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Plants of Saline Coastal and Inland Sabkha Areas as Indicators of Environmental Conditions in Southern Jordan

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Abstract

In this study, plants of the coastal and inland saline Sabkhas and their indicator values of the arid regions of South Jordan (Taba Oasis and Aqaba coast) were discussed. Plants which that tolerate salty ground display a quite distinct character regarding their systematic composition at the different localities and distribution in Jordan. Most plants species which that thrive in the Gulf of Aqaba were considered fast fast-growing halophytes growing along the Gulf of Aqaba in a salty environment.

Zonation was recorded in the Taba wetland with low biodiversity due to high environmental stress. Taba plants were dominated by different salt-tolerant, heat heat-stress-tolerant, and drought drought-resistant plant communities. Plants in dry environments were being affected by human development activities and climate change. In Jordan, with its arid climate, most plant species were sensitive to environmental changes so that small changes in water availability and salinity due to climatic conditions were reflected in changes in occurrence, distribution, and richness of native plant communities.

The study builds baseline knowledge of the environmental conditions of both the Aqaba and Taba areas to serve future evaluations of changes taking place in these areas due to human activities. It is thought ofto be seriously taken by policy-makers in order to safely plan future developments in orderto minimize actions leading to detrimental environmental changes resulting from human settlements, industry, and others related anthropogenic activities.

Keywords: *Halophytes, saline-alkaline tolerance, environmental indicators, wetland, climate change*

1. Introduction

Plants in wetland and coastal areas are of economic and ecological values, including; their roles in natural water purification from sediments, pollutants, and nutrients; Some of these wild plants are edible and some are used in traditional medicinal treatments; they can combat desertification by fixing sand dunes and preventing wind erosion; they can provide forages for grazing animals; they can be a keystone by providing wild animals food, shelter and nesting place and therefore helps in ecosystems integrity and enhance biodiversity in such harsh(Whigham et al., 1988; Kuusemets and Mander, 1999; Crumpton, 2001; Reed and Carpenter, 2002).

Several types of ecosystems under different environmental conditions are characterized by distinct plant communities that can be used to identify and evaluate their integrity (Fort and Freschet, 2020; Squires and van der Valk, 1992). Many studies confirmed that plants are powerful indicators of environmental conditions given their rapid response to environmental changes that reflect accumulative long and short time changes in the ecosystem, including water turbidity, nutrient enrichment, and organic and chemical pollutants (Craft and Richardson, 1998; Wardrop and Brooks, 1998; Bayouli et al., 2021). The other reason to use them as bioindicators is their immobility as organisms and their occurrence in all wetlands. The taxonomy of the floral species of Jordan was well described and identified by Zohary (1973), Albert et al. (2004), AL-Eisawi (1998), and others. Wetlands, dry lands, and aquatic bodies in Jordan, have characteristic sets of plant species, which sometimes provide good indicators of environmental conditions. For example, Azraq Sabkha with salt-tolerant indicator species includes the flora Spergularia media, Suaeda vera, Tamarix passerinoides, and Spergularia marina (Alhejoj et al., 2015). Additionally, Al Khateeb (2018) studied the use of wild plants as a pollution bioindicator to assess their geno-toxicity.

Jordan is situated in the transition zone between arid and semiarid bioclimates and although the distance between the northern and the southern borders is only about 400 km, the annual rainfall can be as high as 600 mm in the north-western mountains and as low as 50 mm in the southern and eastern desert regions (MoWI and DOM open files). The strong spacial variation in the climate results in conspicuous changes in the vegetation and in the composition of the flora over relatively short distances (Zohary, 1973). Jordan is also the meeting place of four major phytogeographic regions: the Mediterranean (subhumid and semiarid Mediterranean), the Irano-Turanian (arid Mediterranean), the Saharo-Arabian and the Sudanian regions (Zohary, 1973;

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Al-Eisawi, 1985, 1996; Albert et al., 2004; Muhaidat et al., 2018). In the bioclimatic analyses by Al-Eisawi (1985, 1996), nine subdivisions are considered that fall under four main bioclimatic regions, representing a gradient of decreasing precipitation and increasing temperature: (I) subhumid Mediterranean bioclimate; (II) semiarid Mediterranean bioclimate; (III) arid Mediterranean bioclimate; and (IV) Saharan Mediterranean bioclimate. These bioindicators are faced by several problems including: soil salinity, deep groundwater levels, and temporal rapidly changing rainfall and temperatures. Salinity and climate change are worldwide environmental issues and are the main factors affecting plant species diversity and occurrences.

The main objective of this study is to discuss the use of plants as indicators of the prevailing environmental conditions in the coastal area of Aqaba and the Sabkha of Taba in southern Jordan (Fig.1). In addition, this study will discuss and correlate the occurrences of the same plant species in other areas in Jordan.

