

Introduction to the Ecology of the Littoral Halophytes of Yemen

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ABSTRACT. The coastal belts of Yemen (about 1950 Km) extend along the Red Sea coast (about 550 Km) and the Gulf of Aden Coast (about 1445 Km). In both coastal belts the climate is arid, hot and dry. Soil is of the aridosols type: sandy, saline and contains considerable amounts of calcium carbonates.

The littoral halophytes of Yemen are grouped under six types: seagrasses, mangroves, salt marshes, sand dunes, reed swamps and palm groves. The common species of these types include: *Cymodocea* spp., *Halophila* spp., *Halodule uninervis*, *Avicennia marina*, *Typha domingensis*, *Phragmites australis*, *Cyperus* spp., *Arthrocneumum glacum*, *Halopeplis perfoliata*, *Suaeda* spp., *Salsola* spp., *Tamarix* spp., *Zygophyllum album*, *Halopyrum mucronatum*, *Hyphaéne thebaica* and *Phoenix dactylifera*.

Yemen is located in the South Western corner of the Arabian Peninsula (Fig. 1). Being in the cross-road between Asia and Africa, its flora comprises elements of both continents. Many of these taxa are unique within the Arabian Peninsula.

The first scientific report about the flora of Yemen was that of Försskal (1775) followed by those of Fresenius (1834), Deflers (1986), Schweinfurth (1894-1899, 1912) and Blatter (1914-1916). The other published works include: Schwartze

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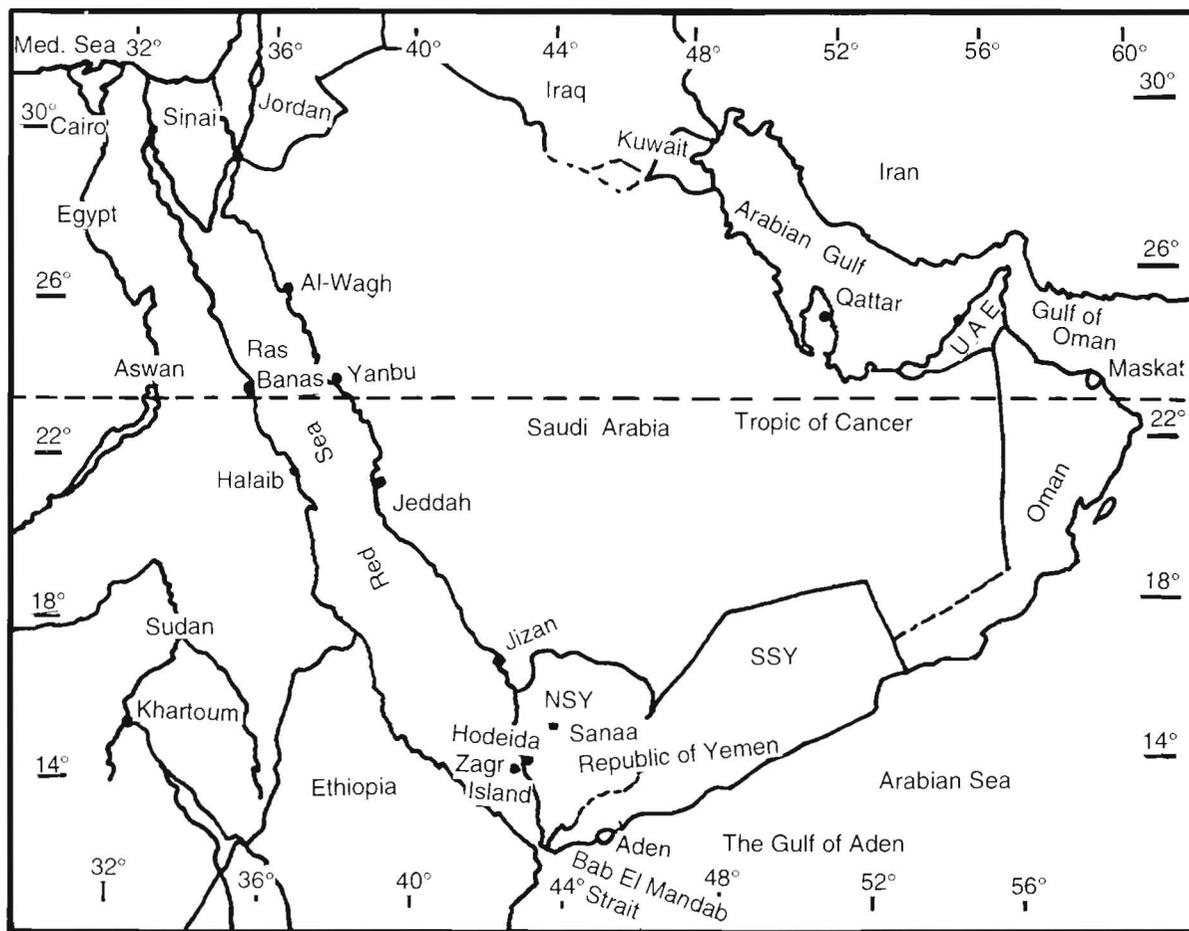


