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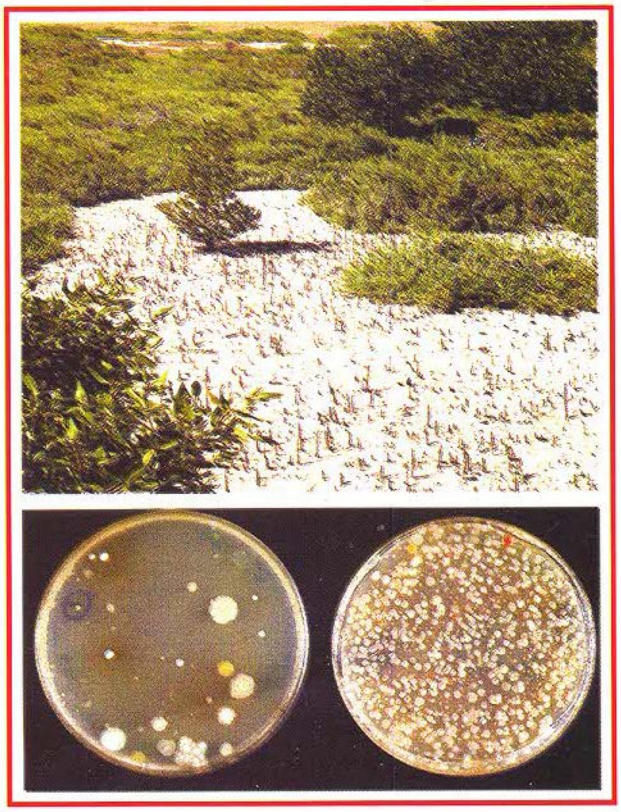
Ecology of Halophytes and their Bacterial Inhabitants in the Coastal Salt Marsh of Al-Dhakhira, Qatar



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Contents

Abstract

The halophytic vegetation and the soil characteristics in the coastal salt marsh of Al-Dhakhira region were studied during the dry season. Moreover, the bacteria colonizing the non-rhizosphere, the rhizosphere and phyllosphere of halophytes were isolated, purified and their morphological and biochemical characteristics were investigated. The chemical composition of the aqueous washings of the green and senescent shoot parts of succulents and salt-excreting halophytes were carried out in order to identify the possible relationships between the nature of washings and the patterns of bacterial colonization on the phyllosphere.

Cover percentage values for plant species were estimated using the line-intercept method. Thirteen perennial species representing four growth forms were recorded. The vegetation of the study area had a characteristic zonation. Each zone has a dominant species that gives the vegetation its characteristic physiognomy. The five main vegetation zones included: *Avicennia marina* zone, *Arthrocnemum machrostachyum* zone, *Halocnemum strobilaceum* zone, mixed zone and *Zygophyllum qatarense* zone. The coastal and shoreline communities appeared to be subjected to salt stress and inundation. The habitats of the upper marsh that comprised *H. strobilaceum*, mixed zone and *Z. qatarense* zone inland to the coastal zones were subjected to dry conditions and their contents of soluble salts, total carbonate, organic carbon and silt were lower than those in the costal zones.

The total bacterial count in the rhizosphere was higher than in the non-rhizosphere soil. Moreover, the bacterial counts in the soil supporting the species of the coastal zone were higher than those in the soil of the inland zones. Gram positive cocci predominated in isolations

from the rhizosphere and the non-rhizosphere soil. Isolates with a white colony colour predominated in the rhizosphere.

The aqueous washings of the phyllosphere were analyzed for the chief inorganic and organic solutes. The washings from the green and senescing parts of succulents showed lower contents of sodium, chloride, potassium and higher contents of calcium and magnesium than the washings of excretors. The high contents of the mineral ions in the aqueous washings of excretors were accompanied by low bacterial colonization on the phyllosphere. Irrespective of the salt resistance mechanism (succulence and salt excretion by salt glands), the counts of bacteria on the green parts were higher than on the senescing parts. Moreover, the phyllospheres of the green and senescing parts were characterized by the predominance of Gram-positive bacilli and by the low percentages of isolates producing coloured colonies.

The biochemical activities of the bacterial isolates of each halophytic species were apparent by testing their ability to utilize their substrates. The isolates of the soil, the rhizosphere and the phyllosphere were able to utilize at least 50% of the test substrates. The data indicate that the soil and the phyllospheres of the halophytic species support bacteria, which have diverse biochemical activities enabling them to deal with various nutrients of the salt marsh.

1. Introduction

Halophytes are plants that survive high concentrations of electrolytes in their environment. Halophytes occupy environments ranging from the marine through predominantly wet marine marshes (including tropical mangrove swamps) to arid salt deserts (Adam, 1990; Batanouny, 1994).

There are perhaps as many as 6000 species of terrestrial and tidal halophytes in the world, i.e. some 2% of the flowering plants (Batanouny 1994). Salt-tolerant bacteria, yeasts, fungi, algae and protozoa can grow in habitats containing high concentrations of salts. The natural environments for salt-tolerant microbes may be similar to the habitats supporting the halophytic angiosperms or, may be more extreme natural environments such as inland lakes, which are found in sub-tropical or tropical climatic areas (Zahran, 1999).

There are various means by which a plant can regulate (or avoid) salinity. Among the mechanisms that occur in the aerial plant surface, one can mention the salt excretion by salt glands and salt bladders, succulence of leaf and/or stem and shedding of salt-loaded plant parts. Salt regulation in mangroves (such as *Avicennia marina*) is by avoidance of intake of salt or what is known as salt filtration through salt-transport prevention. This is achieved through salt exclusion from the roots to the rhizosphere (Lambers *et al.*, 1998; Hogarth, 1999).

The chemical analysis of the material excreted by the epidermal glands of halophytes indicates the presence of mineral elements and some organic compounds (Godfrey, 1976; Fahmy, 1991; Batanouny *et al.*, 1992). These are not only attributed to the epidermal glands, but also are due to deposits from the air such as mineral particles, pollen grains and rain water. The greater proportion, however, has its origin within the plant and passes through the outer tissues into water that is in contact with the surface layers of the plant organs (leaves-stems or roots). This process is usually referred to as "leaching" (Godfrey, 1976).

The aerial surfaces of higher plants growing under natural conditions are usually covered with large and varied populations of microorganisms (Mercier and Lindow, 2000; Lindow and Brandl, 2003).

Few of these organisms are able to grow extensively on the surfaces of healthy plants, others are apparently only able to grow beyond the limitations imposed by their endogenous nutrients when the tissues on which they occur begin to senesce or are physically or physiologically damaged.

Previous studies on the desert plants of Egypt indicated that the fungal species inhabiting the surface of senescent leaves of the succulent halophyte *Zygophyllum album* L. appeared to be adapted to stressful conditions of their microhabitats, namely high convective heat, dry conditions and high salt content of their leachates (Fahmy and Ouf, 1999).

It is apparent that the presence of salt crust excreted by the epidermal salt glands and/or the occurrence of leachates on the plant surfaces may affect the colonization and growth of microorganisms by the virtue of the nutrients they contain (Ouf, 1993). Likewise, the presence of root exudates in the rhizosphere may encourage or inhibit the soil micro-organisms (Quesada *et al.*, 1982). At the same time, the tendency of the inhabitant micro-organisms to survive under the influence of the micro-environment of the plant surface depends on their ability to tolerate desiccation, sunlight and the high exudation of organic and inorganic solutes, which are formed due to secretion and leaching processes.

The objectives of the present study included

1- Screening the halophytic flowering plants in the coastal salt marsh of Al-Dhakhira region.

2- Identification of the halophytic vegetation and its relationship to soil conditions.

3- Analyzing the inorganic and organic composition of the salt crust of the salt-excreting halophytes and in the aqueous washings of the non-excreting ones (succulents and non-succulents). Chemical analyses included the salt crusts and the washings of the green as well as the senescent plant parts.

5- Isolation and biochemical characterization of bacteria and actinomycetes from the plant surfaces (the green and the senescent parts), the rhizosphere and the non-rhizosphere soils supporting the halophytic species.

6- The significance of the different biochemical activities of the bacterial isolates in their adaptation to salinity stress of the soil as well as of the plant surfaces of succulents and salt excreting halophytes.

2. Materials and Methods

2.1 Plant measurements and soil analysis

2.1.1 The study area

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 km^2. Qatar lies within the vast desert belt extending from North Africa to central Asia. Rainfall is scant (54.6 to 76.1 mm yr^{-1}), erratic and variable in time and space. The northern part of Qatar receives 30-60% more rainfall than the southern part. More rainfall is expected between December and March. Qatar has a hot desert climate, with mild winters and very hot summers (Batanouny, 1981).

Qatar has a number of islands mostly to the east and west of the country, surrounded on three sides by the deep waters of the Arabian Gulf and connected to the south by Saudi Arabia (Abulfatih *et al.*, 1999). Land elevation ranges between -6 to +103 m from gulf level. Most of the land in Qatar is only few meters above sea level. The landscape is generally flat to undulating. The high land-form types of the rocky and conglomerate "Hamada" occupy the major areas of the peninsula, whereas the maritime salt marshes occupy a narrow fringe bordering on these raised areas (Abdel-Razik and Ismail, 1990).

The study area is a littoral salt marsh at Al-Dakhira region on the north-eastern coast of the country (25° 45′ N, 51° 30′ E). This study was performed during three months (September, October and November) within the dry rainless period of 2004.

2.1.2 Vegetation

Line transects were surveyed starting at the Gulf frontier and ending at about 1.0 km inland at the uppermost part of the salt marsh. The recorded species were identified according to Batanouny (1981). The life form, the palatability and the photosynthetic pathway type of each species was obtained from Batanouny (1994).

Absolute cover percentages of plant species were estimated using the line-intercept method (Mueller-Dombois and Ellenberg, 1974). Twenty-seven locations (intervals) were sampled along each line transect. Each interval was 30 meters length. The total length of each line transect was 810 meters. The data were the mean of three transects in the study area. Zones of vegetation (along the transects) were named after the dominant species.

2.1.3 Soil analysis

Three soil samples were collected from the root zone (at about 20-cmdepth) supporting each plant species. Soil water content was determined after oven drying (105°C) to constant weight. Soil mechanical analysis was determined by the hydrometer method (Cox, 1996). The total carbonates and organic carbon were determined in the oven dry soil according to the methods described by Jackson (1958). For the determination of the redox potential, a soil-water (deionized) extract (1:1) was prepared and allowed to stand for few minutes before the mV values were recorded by a portable pH/mV meter (Model Jenway 3305). A soil-water (deionized) extract (1:2) was prepared for the determination of pH, electrical conductivity and chloride (Jackson, 1958). The contents of sodium, potassium, calcium and magnesium in the soil-water extract were determined by the inductively coupled plasma spectrometer (Model ICP-MS Series 7500) at the Laboratory of Chemical Analysis, The Unit of Central Laboratories, Qatar University.