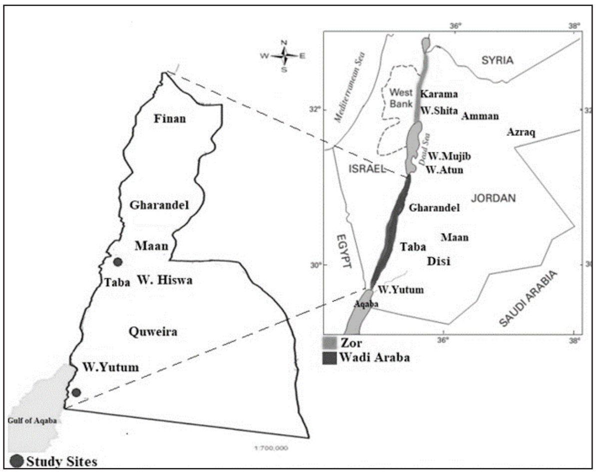

Figure 1. Location map of the studied sites in Southern Jordan. 1. The coastal area of the hotel complex and the Royal Diving Club in Aqaba. 2. The Sabkha of Taba in Wadi Araba.)

2. Methodology

This study builds on the intensive field and laboratory work, collection of samples and their analyses and identification in the field and in the laboratory, interpreting analytical results, and reporting.

3. Discussion of Field and Laboratory Findings

3.1 Coastal plants of The Gulf of Aqaba

The Gulf of Aqaba lies in the southernmost part of Jordan with an ashore length of 26 km. It is the only access of Jordan to the open sea where most import and export activities of the country take place, such as oil, and exports such as phosphate rocks, potash, fertilizers, cement, bromine, magnesium, and other industrial products. The resulting liquid and solid wastes of household and industrial activities are still being disposed of after modest treatment porting. In addition, the shore of Aqaba is a touristic attraction for inland and outland tourism.

The climate in the area is hyper hyper-arid with a a long long-term average precipitation of 30 mm/yr with daily maximum temperatures rising in summer to more than 40^0C degrees (June to August), that which can reach up to 48^0C. Potential evaporation rates reach around 4000 to 4400 mm/yr. (DOM open files).

Plants growing on salty grounds display distinct characteristics regarding their systematic composition in the different climatic zones in Jordan.

Thus a quite specific flora composes the community that had grown next to the Gulf of Aqaba on the uppermost sandy beach that had been separated from the lower beach by an earth wall during construction works (Fig.2). This barrier prevented the flood water of the rare rains in the area falling during the end of March 2014 to simply flow off into the sea and rather to collect in a shallow pond. Rain The rain had fallen one week before our survey, after that the weather became dry and sunny as it is usual for that area. The collected had diluted the salt crust of the soil that had accumulated here during the extended dry period before the raining. The water seeping into the ground moistened it before evaporating, and a dense plant cover grew only in those parts of the small pond that held water and remained moist for a sufficient time to allow the plants to grow. In the last puddles crust of salt formed when the water evaporated.

The plants studied on the 23rd of March 2014 thus reached their size and usually also the flowering and fruiting stage within a time of about 10 days.

Figure 2. Growth zone near the beach of the southern part of the Gulf of Aqaba. The depression near the dam held water which that became so salty that plants could not grow in it.

Albert et al (2004) reviewing data provided by Zohary (1973) suggested that the shore area may have a flora influenced by salinity. *Atriplex halimus, Sueada aegyptiaca, Suaeda monoica, Tamarix negevensis, Tamarix tetragyna,* but also *Typha angustata* were recorded and sandy soils should have *Salsola baryosma, Traganum nudatum, Alhagi maurorum* and *C. cretica* growing on them. But based on field observations, the flora encountered here has a quite different composition. *Tamarix* was not noted at all and probably had no time to grow, and *Traganum* may have been among the young plants encountered by us.

In the area a community of quite a different composition was encountered, *Atriplex holocarpa* with globular green fruits in its upper part is observed. Within the Chenopodiaceae a tendency of efficient uptake of ions and storing them in distinct parts of the plant has developed. High salt concentrations in some cells thus decrease the salt present in the other cells.

A. halimus saltbush is common in Jordanian desert (Albert et al., 2004). But for this first time documented, *A. holocarpa* with greenish globular fruits live in the salty ground of Aqaba (Fig.3A).

While most of the plants encountered us were in full flower, *Opophytum forsskalii* was present only as juvenile and thus had to continue to grow to flower and form seeds, the others had reached maturity and were in the seed production and ripening stage.

Also, the white flowering *Anthemis haussknechtii* with hairy leaves was commonly encountered, but less than *A. holocarpa*. Al- Eisawi (1998, fig. 130) noted that this plant grows in the desert, and we found it also in the dry bed of Wadi Yutum which drains Mudawwara area into the Red Sea at Aqaba. According to Feinbrun-Dothan (1978), its growing environment is the mountain area above 800 m. But *A. haussknechtii* is found on the salty moist ground in Aqaba.