Fig. 1. Map of the Arabian Peninsula showing the location of Yemen.

NSY = Northern Section of Yemen.

SSY = Southern Section of Yemen.

(1939), Lavranos (1975), Newton (1980), Boulos (1988), Gabali and Al-Gifri (1990, 1991) and Dubaie and Al-Khulaidi (1993).

Yemen has a rich flora with an estimated 3000 species in the Northern and Southern sections of Yemen by far the greatest diversity in the Arabian Peninsula. One third of these species are belong to the Sahro-Arabian origin, the remaining two-thirds are of the Sudanian origin. There is a great similarity between the flora and the vegetation of Yemen and the flora and the vegetation of NE Africa, that can be combined in the same Eritrea-Arabian geographical region. This region includes: Yemen, Ethiopia, Somalia, Djibouti and the SW part of Saudi Arabia. Also, Yemen may be considered as one of the centers of succulent distribution compared to Mexico, Chile, South Africa and Madagascar. The variety of succulents is large with a considerable number of endemic in Yemen (Scholte *et al.* 1991).

The published studies on the ecology and the vegetation of Yemen are not comprehensive. These include: Kerfoot (1961), Hepper (1977), Hepper and Wood (1979), Deil and Müller-Hohenstein (1983), Al-Hubaishi *et al.* (1990), Gabali and Al-Gifri (1991) and Scholte *et al.* (1991). None include a phytosociological analysis of the different vegetation types of Yemen. Thus, a scientific long term project aiming at studying the vegetation of Yemen and its ecological relationships deserves to be encouraged. The present paper includes introductory ecological notes on the halophytic vegetation types of the coastal belts of Yemen.

Materials and Methods

The study coastal belts were visited during 1992-1993. Plants collected were identified according to Täckholm (1974) and Migahid (1978). Samples collected from the soils of the different communities were analysed following Jackson (1962).

The Study Area: Coastal Belts

Location and Geomorphology:

Yemen lies at the base of the Arabian Peninsula between latitude 12° 40' N and 19° N and longitudes 42° 30' E and 53° E with an area of about 500,000 km² (Fig. 1). It is bordered at the North by Saudi Arabia, to the South by the Gulf of Aden and the Indian Ocean, to the East by Sultanate of Oman and to the West by the Red Sea.

The coastal belts by Yemen are about 1950 km in length. These coastal belts extend along the Red Sea coast for about 550 km (this represents the Western coastal belt of Yemen) and along the Gulf of Aden coast and part of the Indian Ocean coast

for about 900 km and 500 km respectively, representing its Southern coastal belt.

The Red Sea coastal plain of Yemen (Tihama) is a sandy coastal desert about 30-60 km wide sloping gently from the base of the foothills (at altitudes of 300-400 m a.s.l) of the Red Sea mountains. The Gulf of Aden coast is principally a wide sandy plain backed along most of its length by high mountains which approach the sea in some places with no coastal zone (El-Anbaawy 1985).

Climate:

Over the whole area of the Red Sea basin, winter may extend from mid-October to mid-April with summer occupying the rest of the year. The January mean daily temperature ranges from about 20 °C in the far North to about 29 °C in the far South. The correspondingly July figures being 35 °C and 40 °C, respectively. In the Yemen section of the Red Sea, the mean daily maximum and minimum temperatures range between 41.1 °C and 24.7 °C in summer (July) and 30.1 °C and 18.3 °C in winter (January) respectively, (Anonymous 1993).

Along the Red Sea coast, humidity increases from North to South. In the Yemeni section, the monthly means of relative humidity range between 83% and 90% for the maximum values and 41% and 57% for the minimum values daily variations are rather great. During January 1983, for example, the means of daily maximum and minimum values were 99% and 54% while in October 1989 the corresponding figures were 98% and 39% respectively (Anonymous 1993).

