Interactive effects of salinity and drought stresses on the growth parameters and nitrogen content of three hedge shrubs

Sharam Sedaghatoor and Seyedeh Khadijah Abbasnia Zare

Cogent Environmental Science (2019), 5: 1682106
Interactive effects of salinity and drought stresses on the growth parameters and nitrogen content of three hedge shrubs

Sharam Sedaghathoor1* and Seyedeh Khadijeh Abbasnia Zare1

Abstract: The effect of salinity and drought stresses on three hedge shrubs was studied in a factorial experiment based on a Randomized Complete Block Design with three replications. The studied treatments included salinity at four levels (tap water, 100 mM NaCl, 150 mM NaCl, and Sea water), irrigation at three levels (irrigation intervals of 3, 7 and 10 days), and three hedge shrubs (Buxus hyrcana, Euonymus japonicus var. microphylla and Euonymus japonicus var. aureomarginatum). It was found that the increase in salinity and drought negatively affected the studied traits so that the maximum Na concentration (719.9 mg kg\(^{-1}\)) was obtained for irrigation with Sea water at the intervals of 10 and 7 days. All three shrubs irrigated with Sea water had higher Na concentration than other treatments. The lowest N content (0.393%) was obtained from the treatment of E. japonicus var. microphylla × tap water × 10-day irrigation interval and highest one (0.873%) was obtained from B. hyrcana × 100 mM NaCl × 7-day irrigation interval. The highest plant and root fresh weight (37.86 g) were related to E. japonicus var. microphylla irrigated with tap water. The highest plant dry weight of 18.77 g was related to E. japonicus var. microphylla × tap water and the lowest one (11.47 g) was related to E. japonicus var. microphylla × caspian Sea water. The highest and lowest number of axillary branches was related to irrigation with tap water and Sea water (7.29 and 0.59), respectively.

Keywords: hedge; ornamental shrub; salinity stress; water stress

ABOUT THE AUTHOR
Shahram Sedaghathoor is currently Associate Professor of Horticultural Science at the Faculty of Agricultural Sciences, Rasht branch, Islamic Azad University, Rasht, Iran. Miss Seyedeh Khadijeh Abbasnia Zare is a PhD of Horticultural Science (Ornamental Plants).

PUBLIC INTEREST STATEMENT
Salinity and drought stress are of the most limiting environmental factors of crop growth and yield. The main challenge of crop production in Iran and the world is water deficiency. Due to its special geographical location, Iran has low precipitation. The objective of the present study was to determine the resistance of three hedge shrubs to salinity and drought stresses.
1. Introduction

Hedge shrubs are invaluable plants in horticulture, landscape planning and medicinal herbs and are extensively used as important ornamental plants for building green walls in parks, boulevards and even, houses (Bakhshi Khaniki, 2007; Karimi, 2005; Zaman, 2003). An instance of hedge plants is *Buxus hyrcana* that is a geographical race of *Buxus sempervirens* and is of few evergreen broad-leaf trees in Caspian forests. It grows only in the marine climate and is in the danger of extinction (Asadi, Hosseini, Esmailzadeh, & Ahmadi, 2011; Sabeti, 1995). *Euonymus japonicus* var. aureo-marginatum is an ornamental evergreen shrub with a slow growth rate and long life which is widely grown throughout the world. It is used as an ornamental plant in landscapes or as a hedge plant in pathways, thanks to its beautiful colors (Seifikhani, Chaparzadeh, & Zarandi, 2010). *Euonymus japonicus* var. microphylla is another type of evergreen *Euonymus* similar to mint. It is used as an ornamental plant in the margins of gardens and landscapes (Brickell, 2008).