The characteristic *Aaronsohnia factorovskii* with yellow composite flowers with only disc floret and no ray floret is relatively common. Both composite flowers also grow in the desert e.g.: Wadi Yutum, and were observed here in flower on the same day when they were observed in Aqaba.

O. forsskalii can be found commonly in the company of, *Sclerocephalus arabicus* and *Aizoon canariense* (Fig.3B). Of these, *Sclerocephalus* also grows in the not salty desert Wadi Yutum. Especially *A. canariense* is characteristic of the salty soil on the beach of the Gulf of Aqaba in Jordan. A similar environment on the salty flats of the brackish Karama Reservoir in the Jordan Valley has a similar *Mesembryanthemum*. *Aizoon* prefers to grow in moist and high salinity sandy ground.

The thistle *Centaurea sinaica* can be recognized by its spiny involucres and still without flowers, occurring rarely, while other thistles are missing. *C. sinaica* as noted by Al-Eisawi (1998) has the stem right above the basal rosette branching as is the case in the juvenile plant we found growing on the salty ground near the beach of the Gulf of Aqaba. Otherwise, the plant has been described to grow on cultivated land and waste fields in the highlands of Jordan.

Along the ridge of sand separating the salty area that held the shallow pond during the rain flood, the small bush *Halocnemum strobilaceum* has grown and here also *Amaranthus albus* was found. *Anabasis setifera* forms larger bushes, and *Chenopodium ambrosioides* is one of the larger plants here with large stands of flowers of rather indistinct small size. This bush-like growth also follows former water canals.

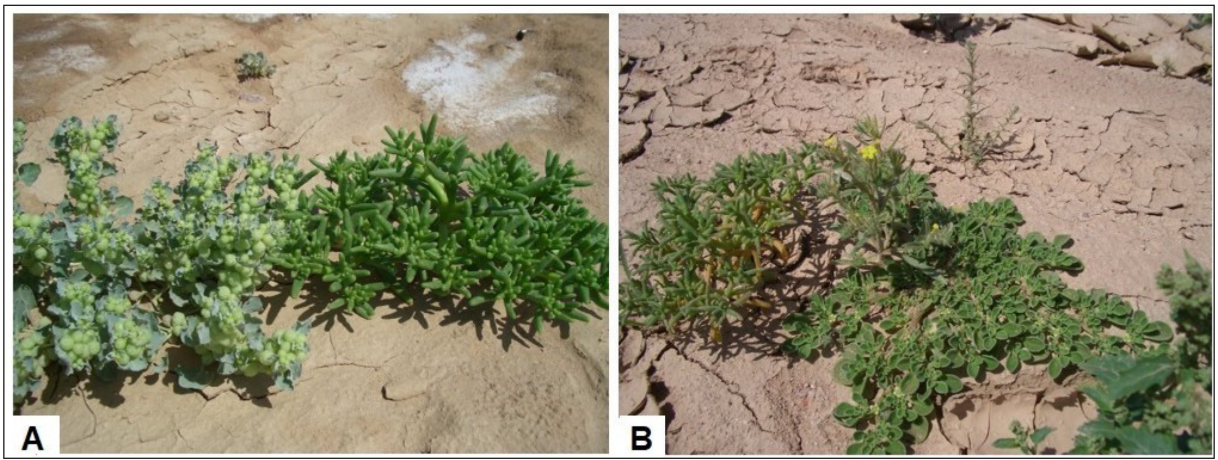

Figure 3. A. Characteristic plant of the population A. holocarpa with O. forsskalii and with salt in a dried-out puddle. B. A. canariense together with O. forsskalii, Chenopodium species, and Arnebia hispidissima.

Among the Brassicaceae four species are present, the most characteristic is the almost *Zilla spinosa* forming thorny bushes with bluish flowers, *Eruca sativa* with larger veined flowers and its relatives *S. septulatum* with yellow flower and *D. harra* of the same character as flowering also in the dry bed of Wadi Yutum. *E. sativa* can not only tolerate relatively dry ground as on the slopes of the Zor in the Jordan Valley but can also grow on the salty ground, as here near the beach at the Gulf of Aqaba. *D. harra*, and *S. septulatum* grow in similar environments in the Jordan Valley probably here also sometimes with salinity higher than usual due to the high evaporation rates. *Z. spinosa* likes hot moist places, also when they are not salty. But they also grow on the dry ground of Wadi Yutum, following the moisture here after floods.

The small clover *Tetraena simplex* with small yellow flowers grows flat on the soil and is found in other salty places in Jordan as well (Al Khateeb et al., 2010; Muhaidat et al., 2018). The other member of the Leguminosae family *Astragalus crenatus* grows elsewhere close to the ground but has purple flowers; both tolerate salty ground but are also found elsewhere.

O. forsskalii was present during March with its characteristic thick leaves but without flowers. Characteristic also is the yellow *Arnebia hispidissima*, bushes of *Ochradenus baccatus* forming plants with a woody base and many green branches with small leaves and yellow small flowers. But all these plants grow also around puddles after strong rains in the Eastern desert in Jordan. *Trichodesma Africana* from the Boranginacea family and Sclerocephalus from the Caryophyllacea family grow here as they do on the sand in Wadi Yutum but here on the Gulf next to flowering *A. canariense* and juvenile *O. forsskalii*, both are typical halophytes.

