INTERACTIVE EFFECT OF PLANTING DISTANCE, IRRIGATION TYPE AND INTERTIDAL ZONE ON THE GROWTH OF GREY MANGROVE SEEDLINGS IN QESHM ISLAND, IRAN

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Received March 2008

MOHAMMADIZADEH M, FARSHCHI P, DANEHKAR A, MAHMOODI-MADJDABADI M, HASSANI M & MOHAMMADIZADEH F. 2009. Interactive effect of planting distance, irrigation type and intertidal zone on the growth of grey mangrove seedlings in Qeshm Island, Iran. The interactive effect of planting distance, irrigation and intertidal zone on the growth of grey mangrove (*Avicennia marina*) seedlings was investigated in Qeshm Island area for a period of 18 months. A total of 720 seedlings in two groups were planted at different parts of the intertidal zone, with two irrigation types and two planting distances. Based on ANOVA, the interactive effect of seedling planting distance, type of irrigation and intertidal zone on seedling growth criteria (stem diameter, height and ratio of stem height to stem diameter) indicated a significant difference ($p < 0.01$). Stem diameter increment of seedling flooded by sea water in lower intertidal zone with planting distance of 0.5 m was greater in comparison with the rest of the planted seedlings. Seedlings irrigated with fresh water in lower intertidal zone with planting distance of 0.5 m had the greatest stem height. The minimum ratio of stem height to stem diameter was found to be in seedlings flooded by sea water in lower intertidal zone and planting distance of 0.5 m. Results of the study could be applied to any other eco-region with the same or nearly the same ecological characteristics.

Keywords: *Avicennia marina*, Persian Gulf, planting method, artificial regeneration

MOHAMMADIZADEH M, FARSHCHI P, DANEHKAR A, MAHMOODI-MADJDABADI M, HASSANI M & MOHAMMADIZADEH F. 2009. Kesan interaktif jarak penanaman, jenis pengairan dan zon antara perbani terhadap pertumbuhan anak benih bakau *Avicennia marina* di Pulau Qeshm, Iran. Kesan interaktif jarak penanaman, pengairan dan zon antara perbani terhadap pertumbuhan anak benih bakau *Avicennia marina* dikaji di Pulau Qeshm selama 18 bulan. Sebanyak 720 anak benih yang dibahagikan kepada dua kumpulan ditanam di bahagian-bahagian berbeza zon antara perbani. Dua jenis pengairan dan dua jarak penanaman digunakan. Berdasarkan ANOVA kami dapati bahawa kesan interaktif jarak penanaman anak benih, jenis pengairan dan zon antara perbani terhadap kriteria pertumbuhan anak benih menunjukkan perbezaan signifikan ($p < 0.01$). Kriteria yang dikaji ialah diameter batang, ketinggian dan nisbah ketinggian batang kepada diameter batang. Peningkatan diameter batang anak benih yang ditenggelami air laut di zon antara perbani yang lebih rendah dengan jarak penanaman 0.5 m adalah lebih besar berbanding dengan anak benih lain. Anak benih yang diairi air tawar di zon antara perbani yang lebih rendah dan jarak penanaman 0.5 m mempunyai ketinggian batang yang paling besar. Nisbah minimum ketinggian batang kepada diameter batang dicerap pada anak benih yang ditenggelami air laut di zon antara perbani yang lebih rendah yang mempunyai jarak penanaman 0.5 m. Keputusan kajian dapat diguna pakai untuk kawasan lain yang mengalami ciri ekologi yang sama atau hampir sama.

INTRODUCTION

Mangroves are found in tropical and subtropical intertidal zones. Mangrove plants protect the coastline from strong currents and support the accumulation of sediments and organic matter in intertidal zones. Mangroves accelerate the rate of accretion as adventitious roots slow tidal flows and encourage deposition (Saintilan & Williams 1999). They provide excellent wood and non-wood byproducts and wildlife habitats.

Unfortunately, development and demographic pressures in many areas have led to widespread overexploitation of the world's mangrove forests

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at a rate faster than they are being regenerated (Bosire *et al.* 2003). Severely degraded mangrove stands could not regenerate naturally without human intervention due to severe alteration of local environments (Ren *et al.* 2008). Several methods are widely used for artificial regeneration and establishment of mangrove stands on a large scale in many countries. These methods include direct planting of seeds or propagules, transplanting seedlings collected from the wild, and raising seedlings and trees from propagules in a nursery, which are then replanted on site (Aboel-Nil 2001).