Salinity and drought stress are of the most limiting environmental factors of crop growth and yield. The main challenge of crop production in Iran and the world is water deficiency. Due to its special geographical location, Iran has low precipitation. Water resource limitations and drought are the most important causes of drought stress and yield loss (Ahmadikhah, 2009; Jalili Marandi, 2010). Salinity stress is the second most important limiting factor of crop growth and development after drought stress. Earth is a very saline planet in which most waters contain high concentrations of salts and other minerals. High concentrations of chloride and sodium of soil adversely affect crop growth and yield. In total, salinity is the second most serious threat for crop production—the first one being drought—which may turn into a threat to future food supply (Jalili Marandi, 2010; Kafi et al., 2009).

*Buxus* and *Euonymus* are known as saline-resistant ornamental shrubs. The mechanisms of the resistance of ornamental shrubs and trees to salinity include the inhibition of salt uptake, inactive salt excretion and active salt dilution (Jalili Marandi, 2010). Drought influences ornamental trees physically and physiologically. It destroys feeding roots and reduces photosynthesis in these species (Jalili Marandi, 2010). Salehi, Kafi, and Kiani (2009) reported the loss of stem elongation and the increase in the allocation of photosynthates to leaves and finally, the increase in leaf growth in *Kochia* under salinity. Jami Al Ahmadi and Kafi (2008) reported the loss of cell wall thickness under salinity stress. Abadi Almus, Bagherikia, and Mahdavi (2013) stated that salinity stress and higher NaCl concentration decreased seed germination, shoot and root length, fresh and dry weight in *Artemisia vulgaris* L. According to Lebaschi and Sharifi Ashoorabadi (2004), drought stress reduces shoot weight and plant height in *Plantago psyllium*, yarrow, sage, marigold and chamomile. The objective of the present study was to determine the resistance of three hedge shrubs to salinity and drought stresses.

2. Material and methods

2.1. Experimental design

The present study carried out as a factorial experiment with three factors (hedge shrub type, salinity stress, and drought stress) with three replications. The first factor was ornamental shrubs at three levels (*Buxus hyrcana, Euonymus japonicus* var. microphylla and *Euonymus japonicus* var. aureo-marginatum), the second factor was salinity stress at four levels (tap water, 100 mM NaCl, 150 mM NaCl and Caspian Sea water) and the third factor was drought stress or deficit-irrigation intervals at three levels (irrigation intervals of 3, 7 and 10 days). Salinity treatments of 100 and 150 mM NaCl were prepared by sodium chloride. Tap water was used as a control. Caspian Sea water, as one salinity treatment, was prepared from the Anzali port seaside. Drought stress was applied by irrigation intervals of 3, 7 and 10 days. The temperature and humidity of the glasshouse were at 25–35°C and 75–85%. The treated plants were one-year old. The saline treatments were prepared by distilled water.
2.2. Plant measurement and data collection

The recorded traits included plant height, a number of axillary branches, shoot fresh and dry weight, root fresh and dry weight, and leaf N and Na content. Plant height was measured from the ground up to the plant canopy. Number of axillary branches per plant were counted after 90 days. To measure nutrients (N and Na), first the plant was extracted. Then, 0.3 g of the powdered dry shoot was poured into 50-ml volumetric flask. Then, 2.3 ml of mixed acids (100 ml H$_2$SO$_4$ + 6 g C$_7$H$_6$O$_3$ + 18 ml H$_2$O$_2$) was added. Twenty-four hours later, the samples were digested as long as their color turned into light yellow. Then, they were filtrated through filter paper and were diluted to 50 ml with distilled water. The solution was used to measure N and Na content. N content was estimated by Kjeldahl method and N percentage was calculated by the following equation (Emami, 1996):

\[
N\% = 0.56 \times t \times (a - b) \times \frac{V}{W} \times \frac{100}{DM}
\]

where

- \( t \) = the concentration of acid used for titration (mol kg$^{-1}$),
- \( a \) = the amount of acid used as a sample (ml),
- \( b \) = the amount of acid used as control (ml),
- \( V \) = the volume of extract obtained from digestion (ml),
- \( W \) = the weight of plant sample for digestion (g), and
- \( DM \) = dry matter percentage.

