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Assessment of *Avicennia marina* Growth Characteristics on an Artificial Inlet at Bushehr, Iran

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Abstract: The purpose of this project was to asses ecological development of *Avicennia marina* in hyper saline condition. During 2001 and 2002 a restoration mangrove project planting *A. marina* in artificial inlet in Bushehr Province, Iran was carried out in Agriculture and Natural resources research center of Bushehr province in Sabkha lands. Some the vegetative characteristics of such as height, diameter and crown diameter in two aspects were recorded in 2012. To investigate physico-chemical properties of soil were taken in inside and outside of inlet and were analyzed: salinity, soil acidity, potassium, phosphorus, nitrogen, texture of soil were measured. Both of treatments were analyzed by t-test in SAS Software.

Key words: *Avicennia marina*, establishment, hypersaline, Bushehr, Iran

INTRODUCTION

Mangroves are among the most threatened ecosystems in the world owing to high demographic pressures and alteration of freshwater and sediment inflows that nourish and maintain their environment. They have almost disappeared along the East coast of India except in Bengal and continue to face high level of deforestation far exceeding the regrowth capability (Blasco *et al*., 2001). The rapid degradation and removal of mangroves is ascribed to a variety of reasons including fuel and timber extraction, encroachments, brackish water aquaculture and land use change driven by high population densities (Venugopal *et al*., 2010). Estimates of global mangrove losses rate are one million hectares per years (Mohamed, 1996).

Avicennia marina (Forsk.) Vierh (*A. marina*) can be identified by its smooth, green-grey mottled and commonly peeling off bark and its elliptic-oblong or oblong-obovate leaves. The fruit is round to heart shaped, grayish green and measures about 2 cm across. The flowers are commonly orange, small (5-8 mm) and waxy and are identifiable by the odor of a rotten fruit (Tomlinson, 1986). *A. marina* in Bushehr province in Iran has grown in two regions: Bordekhoon (Mond Protected Area) and Assaluyeh (Marine National Park of Nayband).

The mangrove degradation and deforestation are mainly caused by the land-use change, especially the conversion of mangrove forest to aquaculture, urbanization, coastal development and over-harvesting (Duke *et al*., 2007; Donato *et al*., 2011). Restoration of degraded or deforested mangrove sites has only recently received increasing attention, although mangrove restoration projects have been implemented for decades (Stubbs and Saenger, 2002). Elster (2000) stated that mangrove restoration projects have been implemented throughout the world, notwithstanding success or failure.

Stubbs and Saenger (2002) promoted the application of forestry principles to the design, execution and evaluation of mangrove restoration projects and highlighted the concept of site-species matching. In order to select suitable species for any site, it is necessary to assess the soil properties and the factors that determine the site conditions. Furthermore, the selection of suitable species for a given site requires knowledge about the ecological characteristics and site requirements of a certain species and its capability to cope with growth limiting factors. Stubbs and Saenger (2002) pointed out that the most important site factors of mangrove sites are probably: depth and frequency of tidal inundation, degree of water logging [redox-potential of the soil (Eh) and soil water content (%)] and salinity of pore water.

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Saenger (2010) furthermore argues that there is a lack of detailed information on the soil-mangrove relationship, especially the tolerance of mangroves to various salinity levels is still under-studied. In harsh intertidal communities, mechanisms by which plants ameliorate environmental conditions (e.g., shading reduces thermal stress and decreases salinity stress) are particularly important (Bertness, 1991). Likewise, foundation plants that stabilize sediment (Bruno, 2000) or accumulate nutrient-rich sediment (Kumara *et al*., 2010) can also facilitate the success of intertidal plants.

Iranian mangrove forests occur between longitude 25°19' and 27°84' in the North part of the Persian Gulf and Oman sea. In 2002, it was estimated that 93.37 km^2 of Iranian shorelines were covered with mangrove forests with the largest area (67.5 km^2) occurring between the Khamir port and the Northwest side of Qeshm island and the smallest area (0.01 km^2) in the Bardestan estuary. Only two species of mangrove are found in the Persian Gulf: *A. marina* and *Rhizophora macrunata*. *A. marina* is the dominant species in these forests whereas *Rh. macrunata* is found only in the Sirik region. Overexploitation of mangrove leaves and oil pollution are the main causes of mangrove destruction in this region.

In this study, plantation in the artificial inlets is defined as the successful establishment of new individuals in a population. The aim of this study was assessment of *Avicennia marina* growth characteristics on an artificial inlet to determine the effect of desalting in *A. marina* with conductivity of water tides and silt sedimentary in the artificial inlets, Bushehr province, Iran. The data collection was conducted within the frame of an internship in the mangrove restoration project planting *A. marina* in artificial inlet which is implemented by the Agriculture and Natural Resources Research Center of Bushehr province, Iran.