2.1.4 Water content of the plant parts

The green as well as the senescent parts of plants were collected during midday from five different individuals of each species. The plant parts were weighed on a torsion balance in the field and then kept in stoppered sample tubes, stored in an ice box and transferred to the laboratory. The material was dried at 70°C for 48 hours and the dry weights and water contents were determined.

2.1.5 Chemical analysis of the aqueous washings of the green and senescent parts

The green and senescent parts of each species were collected during midday, stored in an ice box and transferred to the laboratory. A known weight of each plant part was washed for 15 minutes in deionized water and the solution was collected in vials. The resulting washings were filtered through 0.45-µm Millipore filter and the filtrate was adjusted to 50 ml with deionized water. Chloride in the washings was determined according to Jackson (1958). The contents of sodium, potassium, calcium and magnesium were determined by the inductively coupled plasma spectrometer (ICP-MS Series 7500) at the Laboratory of Chemical Analysis, The Unit of Central Laboratories, Qatar University. The total soluble sugars were determined by anthrone according to Allen *et al.* (1974) and expressed as glucose. The total amino acids were determined according to Russel (1944) and expressed as glycine. All the results of chemical analyses were expressed in mg 100 g^{-1} dry weight.

2.2 Bacteriological measurements

2.2.1 Microbial counts

Counts of bacteria were determined using the standard methods of serial dilution and plate count techniques for rhizospheric soil (Barakate *et al.* 2002; Bagwell *et al.*, 1998). Soil samples were obtained from the rhizosphere and non-rhizosphere regions. Each soil sample (1.0 g) was suspended axenically in 9.0ml of sterile distilled water, shaken on a vortex for 1 minute and allowed to stand for few minutes, before serial dilutions (up to 10^{-6}) were prepared. Aliquots of 0.1 ml of each dilution were spread over the surface of Bacto Marine Agar 2216 (Becton, USA) for bacterial counts. All plates were incubated at 37°C before colonies were counted after 48-72 h for bacteria and 7 days for streptomycetes isolates.

2.2.2 Culturing, isolation and purification

Pure cultures were isolated by streak plating technique and maintained on Bacto Marine Agar during characterization. After purification, cultures were studied under light microscope; after colonies formed they were suspended in liquid broth and stored at 4°C.

2.2.3 Culture characterization

Colonial status of each isolate was assured by microscopic inspection in wet mounts. Gram-staining characteristics and cell morphologies were determined by standard methods (Gerhardt *et al.*, 1981; Hensyl, 1994). Preliminary physiological characterization and grouping of strains were based on results of biochemical characterization similar to those of API 20 E (Biomerieux Vitek, Inc.) with descriptions as follows: URE (urease activity), NO_3R (nitrate reduction), LAC (lactose fermentation), GEL (gelatin liquefaction), CAS (casein), PHE/PA (phenylalanine decarboxylation), IND (indol production) STA (starch hydrolysis) and CAT (Catalase activity).

2.2.4 Microbial content of phyllosphere

Microbial contents of phyllosphere were determined using standard methods of serial dilution and plate count techniques (Hashidoko *et al.* 2002; Yang *et al.*, 2001; Richardson, 1985). Fresh samples (1.0 g) of green or the senescent plant parts (leaves or shoots) were suspended axenically in 9.0 ml of sterile distilled water and washed for 1.0 minute by shaking on a vortex. Samples were then allowed to stand for 30 minutes before serial dilutions (up to 10^{-6}) of each sample were made. A portion of 0.1 ml of each dilution was spread over the surface of nutrient agar and broth agar for bacterial counts. All plates were incubated at 37°C before colonies were counted for bacteria, and after 7 days for streptomycetes. The bacterial isolates that were purified from the cultures of the plant parts were distinguished from other isolates by their phenotypic and physiological characters.

3. Results

3.1 Plant measurements and soil analysis

3.1.1 The halophytic flora and characteristics of species

As in the majority of salt marshes, the flora of the study area was poor in species. The collected species (14) belonged to 7 families of angiosperms (Table 1). Although *Lycium shawii* is not a halophyte or a xerohalophyte, it has been included in the table since it was associated with *Zygophyllum qatarense* at the upper end of the salt marsh (at the margin of the outermost intervals of the line transect).

The collected halophytes can be classified according to the following characteristics:

Table 1. List, abbreviations and some characteristics of the species in the coastal salt marsh at Al Dhakhira area. (Abb.=abbreviations of the Latin names; Life-forms: P=Phanerophyte, CH=Chamaephyte,H= Hemicryptophyte, T= Therophyte; Palatability: Pa=Palatable, NPa= Nonpalatable; Photosynthetic Pathway Type=PPT). Life-forms, palatability and photosynthetic pathway types are obtained from Batanouny 1994).

Species	**Abb.**	**Family**	**Life-form and habit**	**Palatability**	**PPT**
Aeluropus lagopoides (L.) Trin. ex Thwaites	*Al*	Gramineae	H, creeping salt excreting	Pa	C_4
Anabasis setifera Moq.	*As*	Chenopodiaceae	CH, leaf and stem succulent	Pa	C_4
Arthrocnemum macrostachyum (Moric.) K. Koch	*Am*	Chenopodiaceae	CH, stem succulent	NPa	C_3
Avicennia marina (Forssk.) Vierh.	*Av*	Avicenniaceae	P, salt excreting	Pa	C_3
Cressa cretica L.	*Cc*	Convolulaceae	H, salt excreting	NPa	C_3
Halocnemum strobilaceum (Pall.) M. Bieb	*Hs*	Chenopodiaceae	CH, stem succulent	NPa	C_3
Halopeplis perfoliata (Forssk.) Asch.	*Hp*	Chenopodiaceae	CH, H, succulent leaves	NPa	C_3
Limonium axillare (Forssk.) Kuntze.	*La*	Plumbaginaceae	CH, salt excreting	NPa	C_3
Lycium shawii Roem.& Schult.	*Ls*	Solanaceae	P, non-succulent xerophyte	Pa	C_3
Salicornai europaea L.	*Se*	Chenopodiaceae	T, succulent	NPa	C_3
Salsola soda L.	*Ss*	Chenopodiaceae	T, succulent leaves	NPa	C_4
Sporobolus arabicus Boiss.	*Sa*	Gramineae	H, salt excreting	Pa	C_4
Suaeda vermiculata Forssk. Ex J. F. Gmel.	*Sv*	Chenopodiaceae	CH, P, succulent leaves	Pa	C_4
Zygophyllum qatarense Hadidi	*Zq*	Zygophyllaceae	CH, succulent leaves	Occasionally Pa	C_3

A- Adaptability to saline soil

The halophytes are either succulents or recretors. The succulents resist the rising of salt content in their tissues by an increase of their water content to dilute excess salts. The recretors have glandular cells on their aerial parts, capable of excreting (recreting) excess salts.

B- Life-forms

According to Raunkiaer's life-form classification (1934), the halophytes of the study area are grouped under phanerophytes (P) that include trees and shrubs; chamaephytes (CH) that include small shrubs; hemicryptophytes (H) that include perennial herbs with perennating buds just above the soil surface and therophytes (T) which are annual plants that complete their life cycle during the growing season (Table 1).

Information about the palatability was based on Batanouny (1992).
It is clear that out of the 13 species collected there were 6 palatable and 5 were C_4 species. Most of the C_4 species belong to Chenopodiaceae and Gramineae.

3.1.2 Vegetation composition

Species were recorded in the study area during October 2003, which represents the dry rainless period (Table 2). The plant growth was recognized as it is formed characteristic zonation. Each zone has a dominant species that gives the vegetation its characteristic physiognomy. The total intercepts of all species along the 810 m line transect were 181.27 m which were equivalent to a total vegetation cover of 22.4% in the study area.

The different main vegetation zones, defined by the dominant species, are the following:

1. *Avicennia marina* zone

This zone comprised mangrove trees of different heights, adjacent to the intertidal zone of the Gulf coast (Plate 1). The trees were subjected to semidiurnal tidal inundation that sometimes creates swamps divided by intertidal channels. Near the frontier of the Gulf water, *A. marina* trees were inundated by water and usually pure populations occurred (Plate 2) with a relative cover of 14.1% (Table 2, Plate 1). Other trees were usually inundated during the high tide and were associated with *Salsola soda* (relative cover of 0.001%) and *Salicornia europaea* (relative cover of 1.12%). The zone of *Avicennia* extends about 50 meters along the 810 m transect. In the sub- and inter-canopy positions of the trees, numerous respiratory roots (pneumatophores) emerged as dense cylindrical projections through the soil surface (Plates 2 and 3). The pneumatophores were usually exposed to air, at least during the low tide.

2. *Arthrocnemum macrostachyum* zone

This zone extended about 60 m along the 810 m line transect. The plants dominated a strip (Plate 2), which was frequently inundated with seawater (Plate 4) or present as strips which fringed the zone of *A. marina* above the level of the high tide (Platc 5). These conditions characterized the zone as a low salt marsh habitat. The relative cover of *A. macrostachyum* was higher than *A. marina* (Table 2). The associated species were *Salsola soda*, *Salicornia europaea* and *Halocnemum strobilaceum.*

3. *Halocnemum strobilaceum* zone

The plants occupied wider area than those of *A. marina* and *A. macrostachyum* (Plates 1 and Table 2). *H. strobilaceum* plants were widespread in the study area in the westward direction away from the coast. The zone of *H. strobilaceum* extended about 210 m along the line transect. The relative cover of this zone reached 47.2% (Table 2). In this zone, the

Table 2. Relative cover (% of the total plant cover) of the different species along 810 meters line transect in the coastal salt marsh at Al Dhakhira area. The transect was divided into 27 intervals each was 30 meters length. See Table 1 for full name of each species. Results are the average of data obtained from two transects. October 2004.