Individual mangrove species perform optimally in certain tidal zones. Therefore, selection of appropriate sites within the intertidal zone is of high importance for the establishment and growth of mangrove seedlings. *Rhizophora apiculata* seedlings have been reported to show rapid growth in lower than in upper intertidal zones (Kathiresan 2000). Likewise, *Rhizophora mangle* also grew better at lower intertidal positions with deeper water levels and longer hydroperiods (Ellison & Farnsworth 1997). Mangroves showing higher survival at lower elevation are considered to have higher tolerance to higher water level. It has been reported that prolonged inundation resulted in the loss of *Avicennia marina* and its associated flora and fauna (Ye *et al.* 2004).

In general, seedlings planted along or near the tidal line show maximum survivability (Bhat *et al.* 2004). Most seedlings that were established at low and high tidal levels died during the second year of planting and only trees that grow at the mid-tidal level survived (Tamaei 2004).

Selection of appropriate distance of plantation is yet another important factor for establishment of mangroves seedlings. Optimal density of planting depends on species requirement for environmental conditions (Imbert *et al.* 2000). For example, high-density planting of seedlings at 25-cm intervals could increase their survival because a dense patch of seedlings has more resistance to covering with seawater and flotsam than a single seedling (Tamaei 2004).

Most mangroves are facultative halophytes, i.e. they grow better in some salt but do not necessarily require it for growth. Mangroves can grow in a range of salinities, extending from primarily freshwater environments to hypersaline areas. The optimal range of physiological function and growth of seedlings is approximately from 3 to 27 ppt, although salinity optima have been shown to vary with seedling age in that their salt requirements increase with growth (Krauss *et al.* 2008). In general, mangrove vegetation tends to be more luxuriant at lower salinities. High salinity stunts tree growth in *A. marina* stands (Kathiresan 2000).

Natural mangrove stands of Qeshm Island, Iran have experienced unprecedented damages due to overexploitation to the extent that their natural regeneration has greatly declined. Indiscriminate cutting of tree twigs and branches occur all over the region for feeding livestock. Moreover, mangroves are destroyed by camels stepping on their roots. Reforestation and development of mangrove forests is the prime concern of the region.

Human intervention through artificial regeneration seems to be a necessity in this area. Recently, the Forest and Ranges Organization of the Islamic Republic of Iran has initiated the development of a guideline for mangrove plantation. The present research was conducted to demonstrate plantation method for artificial regeneration of *A. marina* specific to the region.

In this study, we hypothesized that planting distance, types of irrigation and planting location (upper or lower intertidal zone) have an interactive effect on the growth of grey mangrove seedlings (stem height, stem diameter and the ratio of stem height to stem diameter).

MATERIALS AND METHODS

Study area

The study area, known as 'Hara Protected Area', is located between Qeshm Island and the southern coast of Iran in Hormozgan province. Hara Protected Area is located at 26° 40'–27° 00' N and 55° 21'–55° 52' E.

In 1972, the main area of mangroves and mudflats (an area of 82 360 ha) was designated as a Protected Area and then in 1975, as a National Park. In July 1976 it was declared as a Biosphere Reserve with an area of 85 686 ha. However, due to the rapid decline of its mangroves and mudflats, it was downgraded to Protected Area in 1980. Figure 1 illustrates the Hara Protected Area and the selected site for grey mangrove seedlings plantation.

Qeshm Island is mostly rocky and barren with average annual rainfall of 200 mm. The mangrove forests are located in an extremely hot, arid region with very low rainfall. The climate is subtropical and summers are extremely hot with temperatures reaching 45 °C. The area has warm desert and semi-desert biome. Relative annual humidity is 64%. During winter, most regional winds blow north-west. The alkaline soil (pH = 7.67) of the field has a very fine texture and is composed of loam, sand and clay and can retain 56.8% humidity when saturated. Electrical conductivity of the saturated soil is 63.5 dS/m while salinity of regional water is 37.5 to 38.5 ppt (Khodadadi-Jokari 2003). High and low tides occur twice a day, each continuing for six hours. The maximum amount of flow reaches 4.6 m in fall and spring, while the minimum amount is 0.3 m in winter and summer. Almost all parts of mangrove trees, except for the crowns, immerse under water at the time of flow. The grey mangrove, *A. marina*, is the dominant plant of the region.

