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Effects of irrigation with saline water on seedlings growth of forest species and their soil characteristics

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Abstract

According to the limited amount of fresh water resources in the country, identifying and evaluating the effects of irrigation with saline water is necessary to produce tree seedlings for reviving the destructed lands, agroforestry and forest enrichment. One of the sources of providing saline water in north of the country is Caspian Sea. Seedlings of six species including alder, oak, eucalyptus, hackberry, *Cupressus sempervirens* and *Cupressus arizonica* were used. This study was done in a completely randomized design with four replications for each species and each irrigation. The parameters of diameter and height of the seedlings were measured at the beginning of the study period (March 2013, before stress application). After the treatments application, these parameters were monthly measured. Soil samples were taken at the beginning (March 2013) and end (October 2013) of the period. Based on the results, the highest and lowest diameter growth of saline water treatment was observed for *Cupressus sempervirens* and alder, respectively. The highest and lowest height growth of saline water treatment was observed for *Cupressus sempervirens* and oak, respectively. The highest and lowest soil electrical conductivity of saline water treatment was observed for alder and *Cupressus sempervirens*, respectively. The result of this study showed that irrigation with saline water had influence on diameter and height growth as well as soil characteristics and conifers had shown higher resistance than hardwoods. Therefore, it is suggested to examine the effect of irrigation with saline water on other conifers and native species in further studies.

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Introduction

The water crisis is one of the most important concerns in the world today (Abbasian, 2004). Population growth, forest and pasture degradation, the spread of saline land and water logging due to excessive irrigation, pollution of groundwater and surface-water resources due to the use of synthetic fertilizers and pesticides have limited water consumption. The shortage of water resources with good quality and salinity expansion is inevitable. Therefore, comprehensive and effective measures should be performed in order to develop biological systems that are resistant to salinity. Especially, saline water resources in the world are more extensive than renewable freshwater. The huge volume of saline water in the world and results that are obtained traditionally or in experimental agricultural fields by using saline water, have considered the use of these water resources as a strategic approach in food production process. So that even European countries, which have adequate water resources, have studied the use of saline water in agricultural researches and obtained promising technologies so far. Low quality water such as saline water contains large amounts of soluble salts which the use of this water for a long time regardless observing of using saline water principles, and subsequent accumulation of salts in the soil or the occurrence of sodic soil condition in around roots, could cause irreparable damage to the soil, plants and the environment. Therefore, the main requirement of good management of non-conventional and saline water is further studies in this field and regarding the principles that not only secure the use of soil and water resources, but also should include environmental survival factors for current and future generations as well (Abdollahi, 2011).

A major part of our country is classified as arid and semi arid areas because of the high evapotranspiration and low precipitation. In these areas the needed water for agricultural products is mainly provided by irrigation and the lack of good quality water resources for agriculture makes the farmers to inevitably use low quality water such as saline water which cause more soil salinization (Osareh and Shariat, 2009).

In these regions only plants resistant to salinity are able to grow. However, if we could find some plants that are resistance to high salinity and have the potential to absorb salt form water and soil and cover soil surface, then some fine goals like economic culture, reducing the amount of salt in the soil and water by harvesting these plants, covering the soil and prevent the spread of dust could be achieved. Generally, the effect of irrigation with saline water on the plants can be mentioned as a combination of morphological, physiological and biochemical effects. Some morphological effects include changes in the characteristics of plant phenology, decreasing in growth and dry weight of root, impact on the vitality and increasing in cell volume. The physiological characteristics, which are influenced by irrigation with saline water, is reduction of osmosis process, water absorption, energy consumption and photosynthesis and creation of special ion property leading to the imbalance of essential nutrients such as Ca^{2+}, K^{+}, Mg^{2+} from the soil to the plant.

Some of halophytes plants resist to salinity by reducing sodium and chloride absorption and transport of nutrients to the leaves, high absorption of potassium along with sodium, increasing amino acid, proline, glycine, and biotin. Biochemical characteristics, which are affected the salinity, are changes in plant hormones, changes in protein synthesis and decreasing in the enzymatic activity of the plant. Salts in saline waters could affect some physical and chemical properties of soil, which these properties can affect the soil as an ideal environment for plant growth.