Intervals	***Av***	***Se***	***Am***	***Ss***	***Hp***	***Hs***	***Sv***	***La***	***Cc***	***Al***	***Sa***	***As***	***Zq***	***Ls***
1	5.52	0	0	0	0	0	0	0	0	0	0	0	0	0
2	**8.55**	**1.12**	0	0.001	0	0	0	0	0	0	0	0	0	0
3	0	0	10.12	0.001	0	0	0	0	0	0	0	0	0	0
4	0	0	**10.65**	0	0	1.19	0	0	0	0	0	0	0	0
5	0	0	0	0	0	9.19	0	0	0	0	0	0	0	0
6	0	0	0	0	0	7.34	0	0	0	0	0	0	0	0
7	0	0	0	0	0	**13.79**	0	0	0	0	0	0	0	0
8	0	0	0	0	0	4.52	0	0	0	0	0	0	0	0
9	0	0	0	0	0	1.29	0	0	0	0	0	0	0	0
10	0	0	0	0	0	4.28	0	0	0	0	0	0	0	0
11	0	0	0	0	0.36	3.77	0	0	0	0	0	0	0.07	0
12	0	0	0	0	0.25	1.34	0	0	0	0.07	0	0	0.07	0
13	0	0	0	0	**0.79**	0.49	0	0	0	0.12	0	0	0	0
14	0	0	0	0	0.55	0	0	0	0	0.38	0	0	0.20	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0.23	0
16	0	0	0	0	0.34	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0.82	0
18	0	0	0	0	0.44	0	0.52	0.110	0.14	0.51	0.06	0	0.54	0
19	0	0	0	0	0	0	0.41	0	0	0	0	0	0.14	0
20	0	0	0	0	0	0	0.56	0	0	0	0	0.24	0.68	0
21	0	0	0	0	0	0	0	0	0	0	0	0.02	0.40	0
22	0	0	0	0	0	0	0.19	0	0	0.094	0	0.04	0.68	0
23	0	0	0	0	0	0	0.03	0	0	0	0	0	0.20	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0.99	0
25	0	0	0	0	0	0	0	0	0	0	0	0	1.14	0
26	0	0	0	0	0	0	0	0	0	0	0	0	1.34	0.20
27	0	0	0	0	0	0	0	0	0	0	0	0	1.59	0.14
Relative cover (% of total cover)	14.1	1.1	20.8	0.001	2.7	47.2	1.7	0.11	0.14	1.17	0.06	0.29	9.09	0.34

Plate 1. General view of the coastal salt marsh of Al-Dhakhira region showing the zonation of the plant cover. In the background is a coastal strip of *Avicennia marina* trees forming a pure zone growing in the shallow coastal water. In the foreground are many individuals of *Halocnemum strobilaceum* which constitute a pure zone. October 2004.

Plate 2. General view of *Avicennia marina* growth fringing the shoreline of Al-Dhakhira coastal salt marsh. Note the dense and large tree layer forming a strip on the left side of the plate and that the smaller trees are growing near the frontier of the coast. The respiratory roots (pneumatophores) of the trees are dense and cover the majority of the intertidal zone. October 2004

Plate 3. Numerous respiratory roots (pneumatophores) of *Avicennia marina* trees emerged as dense cylindrical projections through the soil surface. The roots are usually exposed to air during the low tide. Note that some green algal masses are growing on the soil in the interspaces between the roots. October, 2003.

Plate 4. Part of the zone of *Arthrocnemum machrostachyum* plants that form a strip following *Avicennia marina* zone. The plants of *A. machrostachyum* may frquently inundated with Gulf water, a characteristic of the low salt marsh habitat. October 2003.

Plate 5. A strip of *Arthrocnemum macrostachyum* plants above the high tide level inland to thezone of *Avicennia marina*. October 2003.

cover of the plants varied along the studied intervals of the line transect. For example, in the sites of pure populations, the relative cover of *strobilaceum* plants were associated with *Halopeplis perfoliata* and *Zygophyllum qatarense* which had low relative covers (Table 2). It is worthy to mention that *H. strobilaceum* plants that were close to the zone of *A. macrostachyum* had small and short vegetative form, while those which were located at the end of *H. strobilaceum* zone (Plate 1) had larger vegetative form with longer branches and prominent mounds.

4. Mixed zone

This zone was the largest among the studied ones. It extended about 300 m to the west of *H. strobilaceum* zone. It was located in the mid of the marsh. The dominant species were *H. perfoliata* (relative cover=0.55%, interval 14) and *Z. qatarense* (relative cover=0.99%, interval 24) (Table 2 and Plate 6). The associated species were *Cressa cretica*, *Limonium axillare*, *Suaeda vermiculata* and *Anabasis setifera*. *Aeluropus algopoides* plants were found in patches occupying depressions which were interrupted by the presence of other associating species.

Plate 6. The plants of the mixed zone dominated by *Halopeplis perfoliata* (an individual is seen in the foreground) which appear as scattered shrublets. In the background is an area covered by small low shrublets of *Zygophyllum qatarense*, which extend to the west till the end of the marsh after the mixed zone. March 2006.

5. *Zygophyllum qatarense* zone

It extended for 120 m to the west after the end of the mixed zone. The ground surface was sandy, and in some patches it was covered with stone fragments. At the extreme west of the zone, the habitat becomes a hamada. This zone was dominated by the succulent dwarf shrubs of *Zygophyllum qatarense*. The relative cover of the dominant species ranged from 1.14% at the beginning of the zone to 1.6% at the end of the line transect (at interval 27) at the uppermost part of the marsh (Table 2, Plate 6). The associated species was *Lycium shawii*;

a non succulent desert shrub, where the relative cover ranged from 0.14% to 0.20%.

3.1.3 Soil analysis

The soil characteristics of the root zones varied with vegetation zone and the dominating species (Tables 3, 4 & 5). The coastal and shoreline communities appeared to be subjected to salt stress of Gulf water, as well as, severe inundation. The redox potential values were positive and low. They ranged from +37.0 mV in *A. marina* zone (zone I) to +78.6 mV in zone V at the upper end of the salt marsh which was dry and away from the effects of flooding. The most saline and inundation conditions coincided with the zones of *A. marina* and *A. machrostchyum* (Table 3). Such zones had the highest EC, soil moisture, total carbonate (Table 3), sodium and calcium contents (Table 5) and showed lower pH in comparison to other zones along the line transect. Moreover, high organic carbon, clay and silt (Table 4) were characteristic of the coastal and shoreline zones of *A. marina* and *A. machrostchyum*.

The habitats of the upper marsh comprised of *H. strobilaceum*, mixed zone and *Z. qatarense* zone, and inland to the coastal zones, were subject to dry conditions. For example, with further increase in the distance from the coast, there were general reduction in the EC, total carbonate, organic carbon, silt, chloride, sodium and calcium. The *Z. qatarense* zone was linked with combinations of the lowest EC, moisture, carbonate, clay, silt, sodium and chloride in comparison to the other zones of the marsh.

Table 3. Some characteristics of the soil (at 20 cm depth) of the halophytic species in the different vegetation zones in the salt marsh at Al Dhakhira region. Each value is an average of three determinations taken from 3 individualplants of each species. Standard deviations are underlined.

Zone	Species	Redox potential (+mV)		EC ($mS\ cm^{-1}$)		pH		Moisture (% oven dry soil)		Total carbonates (% oven dry soil)		Organic carbon (% oven dry soil)	
I	*Avicennia*	37.0	5.1	24.7	1.3	7.5	0.4	26.8	1.8	55.0	3.5	1.39	0.20
II	*Arthrocnemum*	32.2	2.8	20.1	1.8	7.7	0.6	25.9	2.1	53.5	4.6	0.50	0.03
	Salsola	59.1	4.6	21.5	2.3	8.1	0.4	24.8	1.8	52.1	5.6	0.61	0.04
	Salicornia	49.2	4.1	19.7	1.5	7.9	0.8	22.8	2.1	52.5	4.8	0.54	0.03
III	*Halopeplis*	49.0	5.1	15.0	1.0	8.1	0.6	16.0	1.4	42.0	4.6	0.20	0.03
	Halocnemum	53.5	4.6	19.0	1.3	8.0	0.3	16.9	1.1	41.0	3.7	0.28	0.05
IV	*Suaeda*	68.1	7.0	14.0	1.6	7.6	0.5	17.5	1.5	48.5	5.0	0.31	0.02
	Limonium	68.5	6.1	11.6	1.4	7.9	0.8	14.1	1.3	44.8	4.2	0.30	0.01
	Cressa	72.3	7.2	15.2	1.6	8.4	0.6	16.8	1.5	37.1	2.6	0.35	0.02
	Aeluropus	71.4	8.0	14.5	1.2	8.4	0.7	15.6	1.4	34.2	3.1	0.38	0.01
	Sporobolus	76.1	5.7	11.4	0.8	8.2	0.5	12.4	1.1	33.4	3.6	0.27	0.03
	Anabasis	70.5	6.7	17.3	0.9	8.0	0.6	12.6	1.3	44.0	3.5	0.36	0.01
V	*Zygophyllum*	78.6	8.0	10.4	1.1	8.4	0.5	12.1	0.8	36.5	4.0	0.20	0.01

Table 4. Mechanical analysis (% oven dry weight) of the soil in the root zone (at 20 cm depth) of the halophytic species in the different vegetation zones of the coastal salt marsh at Al Dhakhira region. Each value is an average of three determinations taken from 3 individual plants of each species. Standard deviations are underlined.

Zone	Species	Clay		Silt		Sand	
I	*Avicennia*	13.0	1.5	11.0	0.8	76.0	6.8
II	*Arthrocnemum*	12.5	1.1	27.0	2.4	60.0	5.7
	Salsola	12.0	1.3	25.0	2.0	63.0	4.8
	Salicornia	11.1	1.5	25.2	2.1	64.0	4.5
III	*Halopeplis*	10.5	1.3	17.5	1.3	72.0	6.9
	Halocnemum	10.1	1.4	19.0	2.0	70.9	6.8
IV	*Suaeda*	10.2	1.1	12.0	1.0	77.8	5.3
	Limonium	9.5	0.7	10.1	0.8	80.4	7.9
	Cressa	9.6	0.5	12.5	1.1	77.9	6.8
	Aeluropus	9.0	0.7	13.2	1.5	77.8	7.2
	Sporobolus	10.1	0.5	13.1	1.6	76.8	6.9
	Anabasis	9.2	0.8	11.1	1.3	79.7	8.2
V	*Zygophyllum*	8.1	0.6	9.5	0.8	82.4	7.3

Table 5. The contents of some mineral ions in the oven dry soil (at 20 cm depth) of the halophytic species in the different vegetation zones at Al Dhakhira salt marsh. Each value is an average of three determinations taken from 3 individual plants of each species. Standard deviations are underlined.

Zone	Species	Chloride ($g\ 100g^{-1}$)		Sodium ($g\ 100g^{-1}$)		Potassium ($mg\ 100\ g^{-1}$)		Calcium ($mg\ 100\ g^{-1}$)		Magnesium ($mg\ 100\ g^{-1}$)	
I	*Avicennia*	2.6	0.21	1.8	0.08	140	13.0	206	18.6	210	16.7
II	*Arthrocnemum*	2.2	0.23	1.36	0.11	59	7.1	15	0.2	190	18.4
	Salsola	1.89	0.11	1.81	0.15	41	3.5	17	0.1	120	11.6
	Salicornia	1.80	0.02	1.56	0.13	83	7.4	20	0.1	250	26.3
III	*Halopeplis*	1.79	0.15	1.1	0.08	80	6.3	90	8.6	190	15.8
	Halocnemum	1.68	0.13	0.99	0.12	81	7.2	81	7.5	140	16.1
IV	*Suaeda*	1.31	0.12	0.85	0.06	57	5.1	190	21.1	150	13.0
	Limonium	1.39	0.08	0.90	0.07	154	14.6	132	11.3	200	19.6
	Cressa	0.9	0.07	0.78	0.06	190	17.8	166	14.6	450	33.2
	Aeluropus	1.10	0.07	0.96	0.08	240	25.4	101	12.1	480	47.8
	Sporobolus	1.21	0.14	0.95	0.07	110	10.5	81	7.5	530	60.5
	Anabasis	1.39	0.12	0.91	0.05	151	16.0	91	8.6	130	12.5
V	*Zygophyllum*	1.1	0.09	0.73	0.06	132	11.3	114	13.2	200	17.8

3.1.4 Water content of the green and senescent plant parts of halophytes

Irrespective of the species, the water contents of the green parts were significantly higher than those of the senescent ones (Table 6). Moreover, the water contents of the green and senescent parts of succulents were higher than those in the recretors.