Site selection

An area of about 436.24 m^2 on the intertidal zone of muddy coastlines of the Hara Protected Area was selected for the purpose of this study. The area was divided into two sites. The selected lower intertidal zone is next to the natural grey mangrove stands so that it is protected against tidal energy. The upper intertidal zone is about 20 m away from the grey mangrove stands. The following criteria were taken into consideration for selection of seedling plantation sites: location (appropriate slope, soft texture of soil, full tidal inundation), suitable weather condition, absence of pollutants and accessibility.

Planting process

Due to the presence of mangrove seed predators such as rats and crabs at the selected site, instead of direct sowing, seeds were collected from natural stands of grey mangrove in the region and planted in plastic pots of 17 × 22 cm at the nursery, which is located in the same region of the natural stands of grey mangrove. Seeds were irrigated with fresh water (salinity 0.5 ppt) and kept under the shade for four months to grow into seedlings.

For the second step, about 360 plastic pots of grey mangrove seedlings (50% of total 720 pots planted) were randomly selected and

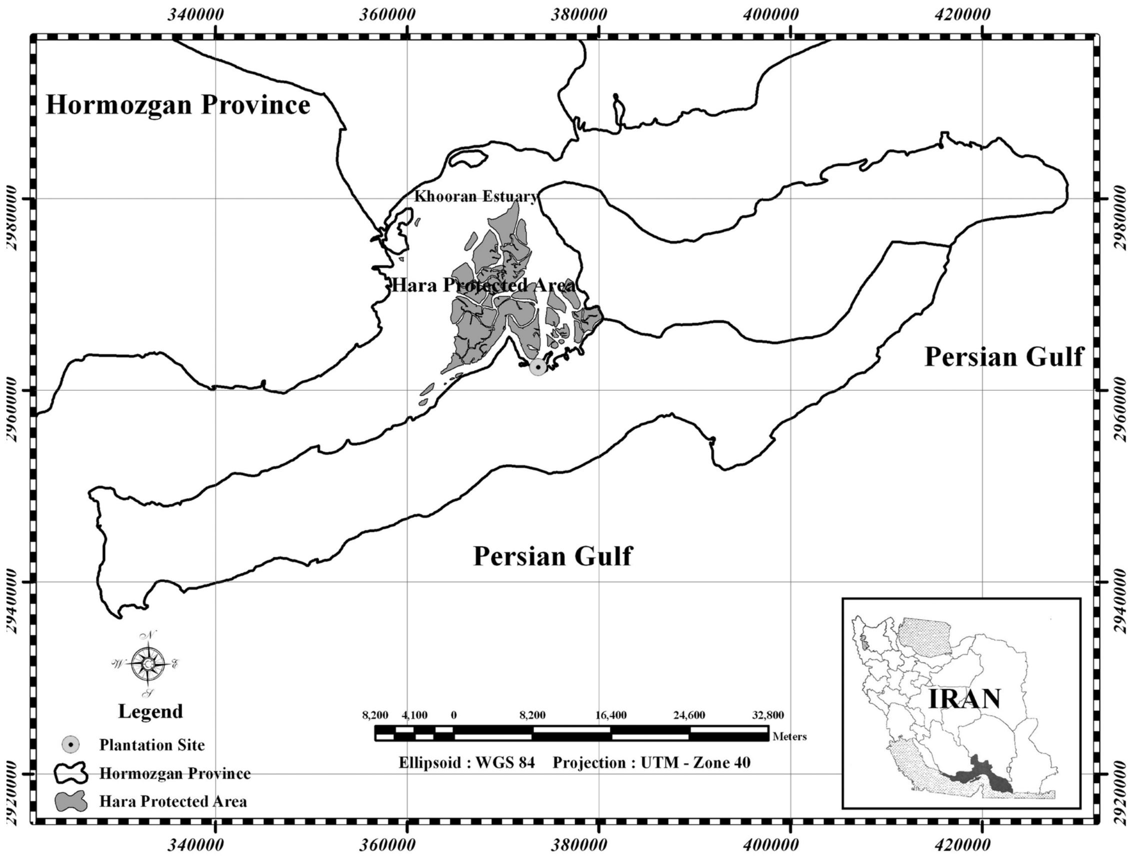

Figure 1 Hara Protected Area and grey mangrove plantation site

transported to the intertidal zone to be flooded by sea waters for three months. These seedlings were considered as 'tidal seedling samples'. The remaining 360 plastic pots of grey mangrove seedlings were retained in the nursery and irrigated with fresh water for three months. These seedlings were considered as 'non-tidal seedling samples'. Finally, after seven months, all seedlings were transferred to the plantation site.