Raising awareness about the plants response to salinity especially at the seedling phase is essential for knowing the seedling establishment and avoiding failures in large-scale reforestation programs. Enhancing the knowledge of resistance to salinity can lead to the development of limited irrigation management in order to save water resources along with increasing in production and reducing the effects of water deficit on plants and their production. In general, a lot of research has been done about the effect of irrigation with saline water in the agricultural sciences however, extensive studies on the native forest species irrigated with saline water has not been conducted yet.

According to the limited amount of fresh water resources in the country, identifying and evaluating the effects of irrigation with saline water is necessary to produce tree seedlings for reviving the destructed lands, agroforestry and forest enrichment as well as providing good sources of salt water is essential for forest seedlings. One of the sources of providing saline water in north of the country is Caspian Sea (Bairami *et al.*, 2003). It can be used to supply the water needed to produce tree seedlings due to the better quality of its water than other resources and short distance towards the forested areas. The purpose of this study was to evaluate the effect of three irrigation treatments including drinking water, distilled water and Caspian Sea water on forest species seedlings growth characteristics and some physical and chemical properties of soil.

Materials and methods

Research Location

Seedlings of six species including alder, oak, eucalyptus, hackberry, *Cupressus sempervirens* and *Cupressus arizonica* were used which were provided from Colude Centre, Amol, North of Iran. The seedlings were planted in plastic pots containing sandy loam soil in March 2013. Then the pots were transferred to the outside place of Sari Agricultural Sciences and Natural Resources University with the 36 39 north and 53 4 east geographical position with a altitude of 10 m above sea level, average annual rainfall of 616 mm, the mean minimum temperature of 11.2 °C and the mean maximum temperature of 23.7 °C.

Methods

This study was done in a completely randomized design with four replications for each species and each irrigation. In order to study the growth properties, the parameters of diameter and height of the seedlings were measured at the beginning of the study period (March 2013, before stress application). After the treatments application, these parameters were monthly measured. In order to examine the soil physical and chemical properties, soil samples were taken at the beginning (March 2013) and end (October 2013) of the period and after transferring the samples to the laboratory, the moisture percent, soil texture, soil acidity, electrical conductivity and organic carbon were measured by weighing and drying method, pH meter, EC meter, Walki Block respectively.

Data analysis

The Statistical analysis of the data and graphs drawing were done using SPSS and Excel software. The Kolmogorov–Smirnov test was used to assess the normality of the data. Then, the Two-way ANOVA analysis was used to compare the quantitative and growth factors between species. The SNK test was used for mean comparison at this stage.

Results

Vegetative characteristics

Diameter growth

Analysis of variance of diameter growth showed that there was a significant difference between study species and irrigation treatments ($p<0.01$). Based on the results, the highest and lowest diameter growth of saline water treatment was observed for *Cupressus sempervirens* and alder, respectively. The SNK test results showed that the diameter growth of saline water treatment was significantly high for eucalyptus, *Cupressus sempervirens* and *Cupressus arizonica* (Table 1).

Height growth

Analysis of variance of height growth showed that there was a significant difference between study species and irrigation treatments ($p<0.01$). The highest and lowest height growth of saline water treatment was observed for *Cupressus sempervirens* and oak, respectively. The SNK test results showed that the height growth of saline water treatment was significantly high for eucalyptus and *Cupressus sempervirens* (Table 2).

Soil properties

Soil texture

The results showed that the soil texture was sandy loam (Figure 1).