Table 6. Water content (% fresh weight) of the green and senescent shoot parts of some succulents and recreting halophytes collected during the dry season from the salt marsh of Al Dhakhira region. Each value is an average of 5 measurements taken from 5 individual plants. The underlined numbers are the standard deviations of the means. The values followed by asterisks indicate that the green and senescent parts are significantly different according to the Student's t-test at the probability levels of 0.05 (*) and 0.001 (**). Sig. = Significant, Ns. = Not significant. October 2004.

Species	**Green Parts**		**Senescent Parts**	
Succulents				
Arthrocnemum macrostachyum	78.1*	6.8	21.7	1.8
Halopeplis perfoliata	78.4**	8.2	15.0	1.3
Suaeda vermiculata	81.3**	7.8	6.8	2.0
Zygophyllum qatarense	79.3**	7.3	25.8	5.7
Mean of succulents	79.3* (1.25)		17.3 (7.3)	
Recretors				
Aeluropus lagopoides	52.0**	4.8	36.1	2.5
Avicennia marina	60.0**	5.4	38.1	4.0
Cressa cretica	62.3**	6.4	20.0	1.9
Sporobolus spicatus	50.5**	3.9	26.0	3.0
Mean of recretors	56.2**	5.8	30.1	8.5
General mean of succulents and recretors	67.7* (12.1)		23.7 (9.7)	
Significance of differences between mean of succulents and recretors	Sig. (p=0.001)		Ns	

3.1.5 Chemical analysis of the aqueous washings of the green and senescent plant parts

The contents of the mineral ions in the aqueous washings (Tables 7, 8) were higher than the metabolic products (Table 9). It is apparent that the washings contained high amounts of sodium and chloride followed by calcium and potassium (Tables 7, 8). Irrespective of the species, the washings from both green and senescent parts of succulents had lower contents of chloride, sodium, potassium and higher contents of calcium and magnesium than the

Table 7. The contents of chloride, sodium and potassium (mg $100g^{-1}$ dry weight) in the aqueous washings of the green and senescent shoot parts of some succulents and recreting halophytes collected during the dry season from the salt marsh of Al Dhakhira region. Each value is an average of 5 measurements taken from 5 individual plants. The underlined numbers are the standard deviations of the means. The values followed by asterisks indicate that the green and senescent parts are significantly different according to the Student's *t*-test at the probability levels of 0.05 (*) and 0.001 (**). Sig.= Significant, Ns.= Not significant. October 2004.

Species	**Chloride**				**Sodium**				**Potassium**			
	Green		**Senescent**		**Green**		**Senescent**		**Green**		**Senescent**	
Succulents												
Arthrocnemum macrostachyum	280.0**	25.4	699.2	57.7	380.5**	35.1	532.4	49.5	35.7**	2.3	165.0	15.5
Halopeplis perfoliata	525.0**	46.7	891.3	94.0	495.3**	47.4	732.0	67.4	47.6**	3.3	230.3	21.4
Suaeda vermiculata	118.7**	12.4	718.6	68.7	249.0**	30.6	530.0	55.1	27.9	2.1	37.2	32.5
Zygophyllum qatarense	515.7**	48.8	870.4	75.4	491.0*	48.6	602.0	61.3	50.8**	4.5	150.1	16.4
Mean of succulent	360.0* (170.1)		795.0 (86.7)		404*.0 (100.6)		599.0(82.0)		40*.5(9.2)		145.6(69.5)	
Recretors												
Aeluropus lagopoides	3800.7	350.3	3507.5	410.7	767.5	67.4	677.5	65.3	292.4	22.4	267.0	23.5
Avicennia marina	573.4**	54.6	1369.3**	127.4	194.4**	21.7	519.4	60.2	26.4**	24.6	128.0	13.5
Cressa cretica	922.4**	89.0	1318.2***	136.1	114.5**	12.5	379.2	31.5	12.8**	1.5	78.2	6.6
Sporobolus spicatus	1775.3**	168.7	1260**	110.5	1214.4**	130.6	445.5	34.0	79.3**	6.3	46.0	3.5
Mean of recretors	1768.0 (1252.4)		1863.8 (949.8)		572.7		505		102.7		129.8	
General mean of succulents and recretors	1063.9 (1137.7)		1329.3 (860.5)		488.3 (335.5)		552.3(108.3)		71.6 (85.5)		137.7(77.7)	
Significance of differences between mean of succulents and recretors	Sig. (*p*=0.05)		Sig. (*p*=0.05)		Ns		Ns		Ns		Ns	

Table 8. The contents of calcium and magnesium (mg 100g^{-1} dry weight) in the aqueous washings of the green and senescent shoot parts of some succulents and recreting halophytes collected during the dry season from the salt marsh of Al Dhakhira region. Each value is an average of 5 measurements taken from 5 individual plants. The underlined numbers are the standard deviations of the means. The values followed by asterisks indicate that the green and senescent parts are significantly different according to the Student's t-test at the probability levels of 0.05 (*) and 0.001 (**). Sig.= Significant, Ns.= Not significant. October 2004.

Species	**Calcium**				**Magnesium**			
	Green		**Senescent**		**Green**		**Senescent**	
Succulents								
Arthrocnemum macrostachyum	25.2**	1.4	44.4	5.0	23.8**	2.1	291.0	25.8
Halopeplis perfoliata	88.6*	2.8	93.0	1.3	90.8**	8.9	272.0	26.0
Suaeda vermiculata	47.6*	4.6	58.0	5.0	76.1*	3.3	104.7	5.1
Zygophyllum qatarense	51.8**	4.3	203.5	18.9	75.0*	7.4	189.0	8.4
Mean of succulents	53.3 (22.8)		99.6 (62.3)		66.4** (25.4)		214.2 (74.2)	
Recretors								
Aeluropus lagopoides	124	14	107.0	9.6	143.0	13.5	139.0	10.0
Avicennia marina	6.1**	0.4	32.4	2.0	19.0*	1.3	60.5	5.8
Cressa cretica	22.3**	1.3	78.6	6.7	23.4**	1.5	83.8	7.3
Sporobolus spicatus	168.0*	14.8	40.1	3.6	223.0**	15.0	71.5	3.5
Mean of recretors	80.1 (68.0)		64.5 (30.1)		102.1** (85.7)		88.7 (30.2)	
General mean of succulents and recretors	66.7 (52.4)		82.1 (52.1)		84.3 (65.7)		151.4 (84.4)	
Significance of differences between mean of succulents and recretors	Ns.		Ns.		Ns.		Sig. (p=0.02)	

Table 9. The contents of total soluble sugars and total amino acids (mg 100g^{-1} dry weight) in the aqueous washings of the green and senescent shoot parts of some succulents and recreting halophytes collected during the dry season from the salt marsh of Al Dhakhira region. Each value is an average of 5 measurements taken from 5 individual plants. The underlined numbers are the standard deviations of the means. The values followed by asterisks indicate that the green and senescent parts are significantly different according to the Student's *t*-test at the probability levels of 0.05 (*) and 0.001 (**). Sig.= Significant, Ns.= Not significant. October 2004.

Species	Total soluble sugars (as glucose)				Total amino acids (as glycine)			
	Green		Senescent		Green		Senescent	
Succulents								
Arthrocnemum macrostachyum	34.0**	2.3	126.0	11.4	3.00**	0.4	4.50	0.34
Halopeplis perfoliata	19.0**	1.4	114.0	13.8	0.31**	0.02	4.40	0.50
Suaeda vermiculata	34.0**	3.5	73.0	6.8	1.34**	0.2	7.20	0.67
Zygophyllum qatarense	38.0**	2.7	239.0	21.0	0.35**	0.01	2.40	0.12
Mean of succulents	31.3* (7.3)		138.0 (61.5)		1.3* (1.1)		4.6 (1.7)	
Recretors								
Aeluropus lagopoides	59.0**	5.8	12.0	0.7	10.0*	1.1	2.6	0.13
Avicennia marina	21.0*	3.0	17.0	2.0	0.95**	0.08	4.3	0.32
Cressa cretica	9.0**	0.7	36.0	2.5	0.94**	0.06	5.3	0.45
Sporobolus spicatus	100.0**	9.6	30.0	3.1	13.50**	0.11	4.1	0.35
Mean of recretors	47.3 (35.6)		23.8 (9.7)		6.4 (5.5)		4.1 (1.0)	
General mean of succulents and recretors	39.3 (28.8)		80.9 (72.1)		3.8 (4.7)		4.4 (1.5)	
Significance of differences between mean of succulents and recretors	Ns.		Sig. (p= 0.01)		Ns.		Ns.	

washings of the recretors. Generally, in all species investigated, the contents of sodium, chloride, calcium and potassium in the aqueous washings of the senescent parts were higher than in the green ones. The same trend occurred in succulents with regard to the total soluble sugars and the total amino acids. Moreover, the contents of the total amino acids and total soluble sugars in the washings from the green parts of the recretors were higher than those from the green parts of the succulents.

3.2 Bacteriological measurements

3.2.1 Rhizosphere and soil bacteria

3.2.1.1 Total bacterial count

Counts of total bacteria varied in the soil of the halophytic species, as well as in the different vegetation zones of the salt marsh. Irrespective of the halophytic species and the soil of the different vegetation zones, the total count in the rhizosphere was higher (3.4 x 10^5 cfu /g soil) than in the non-rhizosphere soil (3.01x 10^5 cfu /g soil) (Table 10 and Plates 7 and 8). In the rhizosphere of the different vegetation zones (I-V), variations in counts were also noticed. Counts were high in the rhizosphere and soil supporting *A. marina* (zone I) reaching 5.8 x 10^5 cfu /g soil. Further inland away from the coastal habitat, there was a gradual decline in the total counts. For example, in the zone IV of the upper marsh, the mean of the bacterial counts in the soil varied from 3.4 x 10^5 cfu /g soil in case of *S. vermiculata* to 0.2 x 10^5 cfu /g soil in case of *A. stifera*.