Plant Na content was estimated by flame photometry method using the following equation for Na percentage (Emami, 1996):

\[
Na(mg/kg) = (a - b) \times 0.0001 \times \frac{V}{W} \times \frac{100}{DM}
\]

where

- \( a \) = curve number (Na concentration in the extract in terms of mg.kg$^{-1}$),
- \( b \) = Na concentration in control (mg kg$^{-1}$),
- \( V \) = the volume of plant extract (ml),
- \( W \) = plant fresh weight (g), and
- \( DM \) = plant dry matter percentage.

2.3. Statistical analyses

The data were statistically analyzed by MSTATC Software Package and the means were compared by Tuckey’s HSD test (p < 0.05).

3. Results

3.1. Leaf Na content

Analysis of variance revealed that the effect of plant type, salinity stress and drought stress was significant on leaf Na content (p < 0.01). The interactions of shrub type × salinity and shrub type
salinity × drought were significant for Na content (p < 0.05). Leaf Na content did not significantly change under the interaction of hedge shrub type × drought and salinity × drought (Table 1). Means comparison showed that among the studied shrubs, E. japonicus var. microphylla had the lowest leaf Na content (392.2 mg kg⁻¹). B. hyrcana had the highest Na content (444.7 mg kg⁻¹), but it has no significant difference with that of E. japonicus var. aureo-marginatum (430.9 mg kg⁻¹) (Table 2). Means comparison of the impact of salinity on leaf Na indicated that tap water resulted in the lowest leaf Na content (298.2 mg kg⁻¹) which had no statistically significant difference with those obtained under the treatments of 100 mM NaCl (345.9 mg kg⁻¹) and 150 mM NaCl (317.4 mg kg⁻¹). The highest leaf Na content (719.9 mg kg⁻¹) was related to the irrigation with Caspian Sea water. Therefore, trial plants are able to accumulate twofold Na in their tissues under salinity stress as much as normal conditions (Table 3). Means comparison for the interaction of shrub × salinity on leaf Na content showed significant differences between treatments, so that the highest Na contents were obtained from B. hyrcana × Caspian Sea water (769.1 mg kg⁻¹), E. japonicus var. microphylla × Caspian Sea water (708.9 mg kg⁻¹) and E. japonicus var. aureo-marginatum × Caspian Sea water. The interaction between E. japonicus var. microphylla and tap water resulted in the lowest Na concentration with no significant differences with other treatments (Table 4).

According to means comparison of the effect of different drought levels on leaf Na content, Na was increased with drought (irrigation interval), so that 3-day irrigation interval produced the lowest Na content (348.1 mg kg⁻¹) and 10-day interval produced the highest one (443.3 mg kg⁻¹). However, the 10-day irrigation interval exhibited no significant difference with 7-day irrigation interval (Table 5). Also, means comparison of the trilateral effect of shrub type × salinity × drought for leaf Na content revealed significant differences between treatments. Among different treatments, the highest leaf Na content was related to B. hyrcana irrigated with Caspian Sea water once 7 days and B. hyrcana irrigated with Caspian Sea water once 3 days (782.7 and 765 mg kg⁻¹, respectively). Results showed that plants irrigated with Caspian Sea water had the highest Na concentrations under drought stress, especially when irrigated in 10-day intervals. Also, the lowest Na content (169 mg kg⁻¹) was related to the E. japonicus var. microphylla × tap water × 3-day irrigation interval. The treatments of B. hyrcana × 150 mM NaCl × 3-day irrigation interval and E. japonicus var. microphylla × 150 mM NaCl × 3-day irrigation interval had the second lowest Na contents (230 and 244.3 mg kg⁻¹, respectively) (Table 6).