At the plantation site, seedlings were planted in holes of 30 cm depth. Taking care not to damage the root system, the tap root with its root ball intact was inserted into the holes and back-filled with native soil. Seedlings were planted at two upper and lower intertidal zones. Two planting distances, namely, 0.5 and 1 m from each other were maintained for seedling plantation. Non-tidal and tidal seedling samples were also planted at two upper and lower intertidal zones. Two planting distances, i.e. 0.5 and 1 m were planted with 6 and 10 seedlings in each row respectively. All seedlings were then assigned a specific code.

In order to protect the site from cattle grazing (especially camels), the site was fenced by wooden sticks and plastic ropes right after planting. In addition, local inhabitants were successfully convinced to cooperate in protecting the study area through a public awareness programme.

Statistical analysis

In order to measure the growth of mangrove seedlings and to test the hypotheses of this research, diameter and height of all planted grey mangrove seedlings were measured for 18 months. The first series of measurements were carried out at the time of planting and were recorded as control.

Split-plot factorial design (mixed design) specifically three between and one within subject design was used for the purpose of this study. The structured multivariate repeated measurement (Kirk 1995, Sarmad 2005), SPSS 14.0 and STASTICA 7.0 were used to analyse the data. Analysis of variance (ANOVA) was carried out to determine if the impact of variables in the study was significant. Post-hoc comparison was conducted to check for significance of each parameter. Finally Bonferroni test was used for paired comparison within groups.

RESULTS

Not all seedlings survived throughout the 18 months' observation period. Seedlings irrigated by sea water at planting distance of 1 m in upper intertidal zone had a lesser survival rate (38 out of 90) compared with seedlings irrigated by sea water and planted at 1 m distance in the lower intertidal zone (88 out of 90) (Table 1). Seedlings irrigated by fresh water at planting distance of 0.5 m in upper intertidal zone had a lesser survival rate (74 out of 90) compared with seedlings irrigated by sea water and planted at 0.5 m distance in the upper intertidal zone (87 out of 90) (Table 1).

Stem diameter

The largest stem diameter (8.07 mm) was observed in grey mangrove seedlings flooded by sea water in lower intertidal zone with planting distance of 0.5 m (Table 1). Minimum stem diameter growth was found to be in mangrove seedlings flooded by sea water in upper intertidal zone with planting distance of 1 m.

ANOVA results showed that seedling planting distance, type of irrigation and intertidal zone were found to be independently significant variables on stem diameter growth of seedlings ($p < 0.01$) (Table 2). Although the interactive effect of the intertidal zone versus planting distance was not significant, the interactive effects of type of irrigation versus intertidal zone, planting distance versus type of irrigation, and intertidal zone versus planting distance versus type of irrigation were significant (Table 2). Nevertheless, the interactive impact of all variables, including time, was found to be significant ($p < 0.01$) (Table 2).

Bonferroni test performed in order to pursue exact location of the differences among the variables in this study, reconfirmed that mangrove seedlings flooded by sea water in the lower intertidal zone with planting distance of 0.5 m have the maximum stem diameter growth compared with other seedlings. Minimum stem diameter growth was found to be in mangrove seedlings flooded by sea water in upper intertidal zone with planting distance of 1 m.

Stem height

The greatest mean height of stem (58.40 cm) was found among grey mangrove seedlings irrigated

Table 1 Statistical indices of stem diameter (mm) and height (cm) of seedlings categorized based on intertidal zone, planting distance and type of irrigation