MATERIALS AND METHODS

Study area: This study was conducted in Bushehr province, part of the mangrove forest 39 zones, Iran (latitude 28°56'N, longitude 56°50'E, Fig. 1). The study area is an altitudinal range 0-3 m above sea level. Temperature is 12-16°C in Winter and in Summer to reach 47°C with a total annual rainfall of 227 mm and Winter rainfall often (136.1 mm). *A. marina* dominate the landscape in the plant community in the mangrove forest. High evaporation rates and high relative humidity in the Summer is especially. Wind speeder in Summer than Winter and its intensity increases from morning to evening.

The study area was alluvial soil erosion and sedimentation of adjacent land has been created. Soils with high salinity and this area has geological units Sabkha that these units are extended to the sea and impenetrable clay layer about 20 cm in parts of the gypsum crystal surface is created.

Tidal data from 2009-2010 were taken. Above average high tide events occur frequently during the months of peak mangrove propagule production, providing opportunities for propagule transport. Seeds that were 20-29 mm in length, possessed intact pericarps and had neither insect holes nor any other visible signs of damage were haphazardly distributed to experiment.

Procedure of data collection: Bed preparation operations necessary to prepare the bed include of trapping silt in order to establishment of conditions and provide for the growth of mangroves and disturbing factors are eliminated in 2001. In this regard, 500 m of coastline exposed to erosion and then 5-4 rows along the creek to 50 m, width 1 m and 50 cm deep were dug. These streams were digging 3-5 m distance away from the beach and two

Fig. 1: The study area shown in Iran map

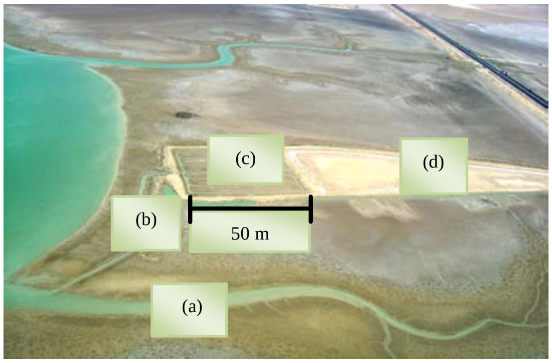

Fig. 2: Artificial inlet for capture of silt and irrigation of plants; a) Natural inlet; b) Water input channel; c) Artificial inlet in two directions parallel and perpendicular to the coastline and d) Road

parallel and perpendicular to the shore. Plantation was done after a 1 year of construction and providing channels, sequestration clay in terms of seedling establishment (Fig. 2).

Planting operations: Seeds collected from the mangrove forest in Male Gonze, Bushehr and seedling were planted within and outside the channel (artificial inlet). When the seedlings reach a approximately 30 cm height then plantation is done. Seedlings were planted in 75×75 centimeter space and 4 or 5 rows along the inlet. Planting of seedlings was performed in 2002. Daily tides were measured using a tides index.

Data analysis: Height (cm by cm accuracy), collar diameter (mm by caliper) and crown diameter in two directions NS and WE (with an accuracy of centimeters to meters) were recorded in 2012.

Furthermore, 15 soil samples were taken at inside and outside of inlet. Soil sample taken from 10-20 cm of soil depth. The samples were taken in the mid of the depth interval, respectively. To investigate the physico-chemical properties of soil were taken in inside and outside of Inlet and were analyzed: Electrical Conductivity (EC), soil acidity, potassium, phosphorus, nitrogen and texture of soil were measured. Grain size and percentage composition of sand, silt and clay in the samples was determined by first ensuring that the dried sample was devoid of clumps of soil and then the sample was sieved. First through a 0.5 mm sieve to separate out the sand grains then the sand grains were weighed. The rest of the sample was sieved through a 0.063 mm sieve to separate out the silt from the clay. The silt and clay were each weighed separately. The weights were recorded and then percentages were determined for each sand, silt and clay by dividing the weight of each by the total weight also recorded and the soil type was identified. This process was repeated for each sample. According to Rhoades *et al.* (1999), soil salinity is defined and can be assessed by the electrical conductivity of the extract of a saturated soil-paste sample (ECe), being a practically and easily measurable index of the concentration of ionized solutes in an aqueous sample.