Table 10. Total bacterial count in the soil supporting halophytes growing in different zones in the coastal salt marsh at Al Dhakhira region. Each value is an average of 5 measurements taken from 5 individual plants. The underlined numbers are the standard deviations of the means. The values followed by asterisks indicate that the count in the rhizosphere and in the non-rhizosphere are significantly different according to the Student's *t*-test at the probability levels of 0.05 (*) and 0.001 (**). cfu= colony forming unit, R= rhizosphere, Non-R= non-rhizosphere. October 2004.

Zone	Species	Total bacterial count ($x\ 10^5$ cfu /gsoil)			
		R		Non-R	
I	*Avicennia marina*	5.8	2.38	5.0	1.2
II	*Arthrocnemum macrostachyum*	3.8	0.38	4.5	1.5
	Salsola soda	5.5	2.08	5.7	2.0
	Salicornia europaea	4.4	0.98	4.6	1.5
III	*Halopeplis perfoliata*	3.2*	0.22	2.8	0.21
IV	*Suaeda vermiculata*	2.5*	0.92	3.4	0.39
	Limonium axillare	3.2*	0.22	2.7	0.31
	Cressa cretica	3.3*	0.12	0.8	1.2
	Aeluropus logopoides	1.6**	0.20	0.6	0.03
	Anabasis setifera	1.1**	0.22	0.2	0.028
V	*Zygophyllum qatarense*	3.2*	0.21	2.8	0.25
	General mean	3.4	1.38	3.0	1.78

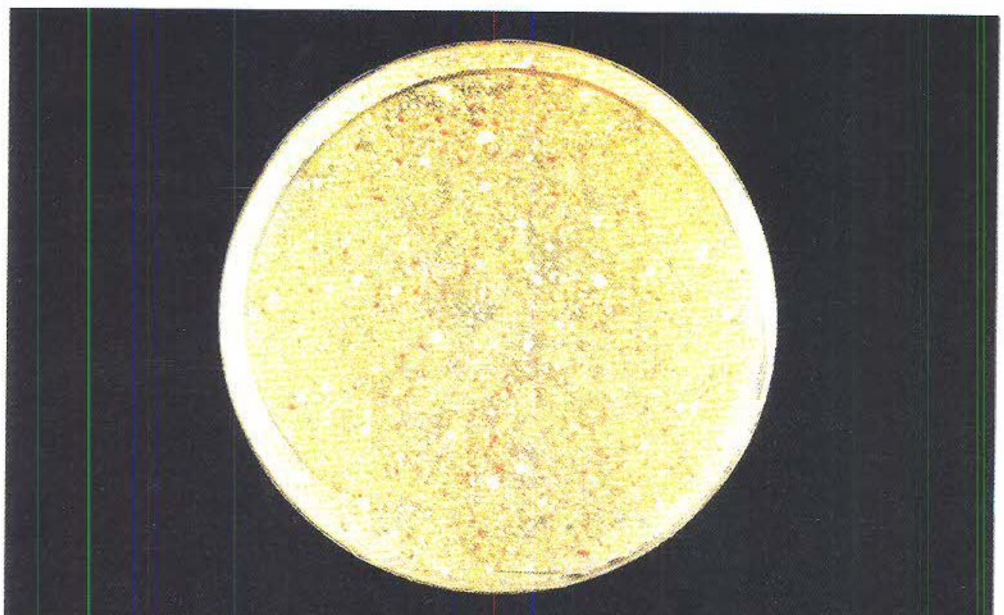


Plate 7. Bacto Marine Agar 2216 colonized by bacteria from the rhizosphere of *Zygophyllum qatarense* plants growing in the coastal solt mash at Al-Dhakhira region.

Plate 8. Bacto Marine Agar 2216 colonized by bacteria isolated from the non-rhizospheric soil of *Zygophyllum qatarens* plants growing in the coastal salt marsh at Al-Dhakhira region.

Despite the bacterial counts of the soil supporting *Z. qatarense* than those recorded previously in the soil supporting *A. marina* in zone I. Counts of Enterobacteriaceae (Table 11) were considered low and were only restricted to the non-rhizospheric soil supporting *S. soda* (300 cfu /g soil) and in the rhizosphere of *S. europaea* (1000 cfu/g soil).

Zone	Species	Count of Enterobacteriaceae (cfu /g soil)		Gram reaction		Cell forms and colour of colony	
		R	Non-R	R	Non-R	R	Non-R
I	*Avicennia marina*	0	0	+	+	Coc, off white	Coc, off white
II	*Arthrocnemum macrostachyum*	0	0	-	+	Coc, orange	Coc, orange
	Salsola soda	0	300	+	+	Coc, off white	Coc, off white
	Salicornia europaea	1000	0	+	+	Coc, off white	Coc, orange
III	*Halopeplis perfoliata*	0	0	+	+	Spi, white	Coc, pink
IV	*Suaeda vermiculata*	0	0	+	+	Bac, off-white	Coc, pink
	Limonium axillare	0	0	-	-	Bac, white	Bac, yellow
	Cressa cretica	0	0	+	+	Coc, white	Coc, pink
	Aeluropus logopoides	0	0	+	+	Coc, white	Coc, off-white
	Anabasis setifera	0	0	+	+	Bac, white	Coc, white
V	*Zygophyllum qatarense*	0	0	+	+	Strept, grey	Bac, white

3.2.1.2 Gram reaction

The majority of isolates were Gram positive (Table 11). The records of Gram negative bacteria were very low and occurred in two individual cases; in the rhizosphere of *A. macrostachyum* and in both the rhizospheric and the non-rhizospheric soils of *L. axillare*.

3.2.1.3 Cell morphology

Generally the cocci forms were dominant in the isolations from the rhizospheric and the non rhizospheric soils, where their occurrence reached 68.2% of the total isolations (15 out of 22 isolations), while the bacilli were only 22.7% (5 out of 22 isolations) (Table 11). The isolates of the rhizosphere contained four different forms. The common form was cocci which amounted to 54.5% of the total rhizospheric isolations, followed by bacilli (27.3%). Both spirilla and filamentous forms attained the lowest percentages and only recovered from the rhizospheres of *H. perfoliata* (spirilla) and *Z. qatarense* (filamentous).

3.2.1.4 Colony colour

The isolates of white coloured colonies predominated in the rhizosphere (81.8) (Table11). The coloured bacteria (yellow, orange, pink and grey) constituted 36.4% of the total isolates and mainly occurred in the non rhizosphere. Sometimes the isolates of the rhizosphere and the non rhizosphere showed similar colony colours; as in *A. marina* (off-white colour) and *A. macrostachyum* (orange colour) or showed different colours; as *S. europaea* (off-white and orange colours) and others (Table 11).

3.2.1.5 Biochemical characterization

Irrespective of the vegetation zone and the plant species, the results in Table 12 showed that low percentage of bacterial isolates (18.2% and 27.3% in the rhizosphere and the non-rhizosphere, respectively) was urease producing. On the contrary, a large proportion of the isolates showed the capacity for nitrate reduction and hydrolysis of lactose and starch. All isolates of the rhizosphere and non rhizosphere showed positive tests for gelatin liquefaction and catalse activity. Generally, the bacterial isolates from the rhizosphere showed relatively infrequent capacity to hydrolyze lactose and casein in comparison to those isolated from the non rhizosphere (Table 12). The percentage of bacterial isolates that demonstrated nitrate reduction was high (72.7%) in both the rhizosphere and the non rhizosphere.

The rhizosphere and the non rhizosphere isolates showed negative tests for phenylalanine decarboxylation, as well as indol reduction. All isolates of the rhizosphere and non rhizosphere showed positive tests for gelatin liquefaction, starch hydrolysis and catalase activity.

The isolates of the rhizosphere and non rhizosphere of the species studied in the five vegetation zones varied in unit incidence (ability of the isolates to attack the substrates of the biochemical tests). For example, the isolates from the rhizosphere of the zones I and II in the lower marsh mostly showed higher activity to decompose the provided substrates of the biochemical tests (high percentage unit incidence) in comparison to the isolates of the zones III and IV at the upper marsh. The lowest percentage of unit incidence was obtained in the soil of zone V in the case of *Z. qatarense* which was characterized by low contents of soil water, organic carbon and relatively high salinity (Tables 3, 5).

Table 12. Biochemical characterizations of bacteria in the soil supporting halophytes growing in different zones in the coastal salt marsh at Al Dhakhira region. R= rhizosphere, NR= non- rhizosphere. October, 2004.

Zone	Species	URE		NO_3 R		LAC		GEL		CAS		PHE/PA		IND		STA		CAT		% Incidence*	
		R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR	R	NR
I	*Avicennia marina*	-	-	+	+	+	+	+	+	-	-	-	-	-	-	+	+	+	+	55.6	55.6
II	*Arthrocnemum macrostachyum*	-	-	+	+	+	+	+	+	-	-	-	-	-	-	+	+	+	+	55.6	55.6
	Salsola soda	-	-	+	+	+	+	+	+	-	-	-	-	-	-	+	+	+	+	55.6	55.6
	Salicornia europaea	-	-	+	+	+	+	+	+	-	-	-	-	-	-	+	+	+	+	55.6	55.6
III	*Halopeplis perfoliata*	-	+	+	+	-	+	+	+	+	+	-	-	-	-	-	+	+	+	44.4	77.8
IV	*Suaeda vermiculata*	-	+	+	-	-	-	+	+	-	-	-	-	-	-	+	+	+	+	44.4	44.4
	Limonium axillare	+	-	+	-	+	-	+	+	+	+	-	-	-	-	+	+	+	+	77.8	44.4
	Cressa cretica	-	+	-	+	-	+	+	+	+	+	-	-	-	-	+	+	+	+	44.4	77.8
	Aeluropus logopoides	+	-	+	+	-	+	+	+	-	-	-	-	-	-	-	+	+	+	44.4	55.6
	Anabasis setifera	-	-	-	+	+	+	+	+	-	+	-	-	-	-	+	+	+	+	44.4	66.6
V	*Zygophyllum qatarense*	-	-	-	-	-	+	+	+	-	+	-	-	-	-	+	+	+	+	33.3	55.6
% occurrence of positive reaction of each biochemical test		18.2	27.3	72.7	72.7	54.6	81.8	100	100	27.3	45.5	0.0	0.0	0.0	0.0	90.9	100	100	100	Mean% incidence R=50.5% NR=58.5%	

* The occurrence of positive reactions as percentage of the total number of each biochemical test

URE=urease activity, NO_3 R= nitrate reduction, LAC= lactose fermentation, GEL= gelatin liquefaction, CAS= casein, PHE/PA= phenylalanine decarboxylation, IND= indol production, STA=starch hydrolysis, CAT=catalase activity