Rainfall over the Red Sea coasts as a whole is sparse and occurs sporadic and often very localized. A particular location may receive no rain for months or years, then it experiences a brief heavy rainfall which may not be repeated for a similar lengthy period. This can be observed in available data of the rainfall over Hodaydah coast. During 1989, the total annual rainfall was 207.3 mm distributed between January (31.4 mm), February (10.5 mm), March (56.4 mm) and April (89.0 mm). In 1988, the total annual rainfall was 127 mm distributed between April (39.0 mm), August (61.4 mm) and September (27.5 mm). These two years were exceptionally wet. However, the mean annual at Hodaydah coast usually ranges between 35-60 mm, mainly during October-April period (Anonymous 1993).

The Southern coastal belt of Yemen (Gulf of Aden coast) is influenced by two distinct monsoon seasons: the SW monsoon of the Indian Ocean that occurs between May and September and the NE monsoon which occurs between October and April. Although the term 'monsoon' generally implies heavy seasonal rains, both monsoons of Yemeni Southern coastal belts are dry. The means of the annual,

maximum and minimum temperatures are: 32 °C and 31 °C and 25 °C and 25 °C, respectively. The highest temperature usually occur in June (37 °C) and the lowest minimum temperature in January (19 °C). Relative humidity in this coastal belt varies within narrow range: between 56-58% in December, as the lowest values, and 73-75% in September, as the highest values. The mean annual relative humidity ranges between 65 and 66%. Precipitation, generally low, may occur in all months of the year except June. The total annual rainfall ranges between 39 mm and 63 mm.

Soil Properties:

The climatic aridity of the Yemeni coastal belts have pronounced effects on their edaphic characteristics. High temperature causes increase of water loss from soil and as precipitation is low there is insufficient leaching and salts accumulate particularly on the surface layers. Surface salt crusts are a common features in the sabkhas of these coastal belts.

Representative soil samples were collected from different habitats of Yemeni coastal belts. The results shown in Table 1 indicate that these soils are generally sandy in texture, salt affected, alkaline in reaction and contain a considerable amounts of carbonates (estimated as calcium carbonates).

The substratum of the mangrove is muddy (the proportions of salt and clay are 38% and the sand fraction constitutes 62% of the soil), black in colour due to its high contents of humus and foul smelling. Its calcium carbonate content (34%) is highest among the soils of the other habitats but it contains the relatively smallest amounts (1.8%) of soluble salts. On the other hand, the sabkhas (salt marshes) contain the highest amounts of soluble salts ranging between 10.3 and 16.0% on the surface layers and 4.2-8.9 in the subsurface layers. On the sandy soils of palm groves, soil salinity ranges between 3.4 and 2.3%. In the surface and subsurface layers, respectively. The main bulk of the soluble salts in all soil samples is formed of chlorides and sulphates. Bicarbonates, however, occur in smaller amounts whereas carbonates are nil.

Except for the mangrove muddy soil, the sand fraction forms the major constituent of the soils of the Yemeni coastal belts with values ranging between 74-85% and 72-74% in the surface and subsurface layers (for the sabkhas soils) and up to 88% and 87% on the palm groves soils, respectively. The pH values indicate that the soils of the mangroves and palm groves are slightly alkaline (pH = 7.4 and 7.5, respectively). The soils of the salt marshes are moderate to high alkaline (pH = 8.2-9.2).

Table 1. Results of the physical and chemical analysis of soil samples collected from the coastal belts of Yemen. RS = Red Sea coast, GA = Gulf of Aden coast, TSS = Total Soluble Salts

Locations	Sample No.	Depth (cm)	Soil texture			pH	Chemical analysis						
			Sand	(% Silt)	Clay		CaCO ₃ (%)	Soluble salts (%)					
								TSS	Cl	SO ₄	HCO ₃	CO ₃	
A. RS a. Mangroves	1	0-30	62	24	14.0	7.5	34.0	1.8	0.6	0.39	0.09	0.0	
	b. Sabkhas	2	0-20	76	18	6.0	8.9	32.4	16.0	6.4	4.60	0.92	0.0
		3	20-40	72	20	8.0	8.4	31.8	8.9	4.2	3.10	0.73	0.0
	c. Palm groves	4	0-30	85	10	5.0	8.6	33.3	10.8	4.7	3.00	0.61	0.0
		5	30-60	74	19	7.0	8.2	32.6	4.2	2.2	1.40	0.28	0.0
		6	0-25	88	11	1.0	7.4	32.1	3.4	1.4	0.85	0.12	0.0
			7	25-50	87	10	3.0	7.5	31.7	2.3	0.9	0.90	0.08
B. GA a. Sabkhas	8	0-20	75	19	6.0	9.2	31.5	10.3	4.2	3.60	0.74	0	
	9	20-60	70	22	8.0	8.9	30.7	5.2	1.7	1.30	0.3	0	
	10	0-25	74	21	5.0	8.5	32	9.5	3.9	2.50	0.56	0	
	11	25-50	72	19	9.0	8.2	30.1	6.4	1.2	1.00	0.2	0	