### 3.2. Plant N percentage

According to analysis of variance, significant differences were observed in the plant N content under different treatments of hedge shrub, salinity and drought stress and some of their interactions (p < 0.01). The interaction of shrub × drought was significant for plant N percentage at p < 0.05 (Table 1). Means comparison of the effect of hedge shrub type on the plant N percentage revealed that B. hyrcana had the highest N content (0.64%) and E. japonicus var. microphylla had the lowest quantity (0.57%) (Table 2). According to means comparison of the effect of salinity levels on the N percentage, the highest N content (0.66%) was related to Caspian Sea water which had no significant difference with the treatment of 100 mM NaCl. The lowest plant N content was obtained from the treatments of 150 mM NaCl and tap water (0.57% and 0.58%, respectively) (Table 3). Interaction of hedge shrub × salinity resulted in significant differences in plant N percentage. The highest N percentage (0.81%) was related to B. hyrcana treated with 100 mM NaCl and the lowest one (0.53%) was related to E. japonicus var. microphylla irrigated with tap water which showed no significant difference with those of B. hyrcana treated with 150 mM NaCl (0.54%), E. japonicus var. microphylla treated with 100 mM NaCl (0.56%), E. japonicus var. aureo-marginatum treated with 100 mM NaCl (0.57%) and E. japonicus var. microphylla treated with 150 mM NaCl (0.56%) (Table 4). Means comparison of the effect of drought on plant N percentage indicated that the highest N content (0.65%) was obtained under 7-day irrigation interval with no significant difference with 3-day irrigation interval (0.63%). The lowest N content (0.56%) was related to 10-day irrigation interval (Table 5). A look at the data of the interaction of hedge shrub × drought shows that the highest N content (0.71%) was related to the interaction of
Table 1. Analysis of variance of treatment effects on experimental traits

| Source of Variation | df | Na             | N              | Plant Height | Branches | Plant Fresh weight | Plant Dry weight | Root Fresh weight | Root Dry weight | Shoot Fresh weight | Shoot Dry Weight |
|---------------------|----|----------------|----------------|--------------|----------|--------------------|------------------|-------------------|-----------------|-------------------|------------------|
| Replication         | 2  | 3039.5**       | 0.004**        | 70.8**       | 7.62**   | 26.08**            | 19.9**           | 27.3*             | 26.9**          | 44.17**           | 5.68**           |
| Shrub Type (A)      | 2  | 26,717.1**     | 0.045**        | 224.5**      | 3.23**   | 71.07*             | 25.8*            | 33.5**            | 26.9**          | 12.97**           | 2.22**           |
| Salinity (B)        | 3  | 1,075,833.04** | 0.06**         | 661.3**      | 217.6**  | 485.9**            | 96.8**           | 53.4**            | 32.6**          | 287.6**           | 21.6**           |
| AB                  | 6  | 7506.7*        | 0.07**         | 23.6**       | 1.04**   | 50.18*             | 15.1*            | 23.5**            | 7.16**          | 14.69**           | 2.45**           |
| Drought (C)         | 2  | 40,116.6**     | 0.07**         | 34.4**       | 5.12**   | 6.82**             | 1.96**           | 4.6**             | 2.97**          | 1.74**            | 0.6**            |
| AC                  | 4  | 1847.5**       | 0.023*         | 2.9**        | 0.42**   | 9.38**             | 4.12**           | 3.8**             | 1.53**          | 7.01**            | 0.57**           |
| BC                  | 6  | 5368.3**       | 0.026**        | 10.5*        | 0.23**   | 2.71**             | 6.62**           | 2.77**            | 1.59**          | 3.75**            | 1.08**           |
| ABC                 | 12 | 6323.3*        | 0.028**        | 2.6**        | 1.38**   | 5.80**             | 5.9**            | 2.47**            | 1.82**          | 2.28**            | 1.43**           |
| Error               | 70 | 2729.6         | 0.008          | 3.59         | 2.57     | 18.04              | 6.61             | 6.75              | 2.28            | 10.07             | 2.08             |
| CV (%)              | -  | 12.36          | 14.76          | 7.56         | 45.95    | 14.42              | 16.81            | 16.65             | 18.29           | 22.9              | 20.79            |