3.2.2 Phyllosphere bacteria

3.2.2.1 Total bacterial count

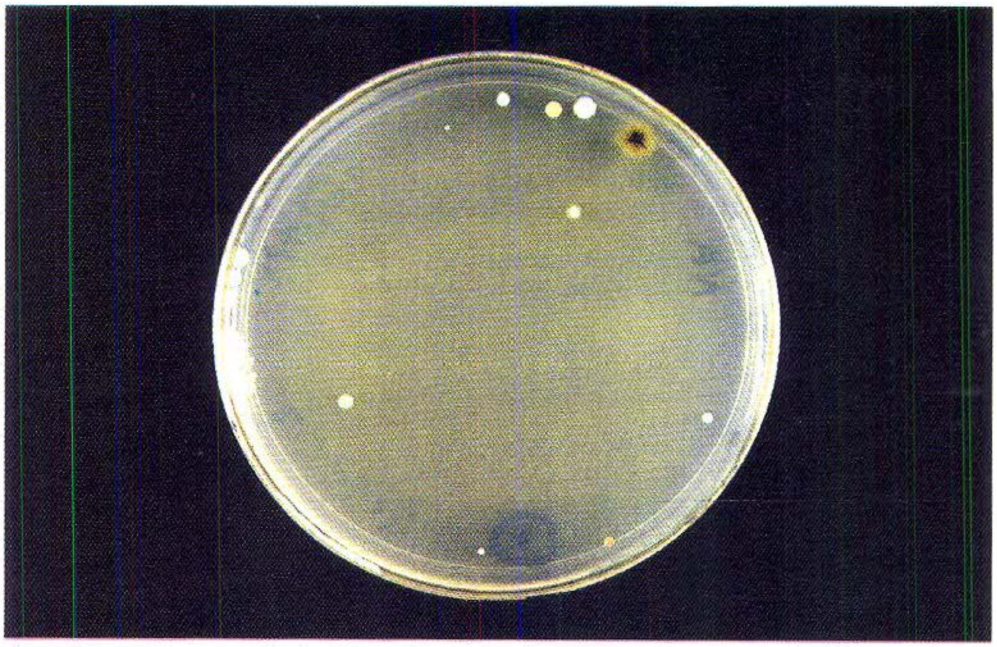
The various vegetation zones, as well as the salt resistance mechanisms (succulence and recretors), the mean total count of the phyllosphere of the green parts (3.13 $x10^5$ cfu/g) was non-significantly different from that of the senescent ones (3.7 $x10^5$ cfu/g) (Table 13; Plates 9 and 10). On the green parts of succulents, the counts were higher (3.4 x $x10^5$ cfu/g) than those on the comparable parts of the recretors (2.8 x $x10^5$ cfu/g). Among succulents, the green and senescent parts of *S. vermiculata* and *A. macrostachyum* showed higher bacterial counts than *H. perfoliata* and *Z. qatarense*. On the other hand, the bacterial count on the green parts of *A. marina* trees which formed characteristic zone in the coastal region (zone I) was higher than the counts on the phyllospheres of other recretors which colonized vegetation zones away from the coast.

3.2.2.2 Gram reaction

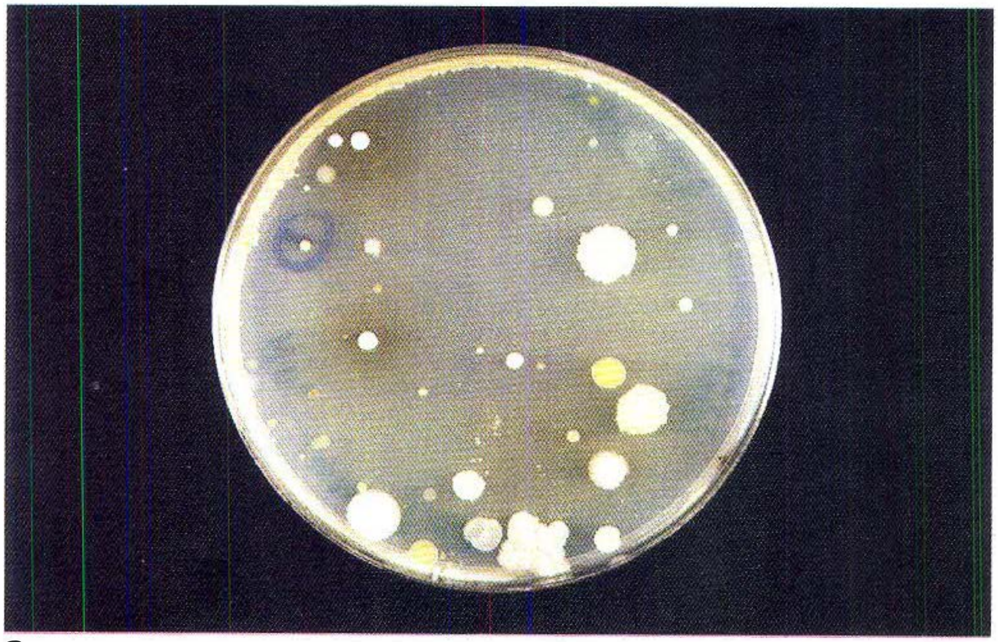
The majority of the isolates of the green and senescent parts of the succulents and recretors were Gram positive (62.5% of the total isolates) (Table 13). Comparison of the green and senescent parts of succulents and recretors revealed that the records of Gram positive bacteria reached 50% in succulents and amounted to 75% in the recretors.

Table 13. Total count and characterization of bacteria on the phyllosphere of green and senescent parts of succulent and salt recreting halophytes in the salt marsh at Al Dhakhira region. Each value is an average of 5 measurements taken from 5 individual plants. The underlined numbers are the standard deviations of the means. The values followed by asterisks indicate that the count on the green and on the senescent parts are significantly different according to the Student's *t*-test at the probability levels of 0.05 (*) and 0.001 (**).cfu= colony forming unit. Sig.= Significant, Ns.= Not significant. October 2004.

Species	Total bacterial count ($x 10^5$ cfu /g)				Cell form		Gram reaction		Colony colour	
	Green		Senescent		Green	Senescent	Green	Senescent	Green	Senescent
Succulents										
Arthrocnemum macrostachyum	3.7	0.6	4.2	0.1	Bacilli	Bacilli	-	-	Off-white	Off-white
Halopeplis perfoliata	3.2*	0.01	2.7	0.38	Spirilla	Bacilli	+	+	Off-white	Off-white
Suaeda vermiculata	4.3	1.1	4.3	1.1	Bacilli	Bacilli	-	-	White	Yellow
Zygophyllum qatarense	2.5*	0.6	3.6	0.51	Cocci	Cocci	+	+	Off-white	Off-white
Mean of succulents	3.4	0.66	3.7	0.64						
Recretors										
Aeluropus lagopoides	1.6**	0.01	1.1	0.1	Bacilli	Bacilli	+	+	Off-white	White
Avicennia marina	4.5*	1.1	2.8	0.27	Bacilli	Bacilli	-	-	Orange	Off-white
Cressa cretica	3.4	0.25	3.4	0.32	Bacilli	Cocci	+	+	White	Pink
Sporobolus spicatus	1.8*	0.2	2.5	0.58	Bacilli	Bacilli	+	+	White	White
Mean of recretors	2.8	1.19	2.5	0.84						
General mean of succulents and recretors	3.13	1.0	3.08	0.97						
Significance of differences between mean of succulents and recretors	Ns.		Sig. (p=0.05)							



A



B

Plate 9. Bacto Marine Agar 2216 colonzied by bacteria isolated from the phyllospheres of the green leaves of *Zygophyllim qatarense* **(A)** and *Limonium axillare* **(B)** plants growing in the coastal salt marsh at Al-Dhakhira region.

A

B

Plate 10. Bacto Marine Agar 2216 colonzied by bacteria isolated from the phyllospheres of the green leaves of *Zygophyllim qatarense* (**A**) and *Limonium axillare* (**B**) plants growing in the coastal salt marsh at Al-Dhakhira region.

3.2.2.3 Cell morphology

Irrespective of the species as well as the salt resistance mechanism, it is apparent that bacilli predominated in the isolated bacteria (75% of the forms as shown in Table 13). The Spirilla were only recorded in the green parts of *H. perfoliata* of the succulents. Comparisons of the green parts of succulents and recretors revealed that bacilli constituted 50% on the phyllosphere of the formers and 100% on those of the laters.

3.2.2.4 Colony colour

The off-white coloured bacteria constituted 50% of the isolates of green and senescent parts (Table 13). The percentage of white colonies was higher in the green parts (37.5%) than in the senescent ones (12.5%). The occurrence of coloured colonies was low on the phyllospheres of senescent parts. Orange coloured colonies were observed on the green parts, while yellow and pink colours were found on the senescent ones.

In the case of succulents, the off-white colonies constituted 75% of the colony colours while the yellow colonies were recovered only in the senescent parts of *S. vermiculata*. In the recretors, the percentage occurrence of the coloured colonies was higher (25% of the total isolates) than in the succulents.

3.2.2.5 Biochemical characterization

Generally, the phyllosphere bacteria on green and senescent parts gave negative results for urease production as well as for phenylalanine decarboxylation and indol production (Table 14). On the contrary, the bacteria

Table 14. Biochemical characterization of bacteria on the phyllosphere of green and senescent parts of succulents and recereting halophytes in different zones in the coastal salt marsh at Al Dhakhira region. G= green parts, S= senescent parts. October, 2004.

Species	URE		NO_3 R		LAC		GEL		CAS		PHE/PA		IND		STA		CAT		% Incidence*	
	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S
Succulents																				
Arthrocnemum	-	-	-	-	-	+	+	+	+	+	-	-	-	-	+	+	+	+	44.4	55.6
Halopeplis	-	-	+	+	+	+	+	+	-	-	-	-	-	-	+	+	+	+	55.6	44.4
Suaeda	-	-	-	+	+	-	+	+	+	+	-	-	-	-	+	+	+	+	55.6	44.4
Zygophyllum	-	-	+	-	+	+	+	+	+	+	-	-	-	-	+	+	+	+	55.6	55.6
% occurrence of positive reaction of each biochemical test	0	0	50	50	75	75	100	100	75	75	0	0	0	0	100	100	100	100	Mean % incidence G= 52.8 S= 50.0	
Recretors																				
Aeluropus	-	-	-	+	+	+	+	+	+	+	-	-	-	-	+	+	+	+	55.6	55.6
Avicennia	-	-	+	-	+	-	+	+	-	-	-	-	-	-	+	+	+	+	55.6	33.3
Limonium	-	-	-	+	-	-	+	+	+	+	-	-	-	-	+	+	+	+	44.4	55.6
Sporobolus	-	-	-	+	+	+	+	+	+	-	-	-	-	-	+	+	+	+	55.6	55.6
% occurrence of positive reaction of each biochemical test	0	0	25	75	75	50	100	100	75	50	0	0	0	0	100	100	100	100	Mean % incidence G= 52.8 S= 50.0	

* The occurrence of positive reactions as percentage of the total number of the biochemical tests

URE=urease activity, NO_3 R= nitrate reduction, LAC= lactose fermentation, GEL= gelatin liquefaction, CAS= casein, PHE/PA= phenylalanine decarboxylation, IND= indol production, STA=starch hydrolysis, CAT=catalase activity on green and senescent parts showed 100% activity in decomposing starch, hydrolysis of gelatin and in catalase production. Although variations in other biochemical activities were also noticed among green and senescent parts, yet the activities in decomposing lactose and casein were higher in bacteria colonizing the green parts than in those on the phyllosphere of the senescent ones. With regard to nitrate reduction, the bacteria recovered from the green parts showed lower percentage activity than the senescent ones.