The Littoral Halophytes:

The littoral belts of Yemen along the Red Sea and Gulf of Aden extend landward to the limits of the extremes of tidal inundation, sea-water spray and underground water seepage. These belts offer a large variety of littoral habitats where different types of halophytes grow. Apart from being tolerant to high soil salinity and climatic aridity, these halophytes have considerable stabilising abilities.

Six vegetation types are recognized in the Yemeni coastal belts, namely: seagrasses, mangroves swamps, reedswamps, salt marshes (sabkhas), sand dunes and palm groves.

1. *Seagrasses:* Seagrasses are rooted plants which require soft sediments for colonisation. Once established they collect and consolidate sediments by slowing water movement within the bed, thus stabilising coastal sediments.

Seagrass beds occur from the mid-intertidal to about 50 m depth on a wide range of substrates, from mud to coarse sand, being most common in shallow water, soft-bottom habitats. The upper limits of distribution are determined by instability of substrate or exposure to low tide. Lower limits for plant growth are determined by light availability. Some genera can tolerate low salinity (10‰) and low water temperature (> 0 °C), different species can tolerate elevated salinities and temperature, MEBA (1992), and Parsons (1992).

In Yemeni coastal belts, there are a number of factors limiting the absolute area for seagrass colonisation (IUCN/PERSGA 1987). These include diurnal tidal range and seasonal changes in mean sea level. In addition, freshwater flush flooding and groundwater seepage, providing nutrients and substrates, may have particular implications for seagrass productivity.

Despite the fact that shallow waters are extensive in the shorelines of Yemen, seagrass beds are not particularly widespread. Many of these shallows are often not sufficiently sheltered and substrates are unstable. The water is very turbid resulting in a limited light availability and high sediment loads when suspended materials settle down during calm period. Seasonal changes in mean sea level restrict regular tidal inundation of the upper intertidal to only part of the year. During this time, the pioneer sea weed: *Halodule uninervis* (Förssak) Asch., may colonise. Apart from *H. uninervis*, the sea weeds of Yemen comprise: *Halophila stipulacea* (Förssk.) Asch., *H. ovalis*, R.Br. Hook. f. *Cymodocea serrulata* (R. Br.) Asch. and Magn., *C. rotundata* (Ehr. and Hempr.) Asch. and Schweinf. *C. cilita* (Förssk.) Ehr. Asch and *Posidonia oceanica* (L.) Del.

The number of seagrass beds increases from North of the Red Sea towards South. In the Gulf of Aden, seagrass beds usually occur in more sheltered areas particularly in Hadrmout, Khawnomara and Hemi Bay (IUCN/PERSGA 1987).

2. *Mangrove Swamps*: The usual habitat of the mangal vegetation of the Red Sea is the shallow water along the shorelines especially in protected areas: lagoons, bays, corals or sand bars parallel to the shore (Kassas and Zahran 1967). According to IUCN/PERSGA (1987), the diversity and productivity of mangroves and their associated taxa in many parts of the world are generally higher than those found in the Red Sea and Gulf of Aden coasts. No major deltaic regions characterized by dense growth of mangroves exist in the coastal belts of Yemen.

Avicenia marina (Förssk.) Vierh. constitutes the main bulk of mangrove vegetation in Yemen, where its community occurs in narrow, discontinuous and pure strips. Two other mangrove species have been recorded from the Yemen shorelines, namely: *Rhizophora mucronata* Lam. and *Bruguiera gymnorhiza* (L.) Lam. According to IUCN (1986), *Rhizophora mucronata* occurs in Khawr Katik near Hodaydah fringing one small island. A few small scattered individuals of *Rhizophora mucronata* are also found nearby the coasts. The total area of *Rhizophora mucronata* in the Red Sea coast of Yemen is likely to be less than one hectare. It exists also in the Gulf of Aden coast (Bir Ali) and in a small lagoon west of Mour Airport of Socatra Island. Draz (1956) recorded a single tree of *Bruguiera gymnorhiza* in Hodaydah coast of Red Sea. IUCN/PERSGA (1987) mentioned that *Bruguiera gymnorhiza* was not found during their recent survey. The present authors, also did not record it.