	Intertidal zone	Planting distance	Irrigation	Mean	SE	Confidence interval at 95.00%		N
						Lower	Upper	
Diameter	Lower	0.5 m	Fresh	7.48	0.13	7.21	7.74	76
		0.5 m	Sea	8.07	0.12	7.81	8.32	82
		1 m	Fresh	6.76	0.12	6.51	7.01	85
		1 m	Sea	7.85	0.12	7.61	8.10	88
	Upper	0.5 m	Fresh	6.85	0.13	6.58	7.11	74
		0.5 m	Sea	7.34	0.12	7.09	7.58	87
		1 m	Fresh	7.13	0.14	6.85	7.41	67
		1 m	Sea	6.01	0.18	5.63	6.38	38
Height	Lower	0.5 m	Fresh	58.40	1.06	56.31	60.50	76
		0.5 m	Sea	43.12	1.02	41.10	45.14	82
		1 m	Fresh	52.57	1.00	50.59	54.55	85
		1 m	Sea	3.28	0.99	41.33	45.23	88
	Upper	0.5 m	Fresh	51.36	1.08	49.24	53.49	74
		0.5 m	Sea	39.13	0.99	37.18	41.09	87
		1 m	Fresh	54.25	1.13	52.02	56.48	67
		1 m	Sea	39.09	1.50	36.13	42.05	38

Table 2 ANOVA results of the stem diameter of seedlings

Effect	SS	df	MS	F	P
Intertidal zone (IZ)	12 62.23	1	1262.23	51.29	0.00
Planting distance (PD)	614.63	1	614.63	24.98	0.00
Irrigation (I)	172.08	1	172.08	6.99	0.01
IZ * PD	2.03	1	2.03	0.08	0.77
IZ * I	839.95	1	839.95	34.13	0.00
PD * I	195.69	1	195.69	7.95	0.00
IZ * PD * I	704.84	1	704.84	28.64	0.00
Error	14 495.00	589	24.61	-	-
Time (T)	36 266.06	17	2133.30	1735.62	0.00
T * IZ	581.81	17	34.22	27.84	0.00
T * PD	134.44	17	7.91	6.43	0.00
T * I	473.97	17	27.88	22.68	0.00
T * IZ * PD	156.47	17	9.20	7.49	0.00
T * IZ * I	250.00	17	14.71	11.96	0.00
T * I * PD	189.83	17	11.17	9.08	0.00
T * IZ * PD * I	730.65	17	42.98	34.97	0.00
Error	12 307.22	10 013	1.23	-	-

by fresh water in lower intertidal zone with planting distance of 0.5 m (Table 1). Irrigation and intertidal zone were independently significant variables on stem height growth of seedlings ($p < 0.01$). However, seedling planting distance was not a significant variable on stem height growth of seedlings ($p = 0.37$). The interactive effects of intertidal zone versus planting distance as well as that of intertidal zone versus planting distance versus type of irrigation were significant. Intertidal zone versus type of irrigation and planting distance versus type of irrigation were not significant. However, the interactive impact of all variables was significant at $p < 0.01$ (Table 3).

Bonferroni test results confirmed that mangrove seedlings irrigated with fresh water in lower intertidal zone with planting distance of 0.5 m had the maximum stem height increment compared with other samples. The minimum stem height growth was found to be in mangrove seedlings flooded by sea water in upper intertidal zone and planting distance of 1 m.

The ratio of stem height to stem diameter

The interactive effect of intertidal zone versus planting distance versus type of irrigation was not significant on ratio of stem height to stem diameter of seedlings ($p = 0.17$). All variables had interactive effects on the ratio of stem height to stem diameter, except intertidal zone versus planting distance versus type of irrigation (Table 4).

Bonferroni test results confirmed that mangrove seedlings irrigated by fresh water in upper intertidal zone with planting distance of 1 m have the maximum ratio of stem height to stem diameter compared with other samples. While, the minimum ratio of stem height to stem diameter was found to be in mangrove seedlings flooded by sea water in lower intertidal zone and planting distance of 0.5 m.

DISCUSSION

Field observations revealed that the upper intertidal zone was hardly exposed to tidal flood due to its higher slope. Other factors such as low soil moisture, poor drainage conditions of the surface layer and high salinity prevailed in the upper intertidal zone also increased seedling mortality. Results of this study conformed to findings reported by Bhat *et al.* (2004) on the establishment and growth of *A. marina* in Kuwait.