Table 1. Diameter growth rate for the study species. Dissimilar capital Latin letters indicate significant difference at 1% level by SNK test for one treatment between different species and dissimilar lowercase Latin letters indicate significant differences for one species between different treatments (Numbers in parentheses indicate the standard error).

species	Drinking water	distilled water	Saline water
Eucalyptus	0.64 Aa (0.11)	0.19 Ab (0.07)	0.29 Ab (0.02)
Cupressus sempervirens	0.35 Ba (0.01)	0.1 Bb (0.02)	0.3 Aa (0.02)
Cupressus arizonica	0.37 Ba (0.02)	0.17 Ac (0.02)	0.27Ab (0.01)
Alder	0.28 BCa (0.01)	0.07 Bb (0.007)	0.08Bb (0.009)
Oak	0.2 ABa (0.03)	0.02 Cb (0.02)	0.20 ABa (0.0005)
Hackberry	0.11 Ca (0.01)	0.09 Ba (0.01)	0.11 Ba (0.007)

Moisture

Analysis of variance of soil moisture content showed that there was a significant difference between study species and irrigation treatments ($p<0.01$). Based on the results, the highest and lowest soil moisture percent of saline water treatment was observed for *Cupressus sempervirens* and Eucalyptus, respectively. In addition, the SNK test results showed that the soil moisture percent of saline water treatment for Hackberry was significantly higher than Eucalyptus and other species had not a significant difference with hackberry (Table 3).

Table 2. Height growth rate for the study species. Dissimilar capital Latin letters indicate significant difference at 1% level by SNK test for one treatment between different species and dissimilar lowercase Latin letters indicate significant differences for one species between different treatments (Numbers in parentheses indicate the standard error).

species	Drinking water	distilled water	Saline water
Eucalyptus	27.75 Aa (5.73)	5.4 Ab (1/24)	7.1 Ab (0.99)
Cupressus sempervirens	7.6 Ba (0.95)	4.1 Aa (1/46)	6 ABa (0.69)
Cupressus arizonica	8.45 Ba (0.83)	3.65 ABb (0/02)	8.25 Aa (3.65)
Alder	9.75 Ba (1.18)	1.95 BCa (0/46)	4.95 ABb (0.26)
Oak	6.20 Ba (0.97)	1.95 BCa (0.71)	2.5 Bb (0.05)
Hackberry	4.35 Ba (1.04)	1.6 Cb (0.48)	2.95 Bab (0.36)

The results showed that irrigation with saline water caused a significant increasing in soil moisture for *Cupressus sempervirens, Cupressus arizonica,* oak, alder and hackberry than the control soil (Figure 2).

Soil pH

Analysis of variance of soil acidity showed that there was a significant difference between the species but there was not between irrigation treatments ($p<0.01$). Based on the results, the highest and lowest soil acidity of saline water treatment was observed for *Cupressus arizonica* and oak, respectively. In addition, the SNK test results showed that the soil acidity of saline water treatment for Hackberry was significantly higher than alder, oak and hackberry (Table 4).

Table 3. Soil moisture percent for the study species. Dissimilar capital Latin letters indicate significant difference at 1% level by SNK test for one treatment between different species and dissimilar lowercase Latin letters indicate significant differences for one species between different treatments (Numbers in parentheses indicate the standard error).

species	Drinking water	distilled water	Saline water
Eucalyptus	12.13 BCa (0.81)	113.64 Ca (1.26)	Ba16/41 (2.50)
Cupressus sempervirens	14.00 BCa (1.96)	14.65 BCa (0.74)	20.47 ABa (0.74)
Cupressus arizonica	10.25 Cb (0.18)	10.86 Cb (0.26)	22.45 ABa (0.22)
Alder	17.43 ABa (1.78)	19.43 ABa (2.63)	22.65 ABa (2.19)
Oak	20.78 Aa (1.11)	18.62 ABa (0.67)	20.27 ABa (0.85)
Hackberry	20.05 Ab (2.22)	20.66 Ab (1.98)	24.86 Aa (1.06)

The results showed that irrigation with saline water caused a significant increasing in soil pH for *Cupressus sempervirens* and *Cupressus arizonica* than the control soil (primary) (Figure 3).

Electrical conductivity (EC)

Analysis of variance of soil electrical conductivity showed that there was not a significant difference between the species but there was between irrigation treatments ($p<0.05$). The highest and lowest soil electrical conductivity of saline water treatment was observed for alder and *Cupressus sempervirens*, respectively. The SNK test results showed that the soil electrical conductivity of saline water treatment was not significant for any species (Table 5).