Al-Hubaishi and Müller-Hohenstein (1984) stated that, there are extensive stands of *Avicennia marina* mangrove along the Northern part of the Red Sea coast of Yemen. IUCN (1987) confirms this statement "most of the *Avicennia marina* forests are found North of Al-Luj where it typically forms a fringe along the shoreline 100-200 m wide and up to 5 m high. Approximately 84 km of the Red Sea Coast of Yemen supports this type of vegetation. Less well developed *Avicennia marina* mangrove adds another 38 km to this figure". This means that 22% of the whole Red Sea coastal stretch of Yemen (550 km) is covered with *Avicennia marina* mangrove. However, the picture is different in the Gulf of Aden coast. Extensive human interference (by the uncontrolled cutting), as well as, heavy grazing have their serious effects on the mangal vegetation. It is hard to find a stand of *Avicennia marina* and/or other mangrove species along the shoreline of the Gulf of Aden.

3. *Reed Swamps*: Reed swamps in the Yemeni coastal belts are associated with

semi-enclosed lagoons which allow salinities to drop during low water. In some of these lagoons the water is only slightly brackish. Consequently encrustations were evident in some other areas (IUCN 1986). These reed swamps are dominated by *Typha domingensis* Pers. with *Phragmites australis* (Cav.) Trin. ex. Steud. as abundant or co-dominant species. The other associated species are: *Cyperus conglomeratus* Rottb., *C. rotundus* L., *Fimmbristylis* sp., *Scirpus tuberosus* Desf. and *Echinochloa colonum* (L.) Link. The saline fringes of the reed swamp lagoons are vegetated with halophytes e.g. *Tamarix nilotica* (Ehrenb.) Bge. *Cressa cretica* L., *Zygophyllum album* (L.f.), *Aeluropus lagopoides* (L.) Trin. ex., Thwaites, and *Cyperus laevigatus* L.

4. *Salt Marshes (Sabkhas)*: Much of the Yemeni Red Sea littoral belts is low lying and is seasonally inundated leading to the formation of sabkhas. These sabkhas dry out seasonally to form abiotic salt pans. Some of these sabkhas may partly reflect a previous 2 +m sea level rise about 4000-6000 years ago (IUCN 1986). Sabkhas usually extend just into the lower intertidal to the point where salinity stress is minimized by regular tidal flushing. Here, it may be slightly overlapped with intertidal mangroves in soft-bottom habitats.

The extensive sabkhas of the Red Sea coastal belt of Yemen are often bare sand flats covering the shoreline to about 5 km. in land. Extremely saline conditions prevail (T.S.S. > 16%) because the ground water is shallow and evaporation rate is very high particularly in the surface layers. In these highly saline soils, only the salt tolerant plants (Halophytes) grow and predominate. The dominant halophytes in this coastal belt include: *Suaeda monoica* Förssk., *Suaeda vera* Förssk. ex J.F. Gmel, *Suaeda vermiculata* Förssk., *Halopeplis perfoliata* (Förssk.) Bge. ex Schweinf. *Arthrocnemum glaucum* (Del.) Ung.-Sternb., *Salsola baryosma* (Schult.) Dandy, *Zygophyllum album* L. (succulent halophytes), *Tamarix nilotica* (Ehrenb.) Bge. *Tamarix aphylla* (L.) Karst., *Cressa cretica* L., *Limonium axillare* (Förssk.) Ktze, *Aeluropus lagopoides*, (L.) Trin. Thwaites, *A. massauensis* (Fres.) Mattei, *Sporobolus spicatus* (Vahl.) Kunth and *Atriplex* spp. (excretive halophytes).

According to Al-Gifri (1991), Al-Gifri and Hussein (1993), Gabali and Al-Tifri (1991) and Thulin *et al.* (1992), the littoral salt marsh vegetation of the Gulf of Aden comprises communities dominated by: *Suaeda monoica*, *S. vermiculata* Förssk., *Tamarix nilotica* (Ehrenb.) Bge., *Sporobolus spicatus* (Vahl.) Kunth *Arthrocnemum glaucum* L., *Salicornia fruticosa* L., *Halopeplis perfoliata* (Förssk.) Bge. and *Aeluropus lagopoides* (L.) Trin. Thwaites.