The data was collect in June 2012. None of the sample plots was inundated by tidal water during data collection. This was possible as all soil samples in a certain distance were independent of inside and outside of inlet. A student test was conducted to determine which means growth characteristics were significantly different between inside and outside of inlet. All statistical analyses have been conducted by using the Software SAS 9.1 utilities.

RESULTS AND DISCUSSION

Mean sea level is 0.91 m and the mean tidal range is 0.60 m. Tides exceeding the mean higher high water (MHHW: Mean of the Highest daily High Water height) tidal datum of 1.29 m which is 0.85 m above the mean lower low water (MLLW: Mean of the Lowest daily Low Water height) are fairly infrequent, comprising less than one third of annual high tide events. However, spring tides occasionally reach 1.56 m in height and are sufficient to submerge the seedling in the interior of the region (*A. Ghasemi*, 2009-2010, personal observation). During normal tides, coastal plains of the study area are flooding and during MHHW of the whole area are under water. Table 1 shows the tides states, height tides and frequency tides, Normal and abnormal tides in the region.

The results suggest a significant difference at 5% statistical error level ($p<0.05$) between the mean soil acidity (8-7/6), electrical conductivity (28-20 Dsm-1), nitrogen, phosphorus and potassium (420-480) content and sand (39-55%), clay (45-22%) and silt percent (16-23%) February 7, 2013 of outside of inlet relative inside of inlet where inside of artificial inlet exhibits more favorable condition. Silt sedimentary inside of artificial inlet had a significant effect on the physico-chemical characteristics of soil compared with outside of artificial inlet. These are summarized in the Table 2.

Table 3 shows mean, maximum and minimum of height (centimeter), collar diameter (millimeter) and crown canopy (centimeter) seedlings in artificial inlet. None of the seedlings planted outside inlet was alive. The mortality of seedling inside inlet is reach in 47%. The density of crown canopy is 54%. Trees inside of inlet are regenerate.

Table 1: Summary of the tide

Tidal	Height (m)	Frequency
High water total	0/85	56-62
High water average	1/02	45-59
High water normal	1/10	20-45
High water in Spring	1/40	2-18
High water abnormal	1/56	2

Table 2: The results physico-chemical characteristics of soil inside and outside of artificial inlet

	Treatments	
Characteristics	Inside inlet	Outside inlet
Soil acidity	7/6	*8
Electrical conductivity (Dsm^{-1})	20	*28
Potassium (ppm)	480	420
Phosphorus (ppm)	6/82	4/33
Nitrogen (%)	0/002	0/001
Clay (%)	22	45
Silt (%)	23	16
Sand (%)	55	39

Table 3: Mean, maximum and minimum of height (cm), collar diameter (mm) and crown canopy (cm) seedlings in artificial inlet

Measurements	Height (cm)	Collar diameter (mm)	Crown canopy (cm)
Mean	138/9	72/2	125/5
Maximum	272/5	112/5	270/0
Minimum	82/8	30/0	50/5

Observation indicated that crown and height growth of trees are approximately good and unregularly establishment. Crown growth are done proportional with a height and diameter growth (Fig. 3). Study shows that with increasing distance from the appropriate distribution of respiratory roots and breathing roots of numbers are increasing trend (Fig. 4).

Sedimentary in artificial inlet had a significant effect on the growth of *A. marina* compared with outside of artificial inlet. General patterns of salt decrement and silt sedimentary in inlet were somewhat challenged at coastlines. In Bushehr, mangrove distribution is mainly controlled by soil salinity and thus by duration of tidal immersions. Mangrove sediments in artificial inlet differ from that of plain coastline sediments because of the continuous inputs of fresh water. As a consequence, physico-chemical characteristics of mangrove sediments are highly variable, mangrove tree species being one of the controlling factors (McKee, 1993). As a result, trees experience anoxic soil conditions more frequently than trees further inland (Ehbrecht, 2012). This constitutes a growth limiting factor as below-ground roots must rely on internal gas transport to fulfill their oxygen requirements (Clough, 1992; Stubbs and Saenger, 2002). Furthermore, strongly anoxic conditions can lead to the formation of hydrogen sulfide and other compounds that might be toxic to plants (Clough, 1992).