The mean % incidence in the bacteria colonizing the phyllosphere of the green plants was higher (52.8%) than that in the senescent ones (50%) (Table 14). Moreover, irrespective of the species, succulents and recretors showed equal values of the percentage incidence of biochemical tests. Exceptions of the percentage incidence varied among species of each group. For example, in *Arthrocemum* (succulent) and *Limonium* (excretor), the % of incidence of bacteria colonizing the senescent parts were higher than those of the green ones. The lowest % incidence was observed in the senescent leaves of *A. marina* (33.3%).

4. Discussion

4.1 Patterns of vegetation composition and zonation

Salt marshes and mangrove forests occur at the transition between land and sea. Salt marshes are inundated and drained as a result of lunar driven tides (Moiles, 1999). The daily movements of water gradually sculpt the salt marsh into a gently undulating landscape. Variations in abiotic factors in the salt marsh lead to the development of distinctive low and high elevation communities. The low elevation communities occur at the low salt marsh which is referred to areas subjected to periodic inundation by sea water. The high elevation communities occur at the high salt marsh that are moist flat areas least affected by inundation. The patterns of vegetation composition with elevation appear as the arrangement of species and communities in belts parallel to the shore. This pattern is called zonation.

The zonation of vegetation that was observed in the study site of Al Dhakhira salt marsh is common and a well known feature of coastal halophytes in the Arabian Peninsula (Abdel-Razik and Ismail, 1990; Batanouny 1994; Abulfatih *et al.* 2002). The characteristic mangrove belt observed at the intertidal zone of the study area has also been documented by several researchers. Adam (1990) pointed out that the lowest community of the lower salt marsh forms a clear zone dominated by a single species. Abulfatih *et al.* (2002) found that *Avicennia marina* trees are common at the inetrtidal zone at Al Dhakhira and Al Khor coastal areas. In such mangrove swamps, vivpary (Rabinowitz, 1978), pneumatophore formation (Boaden and Seed, 1985) and salt tolerance

(Sayed, 1994) constituted elements of *A. marina* zone in which the plants are adapted to this anoxic saline environment.

Following the zone I (mangrove zone), it was possible to recognize four more vegetation zones on the basis of their dominant species. Zonation at the level of coastal drainage is the result of the distance of the vegetation from the open water body. With this gradient of inundation, there is also a salinity gradient. Different species vary in their tolerances to the degree and duration of inundation, and to salinity (Day *et al*., 1989).

The predominance of *Arthrocnemum machrostchyum* in the coastal low marsh (zone II) which was usually inundated during the high tide, indicates that this species has some peculiar adaptations to flooding.

Halocnemum strobilaceum that dominated zone III of the marsh is not adapted to flooding since the plants were not frequently inundated with sea water. *H. strobilaceum* plants are tolerant to relatively dry saline areas since the soil salinity in their specific zone was coupled with low soil moisture. Abulfatih *et al.* (2002) identified this zone as the zone of coastal high marsh halophytes, while Abdel-Razik and Ismail (1990) identified it as the mud flat zone. *H. strobilaceum* occupies relatively dry highly saline areas (Tadros, 1953; Fahmy, 1986; Abdel-Razik and Ismail, 1990). In the salt marshes of Qatar, *H. strobilaceum* has wider distribution than *A. machrostchyum* (Batanouny, 1981).

The zone IV which followed *H. strobilaceum* was described by Abdel-Razik and Ismail (1990) as mixed patchy zone. It was apparently a transition habitat between *H. strobilaceum* (zone III) and *Zygophyllum qatarense* (zone V). The species inhabiting the mixed zone were subjected to high soil salinity and low soil moisture. These stress conditions were reflected on the characteristic species composition, where the C_4 species (2 grasses and 2 chenopods, see Table 1) predominated in the zone. These observations agree with some researchers who found that C_4 plants occupy habitats which are transitional or intermediate with respect to soil salinity and available water (Babikir and Kürschner, 1992; Batanouny, 1994; Sayed, 1994). It is now clear that the mixed zone or the salt meadows (Sayed, 1994) occupied a well defined belt between the C_3 halophytic communities (zones I, II and III) and the outermost belt of the xerophytic plant communities (zone V, dominated by *Z. qatarense*). In his study on the zonation of halophytes in littoral salt marshes in Qatar, Sayed (1994) concluded that structural (Kranz anatomy) and functional (high water use efficiency) attributes which characterize the C_4-syndrome are essential for the C_4 plants to survive the salt and moisture stress prevailing in the transitional zone.

4.2 Rhizosphere, soil bacteria and salinity

Counts of rhizosphere and soil bacteria in the soil supporting the different vegetation zones of the study area were inferior to their relative counts in saline soils of other littoral salt marsh habitats. For example, in the salt marsh at Shuaiba lagoon in Saudi Arabia, Zaki *et al.* (1980) found that the total counts ranged from 81 x 10^6 to 1484 x 10^6 per g dry soil. A recent study on the soil bacteria in Qatar revealed that at a depth of 5-10 cm, the total counts of bacteria ranged from 13 x 10^4 to 290 x 10^4 cfu/g dry soil (Al-Thani and Mahasneh, 2002). On the contrary, in the non-rhizospheric soil of the salt marsh at Al Dhakhira area, the same researchers found that the total bacterial count was 0.6 x 10^5 cfu/g dry soil. It is clear that the bacterial counts recorded in the present study were higher than those obtained by Al-Thani and Mahasneh, (2002) for a salt marsh in the same locality at Al-Dakhira region.

Many factors seem to participate in lowering halophilic counts of bacteria, as the poor physicochemical properties of the soil, high salinity level and flooding conditions which dilute nutrients and create improper aeration and reduce the decomposition rates of the soil organic matter (Zaki *et al.,* 1980). Moreover, the nature of root exudates (Alexander, 1977; Zahran, 1999) as well as the increase in the number of detritivores such as meiofauna which feed mainly on bacteria (Wahbeh and Mahasneh, 1984; Bardgett and Griffiths, 1997) participate with the abovementioned factors in inducing reductions in bacterial counts.

It is assumed that the high moisture content and organic carbon in the soil supporting the vegetation of the zones I and II stimulate the production of high bacterial counts which ranged from 3.8 x 10^5 to 5.8 cfu x 10^5 cfu/g soil cfu/g soil in the rhizospheres of *A. macrostchyum* and *A. marina*, respectively. On the contrary, the low soil moisture and the high saline conditions in zone V possibly resulted in the observed low bacterial counts in the rhizosphere.

The predominance of the Gram-positive bacilli and cocci in the majority of rhizosphere and soil isolations of the study area is well documented in saline habitats (Zahran *et al.*, 1992, 1995; Al-Thani and Mahasneh, 2002). The occurrence of small fraction of streptomyces bacteria (=9.1% Of the total isolates of other forms) in the rhizosphere of *Z. qatarense* agrees with Yokoyama *et al.* (1992) who explained that this group is less tolerant to salt stress in comparison to other forms of bacteria. Moreover, the actinomycetes represent only a small fraction of the bacterial flora of saline soils (Quesada *et al.*, 1982; Zahran *et al.*, 1992).

The occurrence of 60% of the isolates with white and off-white colonies was represented in soil and rhizosphere bacteria of the study area. Our findings partially agree with Lindow and Brandl (2003) who state that pigmented bacteria are rarely found in the rhizosphere. Pigmentation has been presumed to confer protection of the epiphytic bacteria against the UV radiation. The pigmented bacteria represented 40% of the bacterial flora isolated from the soil and rhizosphere of the study area at Al Dhakhira. Such observations deserve further studies.

4.3. Aqueous washings of the green and senescent parts and their relation to the surface bacterial populations

It is well known that both organic and inorganic materials are deposited on the outer surfaces of the plants (Godfrey, 1976; Fahmy, 1991; Ouf, 1993; Fahmy and Ouf, 1999). Some of these materials originate outside the plant as deposits from the atmosphere such as mineral particles, air pollutants (Fahmy *et al.*, 2004), pollen grains and rainwater. The greater proportions, however, have their origin within the plant, pass through the outer tissues and finally leached on the surface.

The majority of the materials deposited on the surface of the succulent halophytes have their origin from the atmospheric deposits and from within the plant (Fahmy and Ouf, 1999). Moreover, the deposits on the surface of the recretors have their origin from within the plant; where the materials diffuses outside the epidermal cells, as well as, from the activity of the epidermal salt glands or other glandular structures (Thomson, 1975; Lüttge, 1975,Fahmy, 1991; Batanouny *et al.*, 1992; Fahmy and Ouf, 1992).

Godfrey (1976) indicated that the leachates may have a direct effect on microorganisms, either stimulating or inhibiting growth. As the effect is one of stimulating spore germination and growth, it is usually regarded as nutritional and attributed largely to the carbohydrates and amino acids present. Despite the contents of soluble sugars and total amino acids in the aqueous washings of the green parts of recretors were higher than in those of the succulents, the bacterial count of the formers was lower than the latters. This appears to be largely attributed to the presence of high contents of sodium and chloride ions in the aqueous washings of the recretors. These ions were largely resulted from the activity of the epidermal salt glands. Accordingly, the excreted salts possibly exerted salt stress which affects the colonization and growth of bacteria on the phyllosphere of recretors. ●uf (1993) compared the fungal density on the surface of the angiosperm root parasite *Cynomorium coccineum* with those on the surfaces of halophytic host and healthy plants. He found that the high fungal density on the parasite surface was attributed to the presence of high contents of sugars and amino nitrogen in its aqueous washings in comparison to those of the host and the non infected plant. Studies indicate that the carbon containing nutrients on the leaves are major determinants of the epiphytic bacterial colonization (Mercier and Lindow, 2000; Lindow and Brandl, 2003).

