5 dS/m).

3. Coastal High Marsh Halophytes

High salt marsh with less frequent inundation by seawater experiencing soil moisture fluctuates from wet, moist to dry. Species present in this habitat include: *Halocnemum strobilaceum, Halopeplis perfoliata, Limonium axillare, Aeluropus lagopoides, Anabasis setifera*, and *Cressa cretica*. Soil is strongly saline (49.8 ± 32.19 dS/m).

4. Coastal Sandy Shore Halophytes

Surface soils mostly dry, subsoil moisture moist to wet. Dwarf succulent perennials, grasses and sedges are common on sandy shores. Such type of habitats found in various places along the coastal areas of Qatar, especially in the southeastern region. Species found in the sandy coastal zone are: *Aeluropus lagopoides, Anabasis setifera, Cornulaca aucheri, Cyperus conglomeratus, Heliotropium bacciferum, Limonium axillare, Phoenix dactylifera, Salsola baryosma, Seidlitzia rosmarinus, Sporobolus arabicus,* *Sporobolus spicatus, Suaeda aegyptiaca, Suaeda vermiculata* and *Zygophyllum qatarense*. Soil is strongly saline (11.85 ± 18.1 dS/m).

5. Coastal Sandy-Rocky Shore Halophytes

Surface soil mostly dry, subsoil holds little moisture. Dwarf succulent perennial plants are common on the sandy-rocky shores. Such habitats found in a number of places along the coastal areas. Species found in the sandy rocky coastal habitat include Anabasis setifera, Limonium axillare, Salsola baryosma, Suaeda aegyptiaca, Suaeda vermiculata and Zygophyllum qatarense. Rocky shores are generally rare along the coastal areas of Qatar, and mostly man-made. Soil is moderately saline (6.25 ± 4.16 dS/m).

Life forms of Halophytes

Classification of plant life forms of halophytes, which was solely based on the location of the position of the renewal buds, followed the system proposed by Raunkiaer [20]. The life forms and their representative species are as follows:

Chamaephytes: *Aeluropus lagopoides, Arthrocnemum glaucum, Cornulaca aucheri, Cyperus conglomeratus, Halocnemum strobilaceum, Heliotropium bacciferum, Limonium axillare, Salicornia europaea, Salsola marina, Seidlitzia rosmarinus, Sporobolus arabicus, Suaeda aegyptiaca, Suaeda vermiculata* and *Zygophyllum qatarense*.

Geophytes (Cryptophytes): The following plants behave as Geophytes or Chamaephytes: *Cyperus conglomeratus* and *Phragmites australis*.

Phanerophytes: *Avicennia marina, Tamarix ramossissima* and *Phoenix dactylifera*.

Therophytes: *Cressa cretica, Frankenia pulverulenta* and *Zygophylum simplex*.

Discussion

In the light of freshwater shortage in Qatar it seems necessary to see if some of the halophytes can be converted into crops and/or used for other purposes.

In recent decades, attempts were started to use saline water to irrigate agricultural crops. The shortage of fresh water for human consumption forced agronomists to use treated wastewater and brackish water to irrigate crops. In arid areas of the world, Arabia, SE Asia, North Africa, Australia, Mexico and North America irrigation trials with ocean water were started. Extensive work of many scientists has shown that mangroves and other halophytes can be successfully planted in the deserts of the UAE, irrigated with seawater or other saline water. A few of the salt tolerant genera attracted the attention of many scientists worldwide because of their economic importance as forage or fibers. They include *Kochia, Salicornia, Spartina, Juncus, Scirpus, Typha, Phragmites, Distichlis* and *Atriplex*.

Worldwide, halophytes has been utilized in many ways: timber (Mangrove), fuel (*Atriplex, Tamarix*), food (*Distichlis palmeri*), cooking oil and protein (*Salicornia*), forages (*Atriplex, Sporobolus, Maireana, Aeluropus*, etc.), landscaping (*Prosopis, Acacia, Casuarina*, etc.).

Many of halophytes are utilized as animal feed which support an extensive herding. Some of the halophytic species are high in protien content, although not with high digestibility of protien [31]. However, feed intake and digestibility of these species are low to high salt content and other antiquality components. These species can be used for other purposes such as amenity and greening space, sand dune fixiation and land reclamation, industrial use for dried fruit processing, household uses as detergant... etc. Halophytes are highly efficient in soil reclamation largely because of their ability to produce biomass and accumulate Na^+ in leaves.

Halophyte species in Qatar included mainly perennial dwarf succulents associated with a few species of grasses, shrubs and trees. These plants are ecologically important for the sustainability of the ecosystems. For example, the presence of *Avicenia marina* (mangrove) in abundance in certain areas along the coastal belt of Qatar play a major role in the survival of aquatic birds, fishes, invertebrates and other kinds of life forms. Similarly, coastal and inland salt marshes, salt flats, and wetlands harbor various kinds of living animals.

Having large saline areas (6% of the land) in Qatar urges botanists and agriculturists to develop these areas by promoting the growth of the economically important halophytic plants by implying modern methods and concepts, such as:

1. To improve salt-tolerant crops for use in salt-afflicted agroecosystems using biotechnology.
2. To develop varieties of plants for saline wetlands restoration that will drive high productivity ecosystems without continual human input.
3. To disseminate knowledge about using salt-tolerant plant varieties to develop sustainable agriculture in areas of the world where soils are salinized or only saline water is available for irrigation and to solve wetland restoration problems.
4. To exchange information on the performance of varieties of salt-tolerant plants under various types of agroecosystems (i.e. rainfed, irrigated, tidal) and wetland restoration sites.

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