The results showed that irrigation with saline water caused a significant increasing in soil EC for all species than the control soil (primary) (Figure 4).

Organic carbon Percentage (OC)

Analysis of variance of soil organic carbon percentage showed that there was not a significant difference between the species as well as irrigation treatments. According to the results, the highest and lowest soil organic carbon percentage of saline water treatment was observed for alder and *Cupressus arizonica,* respectively. The SNK test results showed that the soil organic carbon percentage of saline water treatment was significantly higher than the other species (Table 6).

The results of this study showed that irrigation with saline water caused a significant increasing in soil OC for all species than the control soil (primary) (Figure 5).

Table 4. Soil acidity for the study species. Dissimilar capital Latin letters indicate significant difference at 1% level by SNK test for one treatment between different species and dissimilar lowercase Latin letters indicate significant differences for one species between different treatments (Numbers in parentheses indicate the standard error).

species	Drinking water	distilled water	Saline water
Eucalyptus	7.69 Aa (0.04)	7.67 Aa (0.16)	7.52 ABa (0.12)
Cupressus sempervirens	7.63 Aa (0.06)	7.70 Aa (0.04)	7.60 ABa (0.03)
Cupressus arizonica	7.43 Aa (0.05)	7.43 Aa (0.09)	7.81 Aa (0.13)
Alder	7.51 Aa (0.09)	7.36 Aa (0.05)	7.41 Ba (0.05)
Oak	7.52 Aa (0.10)	7.54 Aa (0.03)	7.35 Ba (0.04)
Hackberry	7.60 Aa (0.06)	7.56 Aa (0.07)	7.36 Ba (0.08)

Discussion

In this study, the characteristics of growth and nutritional characteristics of conifers and hardwood species seedlings influenced by irrigation with saline water of the Caspian Sea were studied. The results showed that height growth of hardwood species affected by irrigation with saline water was significantly reduced compared to conifers species, in other words, conifers had been more resistant to saline water. The growth rate of irrigation with saline water in comparison with drinking water between different species was also lower.

Table 5. Soil electrical conductivity for the study species. Dissimilar capital Latin letters indicate significant difference at 1% level by SNK test for one treatment between different species and dissimilar lowercase Latin letters indicate significant differences for one species between different treatments (Numbers in parentheses indicate the standard error).

species	Drinking water	distilled water	Saline water
Eucalyptus	0.29 Ab (0.05)	0.31 Ab (0.02)	0.95 Aa (0.12)
Cupressus sempervirens	0.24 Ab (0.02)	0.22 Ab (0.02)	0.55 Aa (0.06)
Cupressus arizonica	0.38 Ab (0.02)	0.31 Ab (0.02)	0.61 Aa (0.11)
Alder	0.28 Aa (0.03)	0.68 Aa (0.39)	1.16 Aa (0.22)
Oak	0.24 Ab (0.03)	0.24 Ab (0.01)	0.94 Aa (0.12)
Hackberry	0.29 Aa (0.03)	0.29 Aa (0.02)	0.61 Aa (0.25)

Salinity as an effective environmental stresses, can reduce the plant growth and production and ultimately can cause dangerous changes such as reducing enzyme activity, cell wall dissolution, reducing photosynthesis and plant death (Alrasbi *et al.,* 2010). In addition, some responses of plants to salinity are morphological and anatomical changes including leaves thinning, number and size of the stoma, diameter and the number of xylem cell. These changes depend on the species that may an adaptation to salinity or damage caused by salinity (Kozlowski, 1997).