The yellow composite *Picris cyanocarpa* is present here as well as in desert places near dried-out puddles. Its fruits are attached to a pappus and fly off with the wind. The plant grows in the desert and it grows also on the salty ground near Aqaba beach together with *A. canariense* (Fig.4A).

Among the monocotyledons only the lily *Asphodelus tenuifolius* occurs rarely while it commonly occurs on dry stony ground in the Jordan Valley. It is an annual or short-lived perennial herb growing with a hollow stem up to 70 centimeters tall. The root system has a series of tuber-like parts at the base of the stem (Feinbrun-Dothan, 1986; Al-Eisawi, 1998). The inflorescence consists of widely-spaced flowers which are generally white or very pale pink with a neat central longitudinal stripe of brown to reddish-purple (Al-Eisawi, 1998). This is the smaller of the two species of the genus from Jordan and was found in a rather dry environment as well as near River Zarqa spring and also among the plants in Aqaba. Thus it tolerates salty ground but is usually found outside of that also in quite dry areas (Alhejoj et al., 2014). Only three glasses were noted in this small specialized flora. Of these *Polypogon monspeliensis* has a characteristic fluorescence and *Hordeum marinum* is common. *Dichanthium annulatum* grows at irrigated places and ditches as well as banks of water reservoirs in the Jordan Valley. *D. annulatum* also grows along the Gulf of Aqaba even in the salty environment (Fig.4B).

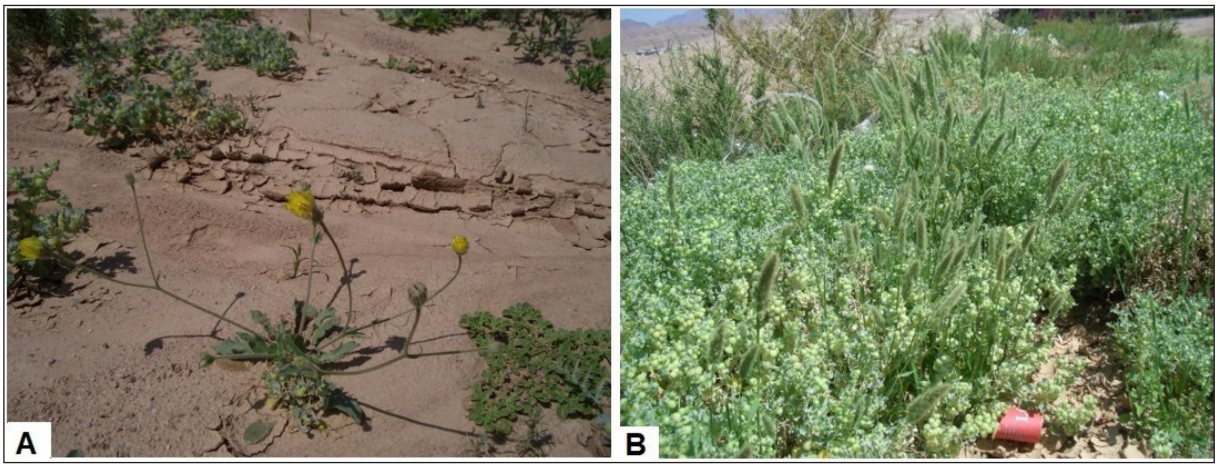

Figure 4. A. *Picris cyanocarpa* next to *A. canariense*. B. *P. monspeliensis, H. marinum, and D. annulatum* from the salty ground at Aqaba growing jointly with *A. holocarpa* and in the same environment as *Z. Spinosa* and *A. setifera* growths.

3.2 Taba Sabkha

Wetland flora includes all different types of vegetation that live in water or sediments which become periodically deficient in oxygen as a result of excessive water content (Cowardin et al., 1979).

The Sabkha of Taba is located in the southern Wadi Araba near Gharandal, about 32 km north of the Gulf of Aqaba. It occupies an area of about 55 km^2 in southern Wadi Araba. The area is characterized by its hyper-arid climate with an average annual rainfall of 30 mm. The daily highest temperature can reach 48◦C. The average rainfall over the eastern mountains is up to 250 mm/year; flood water flows westwards via numerous wadis to Wadi Araba including the Sabkha of Taba.

In Wadi Araba, the Sabkha of Taba is permanently saturated with water with saline, hydric, and peat soils. Hydric soil, resulting in anaerobic (low oxygen) conditions. Plants with aerenchyma tissues often dominate such environments which allow atmospheric oxygen to be transported to their roots (Justin and Armstrong, 1987; Keddy, 2010). Oxygen concentration in wetlands depends on several factors, including soil temperature, chemical reduced elements, and organic matter content (Gambrell and Patrick, 1978). Additionally, Taba soil is covered by salt crusts, which result from the high evapotranspiration rate which exceeds the yearly precipitation by more than 100 fold. The salty surface crusts consist of evaporate minerals (gypsum, and halite) formed due to salt accumulation of evaporation from low salinity shallow groundwater entering the Sabkha from the fan seeping westwards through the Sabkha and from low precipitant with high evaporation.