Table 3 ANOVA results of the stem height of seedlings

Effect	SS	df	MS	F	P
Intertidal zone (IZ)	28 732.32	1	28 732.32	18.46	0.00
Planting distance (PD)	1260.29	1	1260.29	0.81	0.37
Irrigation (I)	42 3574.82	1	4235 74.82	272.08	0.00
IZ * PD	11394.75	1	11 394.75	7.32	0.01
IZ * I	1251.08	1	1251.08	0.80	0.37
PD * I	1466.25	1	1466.25	0.94	0.33
IZ * PD * I	12 508.18	1	12 508.18	8.03	0.00
Error	916 961.12	589	1556.81	-	-
Time (T)	279 337.38	17	16 431.61	444.93	0.00
T * IZ	94 253.79	17	5544.34	150.13	0.00
T * PD	2721.83	17	160.11	4.34	0.00
T * I	4074.99	17	239.71	6.49	0.00
T * IZ * PD	3536.54	17	208.83	5.63	0.00
T * IZ * I	4254.11	17	250.24	6.78	0.00
T * I * PD	3493.75	17	205.51	5.56	0.00
T * IZ * PD * I	10 528.16	17	619.30	16.77	0.00
Error	369 784.36	10 013	36.93	-	-

Table 4 ANOVA results of the ratio of stem height to stem diameter

Effect	SS	df	MS	F	P
Intertidal zone (IZ)	17 094.61	1	117 094.61	6.44	0.01
Planting distance (PD)	35 943.27	1	35 943.27	13.53	0.00
Irrigation (I)	1 491 183.02	1	1 491 183.02	561.38	0.00
IZ * PD	17 926.82	1	17 926.82	6.75	0.01
IZ * I	30 429.91	1	30 429.91	11.46	0.00
PD * I	18 061.02	1	18 061.02	6.80	0.01
IZ * PD * I	4909.51	1	4909.51	1.85	0.17
Error	1 564 556.63	589	2656.29	-	-
Time (T)	1 618 384.55	17	95 199.09	624.63	0.00
T * IZ	1 09 363.24	17	6433.13	42.21	0.00
T * PD	17 058.28	17	1003.43	6.58	0.00
T * I	497 256.59	17	29 250.39	191.92	0.00
T * IZ * PD	13 183.66	17	775.51	5.09	0.00
T* IZ *	15 394.93	17	905.58	5.94	0.00
T* I * PD	6654.25	17	391.43	2.57	0.00
T* IZ * PD * I	9955.77	17	585.63	3.84	0.00
Error	1 526 070.48	10 013	152.41	-	-

During tidal flooding, the lower intertidal zone was fully inundated and, therefore, prevented the soil from becoming dry and facing high salinity. In general, *A. marina* seedlings planted along or near to the tidal line showed maximum height increases.

During the 18 months of our measurements, stem height was assumed as the most suitable parameter for assessment of the planting regime because the seedlings had not reached the stage of competition with one another for space and soil nutrients. Unfavourable ecological conditions of planting site cause retardation or reduction of stem height growth. Therefore, growth of stem height can be considered as an indicator of favourable ecological conditions of the plantation site on which they grow.

As indicated in Table 3, interactive effects of planting distance versus type of irrigation versus location (lower/upper intertidal zone) revealed that seedlings irrigated with fresh water and planted in lower intertidal zone with a 0.5-m planting distance showed greater height increments compared with the rest of the seedlings. Different responses in stem height increments to tidal water level among different mangrove species have been reported by many scientists. For example, seedlings of *Bruguiera gymnorrhiza* and *Kandelia candel* in lower intertidal zone had greater height increments than those in upper intertidal zone (Ye *et al.* 2004). In another study, height increment of established *Laguncularia racemosa* seedlings was greater under tidal flooding than under no flooding but height increment of *Avicennia germinans* did not differ between flooding conditions (Delgado *et al.* 2001). Likewise, stem elongation of *Rhizophora apiculata* decreased with increasing elevation and, thus, under decreased flooding (Kitaya *et al.* 2002). *Avicenia marina* in the landward zone had reduced height compared with trees in the seaward zone (Dahdouh-Guebas *et al.* 2004).

Lack of inundation in upper intertidal zone led to high salinity of the soil compared with those of lower intertidal zone. *Avicennia marina* plants cannot survive in soils that have developed high salinity or surface salt crusts (Embabi 1993). Mangrove soil substratum becomes hypersaline during summer monsoon, ultimately killing or retarding the growth of mangrove seedlings due to poor precipitation and poor free flux of fresh waters (Kathiresan 2000). At higher salinities, gas exchange becomes restricted by both stomatal and non-stomatal (i.e. biochemical) limitations in many halophytes. Prolonged high salinity exposure may result in restricted growth due to water uptake limitations, causing leaves to become small and thick (Krauss *et al.* 2008). Mangroves are basically tolerant of high salt and low oxygen levels. However, very high salinity results in sparse vegetation, small, slender trees and, eventually, a high mortality of both seedlings and trees (Toledo *et al.* 2001).