Table 6. Soil organic carbon percentage for the study species. Dissimilar capital Latin letters indicate significant difference at 1% level by SNK test for one treatment between different species and dissimilar lowercase Latin letters indicate significant differences for one species between different treatments (Numbers in parentheses indicate the standard error).

species	Drinking water	distilled water	Saline water
Eucalyptus	1.97 Aa (0.10)	2.22 Ba (0.15)	2.03 Ba (0.29)
Cupressus sempervirens	1.99 Aa (0.23)	1.87 Ba (0.12)	1.92 Ba (0.27)
Cupressus arizonica	1.91 Aa (0.06)	1.93 Ba (0.10)	1.61 Bb (0.05)
Alder	2.65 Aa (0.13)	2.87 Aa (0.23)	3.41 Aa (0.22)
Oak	2.00 Aa (0.28)	2.27 Ba (0.18)	2.43 Ba (0.23)
Hackberry	2.42 Aa (0.24)	2.38 Ba (0.06)	2.15 Ba (0.21)

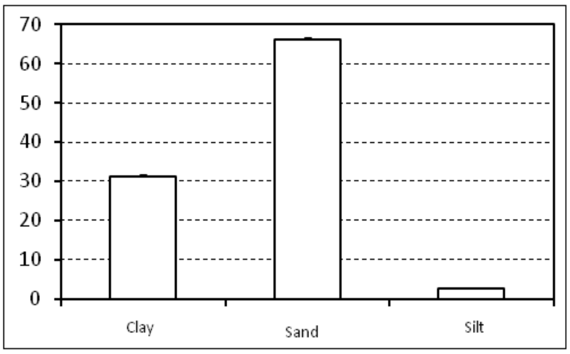

Fig. 1. The amount of Clay, Sand and silt in primary soil.

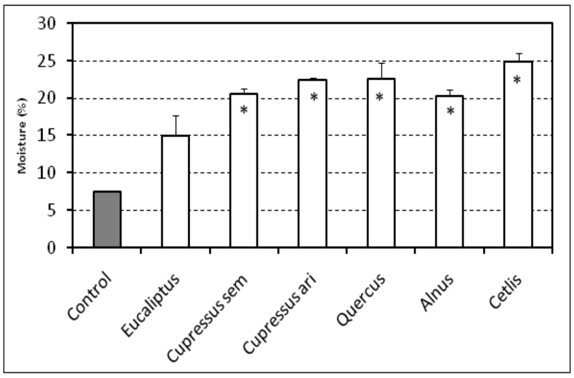

Fig. 2. the effect of irrigation with saline water on soil moisture percent for study species (* indicates a significant difference with the primary soil).

Decreasing in plant growth and biomass influenced by increasing in salinity have been previously reported for other tree and shrub species (Percival, 2005; Najafian, 2008; Banakar and Ranjbar, 2010; Sai Kachout *et al.,* 2009; Da Silva *et al.*, 2008). The reason of reduced growth can be expressed by osmotic effect of salts around roots and the ability of roots in absorbing salts and no transferring to leaf tissue can express the most important reason for plants resistance to salinity (Munns, 2002). The conifers used in this study were resistant to irrigation with saline; however, their growth rate had been influenced, but there was no sign of toxicity and plant death. All hardwood species lost their leaves at the end of the study period. The reason may be due to the high accumulation of chloride and sodium in leaf tissue (Bennett, 1993). Another reason for the growth declining could be the reduced uptake of potassium ions and its deficiency in plants. Because of the physiochemical similarity of K^+ and Na^+, plants would uptake sodium rather than potassium under high salinity conditions (Maathuis, 2006).The uptake of nitrogen, calcium and magnesium are also reduced to a large extent influenced by saline water (Chaparzadeh *et al.,* 2003). Nitrogen and magnesium are the most important elements of plant chlorophyll (Wang *et al.,* 2004). Another factor of low growth can be the reduced activity of stoma. Increased salinity leads to the closure of the plant stoma to reduce water loss. Osmotic balance is very important for maintaining of plant's water (Katerji *et al.,* 1997).