Taba wetland represents an environment in which evaporation is much higher than the water that is added to the shallow depression during the rare winter floods and that of the springs which issue onto the flat from its eastern margin, that water seems to originate from sporadic recharge along the mountain range that separates Wadi Araba and Taba area from the Disi flats. Here the possible connection between Disi and Wadi al Hiswa lay in the area northwest of the town of Quweira to Wadi Araba near Taba (Bandel and Salameh, 2013). The rising mountain chain that accompanies the eastern margin of southern Wadi Araba seems to cut off that connection. But there are still ways for the groundwater to reach the Wadi Araba. The springs at the margin of the Sabkha have, most probably, their origin in Disi.

Taba in Wadi Araba is a typical Sabhka having a characteristic succession of its vegetation as reported by Albert et al. (2004) and our observations confirm. The Taba swamp dry lake can be considered as one of the historic outlets of the Disi groundwater basin before its capture by headword erosion of Wadi Yutum into Aqaba (Bandel and Salameh, 2013).

Taba plant species consist of, *C. cretica,* an alkali weed that grows at the margin of the dry oases near the road. *C. cretica* of the Convolvulaceae has been indicated by Zohary

(1973) to live in a dry salty environment, as was also stated by Feinbrun-Dothan (1978, pl. 46) and repeated by Al-Eisawi (1998, fig.233). *C. cretica* was encountered to also grow and flower in the lower Wadi Shita, north northeast of the Dead Sea on the salt-free ground, whereas, near Taba, the ground contains some salt. *C. cretica* with rose-colored flowers were also found along the dry margin of Mujib River together with *A. halimus, Suaeda aegyptiaca, Alhagi maurorum,* and the grasses *Aeluropus littoralis, Desmostachya bipinnata.* Among the halophytes recorded from the shore of the Red Sea of Saudi Arabia *C. cretica* has also usually been determined.

Next to the Cressa belt, at the base of fans coming from the mountains, bushes of Acacia grow, and on the other side of this grow zone towards the Sabkha *P. dactylifera* is the dominant tree (Figure 5. A). Albert et al (2004) noticed that *Acacia* (near the salty ground) sometimes stores salt in their leaves. When the sun is intense, small leaves and folding of leaves help Acacia against becoming too hot as does a thick cover of hairs that reflects the sunlight. Acacia is present on dry slopes in the Araba and it also occurs near streams in the hot Jordan Valley, here often jointly with the similar *Prosopis*. When flowering, many insects and also a bird with narrow crooked beak come to harvest nectar. *A. tortilis* grows in extremely arid conditions up to 20 m in height. The plant tolerates high alkalinity, drought, high temperatures, sandy and stony soils, and sandblasting. Fruits are often eaten and excreted seeds have a better chance to germinate than such fallen out of the dry fruit. When having passed the digestive system they are within the excrements and thus have a better start for growth than the single seeds, which are often collected by insects for food.

Next to the dried salt flat with its mud cracked cover and thin salt crusts in former puddles a rim of vegetation consisting of palm trees, and *Tamarix* bushes along with *Phragmites* reeds form together dense thickets at the margin of the Sabkha. A zone follows with the loose growths of *J. rigidus, T. nilotica, T. tretragyna,* and quite characteristically *N. retusa* follows (Figure 5. B). *N. retusa* also forms small thicket islands further towards the mud-cracked flats of the Sabkha with no flora around them and no plants on the mud flat due to higher salinity and precipitation of gypsum-halite crust (Figure 6. A, B).

P. dactylifera, date palm, occurs commonly in Jordan, in the wild, and as a fruit tree. When fully grown it ranges from 5 to 15 m forming a tree with a single woody stem. The leaves are compound, pinnate, spiny and about 3 m long. Their flowers have a compound and spiked arrangements and usually appear during the springtime (Zohary, 1973; Al-Eisawi, 1998). The date palm grows near all the springs on the slopes of the Dead Sea. The trunk is surrounded from the ground upward, by a spiral pattern of leaf bases and in not attended trees the dry leaves remain attached forming a protective veneer.

P. dactylifera is an important culture plant in the Sahara-Arabian region, resembling in its importance the olive in the Mediterranean area (Zohary and Hopf, 1994). *Phoenix* tolerates alkaline conditions and also grows with moderately salty water, but high salt content has a negative effect and lowers the quality of the fruit (Morton, 1987). Kharusi et al (2017) stated that soil tolerances of up to 2400 µS/m. Brackish and freshwater springs along the steep slopes of the Dead Sea are usually quite well recognized by the date palm which is usually accompanied by *Phragmites australis*, as is also the case at Taba.