5. *Sand Dunes*: A line of discontinuous sand dunes commonly occur close to the

shorelines of Yemen. These dunes are formed of homogenous sandy slightly saline deposits. Salinity varies but little in the successive layers (0.56%, 0.5% and 0.6%). In the Red Sea coast, *Halopyrum mucronatum* (L.) Stapf., *Zygophyllum album* L. and *Panicum turgidum* Förssk. are also present.

In the sabkhas some dominant halophytes are sand binders. They are capable of building sand hillocks (e.g. *Suaeda monoica* Förssk.) and sand hummockes (e.g. *Zygophyllum album* L., *Halopeplis perfoliata* (Förssk.) Bge., and *Arthrocnemum glaucum* (Del.) Ung. - Sternb.) of different size. Also, the salt tolerant excretive grasses *Aeluropus* spp. may build small sand formations which are cone-like masses of interwoven roots, rhizomes and sands.

The importance of the shoreline sand dunes come from their considerable stabilizing abilities limiting coastal erosion and allowing other less tolerant species (e.g. *Panicum turgidum* Förssk.) to grow.

6. *Palm Groves*: Most of the wadis in the coastal belts of Yemen have outlets into the Red Sea and the Gulf of Aden. This results in a layer of freshwater floating over the sea-water near the coast. There is evidence of freshwater seepage along 98 km. of Yemen Red Sea coast where vegetation varies between dense and sparse (IUCN 1986). It is worth mentioning here that, similar fresh water locations occur in the shoreline of the Egyptian Red Sea coast (Kassas and Zahran 1967).

In contrast to the thin vegetation of the sabkhas, the fresh water vegetation is relatively luxurious. This low salinity tolerance vegetation requires a continuous supply of freshwater which is not sustained by rain but by groundwater supply originating in the highlands behind the inland of the coastal plains. In some places the supply may have originated during historically wetter periods and may weaken as the effect of the more arid conditions of recent take hold.

This palm groves (fresh water) vegetation is dominated by date palms (*Phoenix dactylifera* L.) which form an extensive dense but isolated patches in the Yemeni coastal belts. Dom Palm (*Hyphaene thebiaca* (L.) Mart.) is less common than date palm, possibly reflecting agricultural exclusion resulting from the specific cultivation of the date palms. The Gulf of Aden coast, on the other hand, is characterized by large populations of dom palms and date palms as well.

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مقدمة عن بيئة النباتات الملحية الساحلية باليمن

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تعتبر السواحل اليمنية (١٩٥٠ كم) الممتدة على الساحل الشرقي للبحر الأحمر (٥٥٠ كم) وساحل خليج عدن (١٤٤٥ كم) ضمن المنطقة الجافة بالعالم حيث المتوسط السنوي للأمطار يتراوح ما بين ٣٥-٦٠ مم على ساحل البحر الأحمر ، ٣٩-٦٣ مم على ساحل خليج عدن ودرجات الحرارة عالية حيث تصل إلى ٤١ م ، ٣٧ م صيفاً ، ١٨ م ، ١٩ م شتاءً على ساحلي البحر الأحمر وخليج عدن وتربة هذه السواحل مالحة .

النباتات الملحية الساحلية لليمن يمكن تقسيمها تبعاً للبيئة التي تنمو فيها إلى ستة مجاميع رئيسية هي : الأعشاب البحرية ، مستنقعات الشورى (المانجروف) ، المستنقعات الملحية ، المستنقعات القصبية ، الكثبان الرملية بالإضافة إلى منطقة النخيل . ومن أهم الأنواع النباتية السائدة ما يلي :

Cymodocea spp., *Halophila* spp., *Halodule uninervis*, *Avicennia marina*, *Typha domingensis*, *Phragmites australis*, *Cyperus* spp., *Arthrocnemum glaucum*, *Halopeplis perfoliata*, *Suaeda* spp., *Salsola* spp., *Tamarix* spp., *Zygophyllum album*, *Halopyrum mucronatum*, *Hyphaene thebaica* and *Phoenix dactylifera* .

*١- العنوان الدائم : قسم النبات - كلية العلوم - جامعة المنصورة - مصر .