In the case of senescent parts, the coupling of their low water contents and the high contents of salt in their leachates created consequent changes in their surface microhabitat. Therefore, the pattern of bacterial counts on the surfaces of senescent parts was dependent on the ability of populations to metabolize leachates on the phylloplane. As evidence of the membrane damage and consequent occurrence of leachates, was the high salt content in the aqueous washings from the senescent parts. Blum and Ebercon (1981), Fahmy and Ouf (1999) reported greater leakness of older plant parts as a result of desiccation. It is concluded that the chance of spore survival and bacterial growth,on green parts of succulent and salt recerting halophytes of the present investigation,seemed to be better than on senescent parts,which had high salt content in their leachate. Some exceptions were found in *A. machrostchyum*, *Z. qatarense* and *Sporobolus arabicus* where the bacterial counts on the senescent parts were higher than on the green ones. An explanation may be valid in the case of succulents (*A. machrostchyum*, *Z. qatarense*) where the high contents of metabolic products in the aqueous washings of the senescent parts may possibly favoured high bacterial colonization in comparison to the green parts.

The predominance of Gram positive bacilli in the bacterial isolates from the green and senescent parts is well documented in saline habitats and reflects tolerance to salinity stress (Zahran *et al.*, 1995; Al-Thani and Mahasneh, 2002).

The occurrence of low percentage of coloured colonies among the bacterial isolates from green parts (orange colonies= 12.5% of isolates) and senescent parts (yellow and pink colonies= 25% of isolates) are not in agreement with several studies on the ecology of the phyllosphere (Stout, 1960; Lindow and Brandl, 2003).

Due to their relatively wide laminae and the presence of salt crusts excreted by the epidermal salt glands, it is suggested that the leaves of *A. marina* and *L. axillare* will heat faster and cool slower than the leaves of other recretors of this study. Accordingly, the coupling of pigmented bacteria on the leaves of *A.marina* (orange colonies) and on *L. axillare* (pink colonies) possibly provide the bacterial colonists with options to avoid salt and high temperature stresses.

4.4. Biochemical characterizations of the isolates from soil, rhizosphere and phyllosphere

A common observation in the soil, the rhizosphere and the phyllosphere of different salt marsh plants of the present study was the occurrence of bacterial isolates capable of utilizing various substrates. These activities were apparent from the examination of the ability of the isolates of each halophytic plant to attack (or to show positive reaction) the 9 substrates of the biochemical tests. The results showed that the isolates of the soil, the rhizosphere and the phyllosphere were able to attack at least 50% of the test substrates. This indicates that the soil and the shoot surfaces of the halophytic species have sufficient metabolites necessary to support bacteria which have diverse biochemical activities that enable them to deal with various nutrients of the salt marsh.

All the bacterial isolates were aerobic; since they were catalase producers. The isolates were able to metabolize various substances as nitrogen sources (gelatin) or carbon (such as starch and lactose). The absence of enteric bacteria among the isolates was apparent since they showed no activities in indol production.

The absence of bacterial isolates having urease activity in the phyllosphere agrees with the well known fact that urease producing isolates are mainly present in the soil (Hogarth, 1999; Zahran, 1999) . On the contrary, the low percentage of urease producing bacteria in the soil reflects two possibilities. First, the saline conditions may inactivate the urease action. Second, the soil bacteria depend on other sources to obtain their nitrogen requirements. This assumption is valid since the isolates of the rhizosphere and soil showed positive gelatin liquefaction activity.

Despite the positive redox potential values of the rhizosphere and non rhizosphere were positive (ranged from +37 to +78.6 mV) they are considered low and reflect low oxygen availability. Well aerated soils have a redox potential of up to + 800mV and poorly aerated soils of up to - 350 mV (Schulze *et al.*, 2005).

Although total nitrogen levels in salt marsh soils may be comparable with those in many fertile inland soils, the amount of biologically active available forms of nitrogen are low (cf. Adam, 1990, p. 265). The majority of the soil nitrogen is in the form of organic nitrogen compounds which break down very slowly (Abd.Aziz and

Nedwell, 1979). In the salt marsh, the availability of inorganic nitrogen is possible through the decomposition of organic nitrogen to ammonium (NH^{4}) particularly under anaerobic conditions (Hogarth, 1999). Although some may be lost to the atmosphere, the bulk is probably oxidized by aerobic bacteria, first into nitrite, then into nitrate ions. This process is termed nitrification. Nitrate may be taken up by roots; it may be assimilated by bacteria and immobilized; or it may be reduced by further anaerobic bacterial action into ammonia, gaseous nitrogen or nitrous oxide (Coyne, 1999). The last process is termed denitrification. The anaerobic conditions in the salt marsh soils will tend to promote denitrification (Adam, 1990). This may explain why a high percentage of bacteria isolated form the soil and the rhizosphere (72.7 % of the total isolates) of the study area exhibited positive nitrate reduction test.

The presence of roots, root exudates and aboveground litter production affect the soil matrix and microbial population activity, which results in increased productivity (Coleman, 1994). The organic fraction of the soil contains the substrate needed for microbial development, which makes microbes the most abundant group in the soil system (Alexander, 1977). Studies have indicated that by grazing on the bacterial and fungal populations, micro- and mesofauna, such as protozoa and nematodes maintain a dynamic biological equilibrium of terrestrial habitats (Griffiths and Bardgett, 1997). Our data revealed that the total bacterial count in the rhizosphere of the studied halophytes was higher than in the non-rhizosphere soil. Since the mean percentages of incidence of the biochemical tests of bacteria in the non-rhizosphere soil were higher (58.5%) than those in the rhizosphere soil (50.5%), we assumed that the presence of protozoan and invertebrate populations in the rhizosphere would rather have effects on the metabolic activities of the colonizing bacteria than on the bacterial count. Another explanation for the observed relatively low percentages of incidence of biochemical activities of the bacteria in the rhizospheres of the studied halophytes is the possible release of some allelochemicals from the roots which may affect the microbial metabolism. Melnitchouck *et al.* (2005) have shown a significant increase in water-soluble exudates that could be leached from the rhizosphere during the day compared to the night from 5-week-old maize grown in containers of unsterilized soil. These compounds included phenols and lignin monomers. More studies are recommended to clarify the release, nature and antimicrobial actions of allelochemicals from the living roots of plants from arid lands.

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محتواها من الصوديوم و الكلوريد و البوتاسيوم و بارتفاع محتواها من الكالسيوم و المغنسيوم مقارنة بالمستخلصات المائية من أسطح النباتات مفرزة الأملاح. تميزت أسطح الأنواع النباتية المفرزة للأملاح بكثافة قليلة من البكتريا. و بصرف النظر عن طريقة مقاومة الملوحة في الأنواع النباتية المستهدفة (العصيرية و إفراز الأملاح عن طريق الغدد الملحية) كانت كثافة البكتريا علي أسطح الأعضاء النباتية الخضراء أعلي من الأسطح المسنة. تميزت أسطح الأعضاء النباتية الخضراء بسيادة البكتريا العصوية موجبة صبغة جرام و بانخفاض النسبة المئوية للعزلات البكتيرية التي تكون مستعمرات ملونة.

تم التعرف علي النشاطات الكيماوية الحيوية للبكتيريا المعزولة من كل نوع من النباتات الملحية المستهدفة عن طريق مقدرة البكتريا المعزولة علي تحليل تسعة مواد عضوية مختلفة. أظهرت الاختبارات أن البكتريا المعزولة من التربة ومن المناطق المحيطة بجذور ثمانية أنواع من النباتات الملحية قد تمكنت من تحليل ٥٠% علي الأقل من المواد العضوية و يدل ذلك علي أن الظروف البيئية السائدة علي أسطح المجموع الخضري و علي جذور النباتات الملحية و في التربة غير المحيطة بالجذور تساعد علي تواجد أنواع من البكتريا التي تتميز بقدرات و نشاطات كيميائية تمكنها من التعامل مع الأشكال المختلفة من المواد العضوية في بيئة المستنقعات الملحية الساحلية.

ملخص

أجري هذا البحث أثناء موسم الجفاف في المستنقعات الملحية الساحلية لمنطقة الذخيرة في دولة قطر لدراسة الكساء النباتي و صفات التربة و البكتريا المتواجدة فيها و علي أسطح النباتات الملحية. عزلت البكتريا من التربة و من المنطقة المحيطة بجذور أحد عشر نوعا من النباتات الملحية ومن أسطح المجموع الخضري لثمانية أنواع. أجريت دراسات شكلية و كيميائية حيوية علي البكتريا المعزولة و تحاليل للتعرف علي المكونات الكيماوية للمواد الموجودة علي السطوح الخارجية للأعضاء الخضراء و المسنة في ثمانية أنواع من النباتات الملحية تنتمي إلي المجموعتين المفرزة للأملاح و العصيرية. تهدف التحاليل إلي التعرف علي إمكانية وجود علاقات بين طبيعة المواد الموجودة علي أسطح النباتات الملحية و أنماط تواجد البكتريا عليها.

طبقت طريقة تقاطع الخط لدراسة النسبة المئوية للغطاء النباتي في منطقة الدراسة. و تم تسجيل ثلاثة عشر نوعا من النباتات الملحية تنتمي إلي أربعة أقسام من أشكال من الحياة و هي النباتات الظاهرة و فوق السطحية و نصف المختفية و الحولية. وجدت الأنواع النباتية موزعة في مناطق محددة في منطقة الدراسة. أمكن تمييز كل منطقة منها بالنوع السائد فيها و تعريف خمسة مناطق رئيسية هي: منطقة يسود بها القرم و منطقة يسود بها القلام و منطقة يسود بها الثيلوث و منطقة مختلطة و أخيرا منطقة يسود بها الهرم القطري. تميزت العشائر الساحلية و الشاطئية بتعرضها للأجهادات البيئية المتمثلة في الغمر بماء الخليج ذو الملوحة العالية. تعرضت البيئات الداخلية التي تقع بعيدا عن الساحل إلي ظروف جفاف التربة و التي تميزت بقلة محتواها من الأملاح الذائبة و الكربونات الكلية و الكربون العضوي و محتوي التربة من حبيبات السلت، مقارنة بالبيئات الساحلية التي يسود بها القرم و القلام.

تميزت التربة المحيطة بالجذور بارتفاع محتواها من أعداد البكتريا مقارنة بالتربة غير المحيطة بالجذور. كانت كثافة البكتريا في التربة التي تنمو بها النباتات الملحية الساحلية أعلي من التربة التي تنمو بها الأنواع النباتية الداخلية أو البعيدة عن الساحل. سادت البكتريا الكروية موجبة صبغة الجرام في التربة و المنطقة المحيطة بالجذور و سادت البكتريا المكونة المستعمرات بيضاء اللون في التربة المحيطة بالجذور.

تم أجراء تحاليل كيماوية علي المستخلص المائي للمواد المغسولة من علي أسطح المجموع الخضري للتعرف علي المواد الرئيسية غير العضوية و العضوية. تميزت المستخلصات المائية لأسطح الأجزاء الخضراء و المسنة في الأنواع النباتية العصيرية بقلة

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