N. retusa is a salt-tolerant shrub or bush that grows to 2.5 m, although it is usually less than 1m in height. It has tiny, white to green, fragrant flowers, and small edible red fruit. *N. retusa* was recognized by Zohary (1972, pl. 371) as living in the saline desert and recognized by us in Taba salt pen-lake. It has woody stems with many hanging branches which carry succulent leaves and sharp brownish horns. The leaves are simple, triangular, and alternate with one leaf at each node. The small whitish flowers bear five petals and 15 stamens and the plants flower in March and April. *N. retusa* inhabits salty and dry environments and can live in poor soil quality. It also grows on sand and stony soil near water which at Wadi Atun has a salinity of more than 2000 µS/cm.

J. rigidus is the same reed as that growing near the western pool at Azraq with less salinity in the ground. Its inflorescences are about 60 cm high and its leaves have very acute apices. It grows in salt marshes and saltwater pools near oases. It is also found near springs in Jordan often together with *Juncus acutus*. Feinbrun Dothan (1986, pl.186, 187) noticed the mix of both species, especially in saline soils.

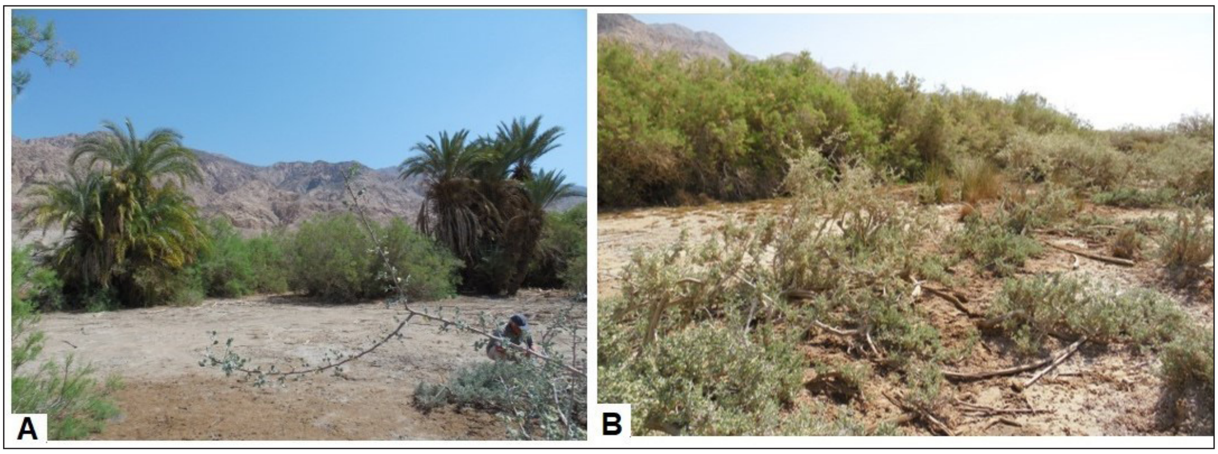

Figure 5. A. The Sabkha of Taba with *Phoenix* tree on the salty soil (2014) B. *N. retusa* community with *Tamarix* bushes in March 2014.

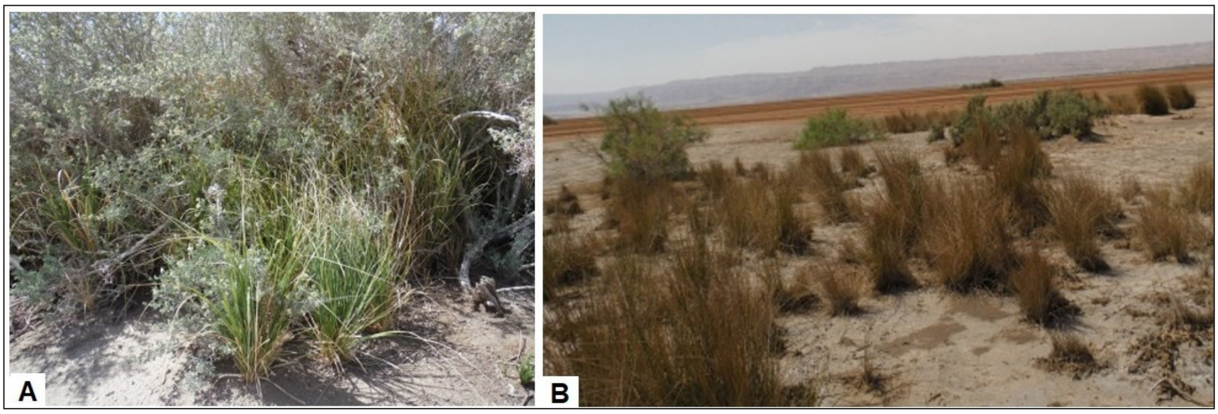

Figure 6. A. *N. retusa* with *Juncus arabicus*. B. *N. retusa and J. rigidus* together with *Tamarix* trees in a mud salt flat, no plants are found in the central part of Taba.