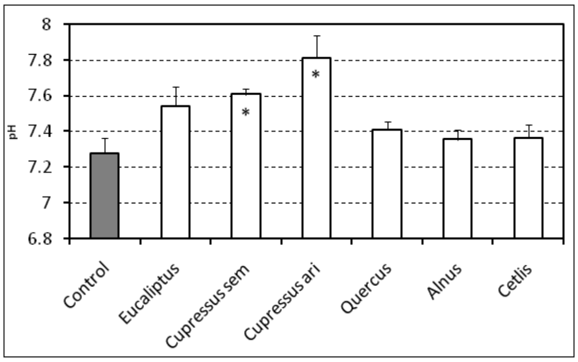

Fig. 3. The effect of irrigation with saline water on soil pH for study species (* indicates a significant difference with the primary soil).

Increased salinity would lead to increased osmotic stress, which would cause the closure of plant stoma in order to prevent water decreasing (Flexas, 2002). The results showed that soil moisture was significantly increased in saline water treatments. These results were consistent with the results of González-Alcaraz *et al* (2014). The main reason for the increase in moisture content could be due to irrigation program .On the other hand, the presence of plant roots partly lead to the increase in soil water storage. Plant roots can increase the water holding capacity of the soil by producing abundant fine-roots and secretion of organic material. Irrigation with saline seawater containing large amounts of sodium could damage the structure of aggregates. Following the destruction of soil structure, water permeability is reduced and the water stays in the soil. Soil aggregates are created by clay particles. Divan elements are the bridging of clay particles. Increasing of Na^+ in soil can cause the replacement of sodium ions rather than elements such as magnesium and destroy clays bridge which result in the destruction of soil aggregates. The results of this study showed that the soil salinity rate was significantly increased by the treatment of saline water. Generally, irrigation with saline water would lead to saline increasing in soil so that limits plant growth (Rengasamy, 2002). Seawater has a very high salinity due to large quantities of alkaline elements such as calcium, potassium, magnesium and sodium. This has led to a significant increase in the electrical conductivity of the soil under the effect of saline water treatment.

Another reason for the increase of salinity in the soil can be due to the large amounts of clay in a soil. Large amounts of clay in the soil would lead to increasing in retention capacity of alkaline cations in the soil.

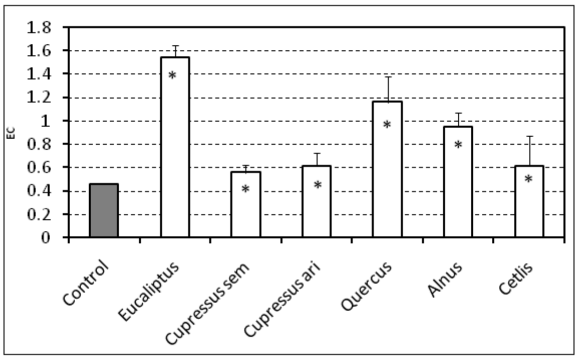

Fig. 4. The effect of irrigation with saline water on soil EC for study species (* indicates a significant difference with the primary soil).

The results showed that the soil organic matter percent influenced by irrigation with saline water was significantly reduced. By increasing in soil salinity, osmotic properties around soil microorganisms would increase. In general, increasing in soil salinity damage the soil microorganisms and reduce the enzyme growth and activity. Therefore, the decomposition process would be slow and the carbon cycle in the soil would be affected.

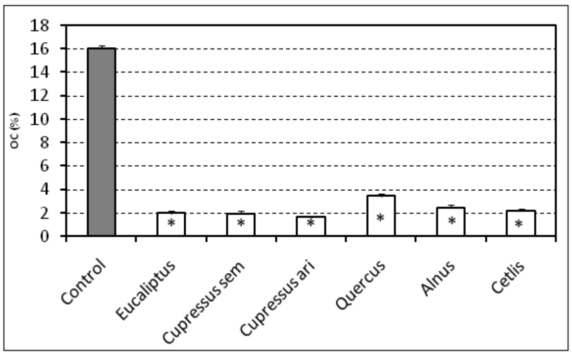

Fig. 5. The effect of irrigation with saline water on soil OC for study species (* indicates a significant difference with the primary soil).

The result of this study showed that irrigation with saline water had influence on diameter and height growth as well as soil characteristics and conifers had shown higher resistance than hardwoods. Therefore, it is suggested to examine the effect of irrigation with saline water on other conifers and native species in further studies.

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