Studies have shown that nutrient addition does not enhance growth of mangrove seedlings in high salinity conditions (Krauss *et al.* 2008). Responses to nutrient additions are dependent on environmental conditions and on the species of mangrove. For example, *R. mangle* often dominates in low nutrient environments while *A. germinans*, in areas with higher nutrient availability (Krauss *et al.* 2008).

Our field surveys also revealed that the leaves and stems of seedlings planted in lower intertidal zone was covered by fine sediments containing nutrients. Organic carbon increases as fine sediment particles increase (Venkatesh Prabhu *et al.* 1993). Khodadadi-Jokari (2003) found that there is a highly significant relationship between the size of sediment particles and the amount of oxidized organic carbon in grey mangrove forests in the studied region. The amount of oxidized organic carbon enhances as fine sediment particles increase. Therefore, height increment of seedlings planted in lower intertidal zone could be attributed to lower salinity, longer period of inundation as well as high nutrient content of sediments. It was also observed that the amount of fine sediments on the pneumatophores, stems and leaves of seedlings in the lower intertidal zone was greater than those of seedlings in the upper intertidal zone. Seedlings in the lower intertidal zone were exposed to more sediment and subsequently exposed to more nutrients. Enhancements in nutrient availability have mostly led to faster growth rates and this could explain the higher growth of stem height in seedlings planted in lower intertidal zone. The growth of *R. apiculata* seedlings living at the edge of progressing mangrove forests in South-East Asia was directly correlated to the nutrient and silt contents of sediments at the site (Duarte *et al.* 1998). Seedlings growing over nutrient-poor, coarse sediments had very low growth rates while seedlings growing over nutrient-rich, silty sediments gained a new leaf every other day. Duarte *et al.* (1998) concluded that increased siltation enhanced seedling growth. Natural mangrove forests have the best conditions for mangrove to grow as indicated by their high contents of organic matter, total N and clay (Ren *et al.* 2008).

Height increments of seedlings irrigated with fresh water in non-tidal nursery showed greater height increments compared with seedlings irrigated by sea water in tidal nursery (Table 3). Even though planting distance alone did not have significant effects on height increments of seedlings, an interactive effect was observed between planting distance and planting location (intertidal zone), in such a way that seedlings with a planting distance of 1 m in lower intertidal zone showed greater height increments. Likewise, Ye *et al.* (2004) in a similar study found that *K. candel* plants in lower intertidal zone had greater height but less leaf number increments than in upper intertidal zone. In this study, the minimum ratio of stem height to stem diameter was found to be in mangrove seedlings flooded by sea water in lower intertidal zone and planting distance of 0.5 m (Table 4). As far as the ratio of stem height to stem diameter is concerned, the lesser the ratio, the stronger and more stable the mangrove species towards unfavorable environmental conditions such as speed of intertidal waters, wind speed and bending due to algal growth.

CONCLUSIONS

Based on results of this study, stem diameter increment of seedling flooded by sea water in lower intertidal zone with planting distance of 0.5 m was greater in comparison with other planted seedlings. The stem height of seedlings irrigated with fresh water in lower intertidal zone with planting distance of 0.5 m was greater than the rest of the seedlings. The minimum ratio of stem height to stem diameter was found to be in seedlings flooded by sea water in lower intertidal zone and at a planting distance of 0.5 m.

Interactive effect of planting distance versus type of irrigation versus planting location revealed that seedlings irrigated with fresh water, planted in lower intertidal zone with a 0.5 m planting distance showed greatest height increments compared with other seedlings.

For optimum stability against severe environmental conditions, seedlings should be transplanted to lower intertidal zone near natural mangrove stands with planting distance of 0.5 m and flooded by sea waters. The findings of this study could be applied to any other eco-region with the same or nearly same geomorphological characteristics.

ACKNOWLEDGEMENTS

Special thanks to SR Beh-Afarin from the Islamic Azad University, Tehran North Branch for the translation of the article from Persian into English. We are grateful to H Karimi for his help in the statistical analysis and to S Givargis, S Safiari, H Ziaie, A Kholdebarin and S Babaei-Kafaki for their helpful comments and suggestions. Comments and support from BF Darreh-Shouri, M Namiranian, SA Razavi, A Ebrahimi, M Dadras and E Parvaresh are greatly appreciated.

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