4. Results

The studied plants have been found to tolerate salty ground on both the shore of the Gulf of Aqaba and the Taba wetland, but they are quite distinct from each other. On the shore of the Gulf of Aqaba, plants grew after heavy rain on the salty ground on a slightly inclined field next to the beach, separated from the Sea by a small earthen wall. The most characteristic plants in Aqaba are *Atriplex holocarpa, A. haussknechtii, and A. factorovskii* which are relatively common in the Jordan desert. The thick green fleshy leaves of *O. forsskalii* can be found commonly with *S. arabicus* and *A. canariense*. Of these, *Sclerocephalus* also grows in the not salty desert of Wadi Yutum. Especially *A. canariense* is characteristic to the salty soil on the beach of the Gulf of Aqaba, while the similar environment of the salty flats of the brackish Karama reservoir has similar Mesembryanthemum. *A. canariense* prefers to grow on soils in places of puddles becoming increasingly saltier due to evaporation, thus a salt crust covers the sandy bottom. Along the ridge of sand separating the salty area from the shallow pond, the small bush *H. strobilaceum* and *A. Albus* have grown. *A. setifera* forms larger bushes, and *C. ambrosioides* is one of the larger plants here with large stands of flowers of rather indistinct small size. Among Brassicaceae four species are present, *Z. spinosa*, *E. sativa*, *S. septulatum,* and *D. harra*. The small *T. simplex* and *A. crenatus* grow commonly on the salty ground. *O. forsskaolii* is present with *A. hispidissima*, bushes of *O. baccatus*. *T. Africana* of the Boraginaceae and Sclerocephalus of the Caryophyllacea grow here as they do on the sand in Wadi Yutum but here on the Gulf next to flowering *A. canariense* and juvenile *O. forsskaolii*, both are typical halophytes.

Many plants in dry areas have been found in both saline and non-saline environments such as *S. arabicus, Z. Spinosa, D. harra, Trigonella stellata, A. fistulosus, T. Africana, A. crenatus*, *P. cyanocarpa*, *E. Sativa* and thorny plant of *C. sinaica* (Table.1).

Taba wetland has a characteristic set of plant species, which provide the best indicators of the very drought-resistant species and saline-alkali environmental conditions. These include the flora *N. retusa, J. rigidus, T. nilotica, T. tretragyna, Phragmites australis*, and *C. cretica*. They are of high drought tolerance and can grow without shallow soil water due to the depth of their roots. In the Sabkha of Taba salt-tolerant plants grow on muddy soil with salt crust as is also found in the surrounding Karama Reservoir lake that contains salty water. The formation of the salt crust led to reducing evaporation rate (Xinhu and Fengzhi, 2019).

Table 1. Summary of plant species indicating salinity in the study area.

Species	Family	Site	Environment	Level of Salinization	Habits
Atriplex holocarpa	Amaranthaceae	Aqaba beach, Dead sea valley	Coastal sandy or gravelly, dry, salt-crusted soils	High	Annual herb
Anabasis setifera	Amaranthaceae	Aqaba beach	Coastal sandy, mostly dry	High	Perennial shrub
Halocnemum strobilaceum	Amaranthaceae	Aqaba beach	Coastal sandy soils	High	Perennial shrub
Amaranthus albus	Amaranthaceae	Aqaba beach	coastal sandy soils	High	Annual herb
Chenopodium ambrosioides	Chenopodiaceae	Aqaba beach	Sandy, salty soils	High	Annual herb
Chenopodium murale	Chenopodiaceae	Aqaba beach	Coastal sandy soils	High	Annual herb
Tetraena simplex	Zygophyllaceae	Aqaba beach	Coastal sandy soils	High	Annual to perennial herb
Zilla Spinosa,	Brassicaceae	Aqaba beach, Wadi Yutum	Sand or gravelly soil	Low to high	Annual herb
Eruca sativa	Brassicaceae	Aqaba beach, Wadi Yutum, and Jordan Valley	Coastal dry sandy or gravelly soils	Low to high	Annual herb