The soil acidity, electrical conductivity, nitrogen, phosphorus and potassium content and sand, clay and silt percent improve enter of artificial inlet. Due to sedimentary in inlet the estimations of mean soil contents are quite robust and allow conclusions to a certain extent. the soil properties can be highly dynamic, depending on varying flooding depths and frequencies as well as precipitation patterns, soil texture, tidal height and the resulting varying evaporation. As the analysis of particle size distribution has shown that clay content is highest in the outside zone (about 45%), the availability of soil water to plants is further limited. This constitutes a potential for water stress in dry periods. The decrease of soil salinity from the outside to the inside of artificial inlet is a function of several factors. Saenger (2010) names tidal inundation, soil type, topography, amount and seasonality of precipitation, freshwater discharge of rivers and evaporation as major factors in the regulation of soil salinity. He furthermore states than an inter-tidal gradient in salinity is directly related to the salinity of tidal water, time interval between inundations, rainfall and evaporation rate.

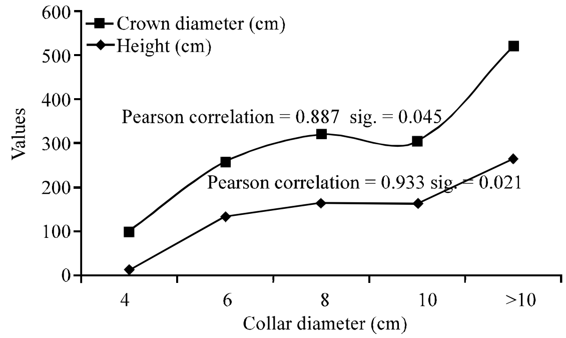

Fig. 3: Crown diameter and height diagram in relation to collar diameter

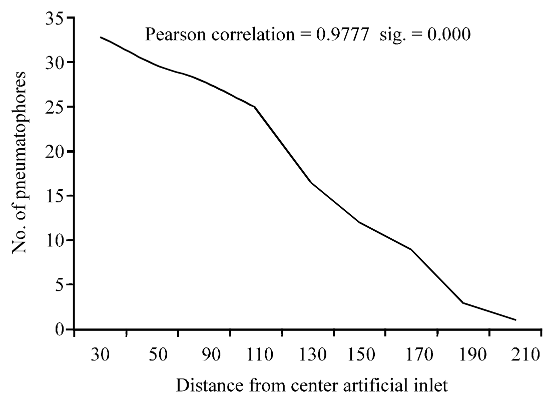

Fig. 4: Relation between number of pneumatophores and distance from inlet diagrams

In contrast to the inside zones, stands well developed forest with a mean height of about 1/4 m, a caller diameter of about 7/2 cm and an crown diameter of about 1/2 cm. A comparison shows that vegetative characteristics of stands in inside zone is more or less similar to what Briggs (1977) found in a primary *A. marina* forest in Australia. The exemplary secondary forest might have had a higher productivity due to more suitable site conditions compared to the examined forest in this study. On the other hand the lower height, caller diameter and crown canopy might be explainable as the examined forest is simply younger in age. Furthermore, anthropogenic impacts in the past and present might be responsible.

After 10 years Halophyte plants such as: *Salicornia herbacea* and *Halocnemum strobilaceum* and animals such as: mudskippers were observed into this area depth and frequency of tidal inundation, the degree of water logging as well as pore water salinity are probably the most important site factors determining species suitability (Stubbs and Saenger, 2002). In some cases, plants facilitate one another through associational resistance to herbivory (Barbosa *et al*., 2009).

Tree growth or successional dynamics are assumed to be the underlying cause of forest zonation whereby accretion processes, depth and frequency of tidal inundation and the mutual interaction of stand and soil are assumed to be the underlying causes of spatial patterns of soil properties. Site conditions have an influence on the growth of seedling which shows a different growth in the artificial inlet. The lack of oxygen availability in Sabkha lands due to frequent inundation by the tides is assumed to be the underlying cause. Trees further in inlet appear as well developed forest where depth and frequency of tidal inundation are adequate frequent. Seedling in outside of inlet show 100% mortality which is assumed to be the result of higher salinities and limited water availability.

CONCLUSION

The result showed that a different significant between inside and outside of inlet in soil acidity, electrical conductivity, potassium content and sand and clay percent. But were not different significant in N and P. After 10 years Halophyte plants such as: *Salicornia herbacea* and *Halocnemum strobilaceum* and animals such as: mudskippers were observed into this area. Sedimentary silt have an influence on the growth of seedling which shows a different growth in the outside and inside of artificial inlets.

RECOMMENDATIONS

In order to support the effectiveness and efficiency of mangrove restoration or reforestation projects, it is recommended to focus further research on mangrove species occurrence in relation to the mentioned limiting factors as proposed by Stubbs and Saenger (2002). To provide more useful information for reforestation efforts, it is necessary to further put an emphasis on prepare condition for specific species to cope with those factors under extreme conditions. In this context it further recommended to study the underlying causes of success or failure of reforestation efforts.

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