Species	Family	Site	Environment	Level of Salinization	Habits
Sisymbrium septulatum	Brassicaceae	Aqaba beach	Coastal sandy soils	Low -High	Annual herb
Diplotaxis harra	Brassicaceae	Aqaba beach, Wadi Yutum	Sandy, gravelly soil	Low to high	Annual herb
Anthemis haussknechtii	Asteraceae	Aqaba beach, Wadi Yutum	Sandy, gravelly soil	Low to high	Annual herb
Aaronsohnia factorovskii	Asteraceae	Aqaba beach, Wadi Yutum	Coast, desert sandy, gravelly soil	Low to high	Annual herb
Centaurea sinaica	Asteraceae	Aqaba beach	Coastal sandy wet soils	Low to high	Annual herb
Picris cyanocarpa	Asteraceae	Aqaba beach	Coastal sandy soils		Annual herb
Opophytum forsskalii	Aizoaceae	Aqaba beach	Coastal salt–crusted sandy soils	Very high	Perennial herb
Aizoon canariense	Aizoaceae	Aqaba beach, Karama	Coastal salt – crusted sandy, rocky soils	Very high	Annual herb
Ochradenus baccatus	Resedaceae	Aqaba beach	Sandy, rocky and dry soils	Low - moderate	Perennial shrub
Astragalus crenatus	Fabaceae (Leguminosae)	Aqaba beach	Costal sandy soil, freshwater wetlands	Low - High	Annual herb
Trigonella stellata	Fabaceae (Leguminosae)	Aqaba beach	Coastal sandy soil and desert	Low - High	Annual herb
Trichodesma Africana	Boraginaceae	Aqaba beach	Coastal sandy soils	Low - High	
Arnebia hispidissima	Boraginaceae	Aqaba beach	Coastal sandy soils	Low- Moderate	Annual herb
Asphodelus tenuifolius	Asphodelaceae	Aqaba beach	Dry, sandy, or rocky grounds	Low - High	Annual herb
Sclerocephalus arabicus	Caryophyllaceae	Aqaba beach, Wadi Yutum	Dry sandy, gravelly soil	Low - High	Annual herb
Nitraria retusa	Nitrariaceae	Taba Sabkha, Dead Sea area (Wadi Atun)	Sandy or rocky with salt crusted and poor soil quality.	Low- High	Perennial shrub
Tamarix nilotica,	Tamaricaceae	Taba Sabkha	Dry, sandy, or rocky grounds	Low - High	Tree
Tamarix tretragyna	Tamaricaceae	Taba Sabkha	Sandy or gravelly and dry soil	Low - High	Tree
Cressa cretica	Convolvulaceae	Taba Sabkha, Mujib	Dry sandy and rocky salty alkaline soil	High	Annual herb
Acacia tortilis	Fabaceae	Taba Sabkha	margins of sabkha Dry, alkaline, sandy, stony soils	Low - Moderate	Tree
Phoenix dactylifera	Arecaceae	Taba Sabkha	margins of Sabkha with alkaline, sandy, and stony soils	Low- Moderate	Tree
Juncus rigidus	Juncaceae	Taba Sabkha, Azraq	Sandy soil near oases and around water pools	Low - High	Perennial herb
Polypogon monspeliensis	Poaceae	Aqaba beach	Coastal wet sandy soils	Low - High	Annual beard-grass
Hordeum marinum	Poaceae	Aqaba beach	Coastal wet sandy soils	Low -High	Annual grass
Dichanthium annulatum	Poaceae	Aqaba beach, Jordan Valley	Coastal wet sandy soils	Low - High	Perennial grass
Phragmites australis	Poaceae	Taba Sabkha	Wet, alkaline, sandy, stony soils	Low - High	Annual reed

5. Conclusions

Plant occurrence and distribution are mainly affected by soil and water types and composition, and by the prevailing climatic conditions such as temperature and rainfall. Climate change is affecting the habitats of several plant species because they are sensitive to salinity and dryness, immobile, and adapted to their specific environment so that they respond to climate change within short periods. A wide range of salinity stress management, monitoring, and mitigation strategies are required to deal with such impacts. Remote sensing and GIS techniques can be used as useful tools for developing soil salinity prediction models in areas experiencing soil salinization (Alqasemi et al., 2021). In addition, Shrivastava and Kumar (2015) study support the use of microorganisms as effective methods for soil salinity alleviation by developing stress-tolerant crop varieties through genetic engineering and plant breeding.

In South Jordan arid to hyper-arid climate with very low rainfall, extremely high evaporation rates, and saline water and soil prevail. Many wild plants that can live in non-saline, moderate, or high saline environments cannot survive such an extremely saline environment. For example, in the Karama area, *Tamarix* bushes grew on the shores of the dam lake in a moderate saline environment but, they dried out because of increasing salinity levels and drought (Fig. 7).

On the other hand, plant species are threatened by human development activities, especially along the coastal area of Aqaba, increasing pollution, erosion, and sedimentation. Even the study site near the shore has been destroyed by the building of new tourist hotels. All of these factors can lead to biodiversity loss of ecosystems.

Both the Wadi Araba and Aqaba areas of Jordan have been declared developmental areas and the government of Jordan allocated millions of dollars for that development. Nonetheless, it is feared that not enough consideration is being given to the potential negative impacts of such development on the environmental conditions there including the biodiversity and especially native plant species.

This study documents the plants tolerant to extremely saline soils and water which have, until now, not been recorded for the studied locations. An example of what can happen is the disappearance of plants in the central part of the Sabkha in Taba due to increasing salinity to an extent, that even salt-tolerant plant species cannot survive the changing environmental conditions.

Figure 7. Dead Tamarix bushes on the dry salty cracked ground on the shore of Karama dam lake.

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