*, **: Significant at 0.01, 0.05 and non-significant, respectively.
B. hyrcana × 3-day irrigation interval. The treatments of E. japonicus var. microphylla × 10-day irrigation interval and E. japonicus var. microphylla × 3-day irrigation interval resulted in the next lowest plant N percentages (0.53% and 0.55%) (Figure 1). The interaction of drought × salinity for plant N percentage showed that 10-day irrigation interval × 150 mM NaCl resulted in the highest N content (0.75%). The lowest N content (0.49%) was related to 3-day irrigation interval treated with 150 mM NaCl (Figure 2). The trilateral interaction of hedge shrub × salinity × drought was significant on N percentage (Table 6), so that the treatments of B. hyrcana × 100 mM NaCl × 7-day irrigation interval and B. hyrcana × 100 mM NaCl × 3-day irrigation interval resulted in the highest N contents of 0.87% and 0.85%, respectively. E. japonicus var. microphylla irrigated with tap water at 10-day intervals and E. japonicus var. microphylla treated with 100 mm NaCl in 10-day intervals resulted in the lowest N contents of 0.39% and 0.45%, respectively.

3.3. Plant height

According to the results of analysis of variance, the effects of hedge shrub type, salinity, hedge shrub × salinity and drought were significant on plant height (p < 0.01). The interaction of salinity × drought was also significant on plant height at the 5% probability level. But, the interactions of hedge shrub × drought and hedge shrub × salinity × drought were not significant for this trait (Table 1). The data on the impact of the shrub type on the plant height show that E. japonicus var. microphylla had the highest plant height (27.95 cm). E. japonicus var. aureo-marginatum had the lowest plant height (23.41 cm) with no significant difference with B. hyrcana (23.88 cm). Means comparison of the impact of salinity on plant height revealed that plant height was decreased with salinity, so that tap water and Caspian sea water resulted in the highest and lowest plant heights (31.20 and 20.17 cm, respectively) (Table 3). According to the data of the interactions of shrub × salinity on plant height, it was seen that the treatments of E. japonicus var. microphylla × tap water and B. hyrcana × tap water had the highest plant heights (32.61 and 32.44 cm, respectively). The lowest plant height (17.37 cm) was related to the treatment of B. hyrcana × Caspian Sea water, followed by E. japonicus var. aureo-marginatum × Caspian Sea water (18.70 cm) and B. hyrcana × 150 mM NaCl (19.8 cm) (Table 4). Means comparison indicated that plant height was decreased with drought, so that the highest plant height (25.97 cm) was obtained under 3-day irrigation interval with no significant difference with 7-day irrigation interval (25.23 cm). The lowest plant height (24.04 cm) was related to 10-day irrigation interval. These findings imply that the studied plants could tolerate 7-day irrigation interval, but the increase in irrigation interval up to 10 days damaged the plants suppressing their vegetative growth (Table 5). Means comparison of the interaction of drought × salinity on plant height showed that irrigation with water containing 100 mM NaCl at 3-day interval and irrigation with tap water at the same interval resulted in the highest plant heights (31.43 and 31.88 cm, respectively). The lowest plant height of 19.63 cm was obtained under an irrigation interval of 10 days with water containing 100 mM NaCl, which showed no significant differences with other treatments (Figure 3).

| Table 2. Mean comparison of effect of hedge shrub type on trial traits |
|---------------------------------------------------------------|
| Shrub types               | Na (mg/kg) | N (%)   | Plant Height (cm) | Plant Fresh Weight (g) | Plant Dry Weight (g) | Root Fresh Weight (g) | Root Dry Weight (g) |
|---------------------------|------------|---------|------------------|------------------------|----------------------|---------------------|---------------------|
| Buxus hyrcana            | 444.7 a    | 0.65a   | 23.9 b           | 29.8 ab                | 15.99 a              | 16.24 a             | 9.06 a              |
| E. japonicus var. microphylla | 392.2 b  | 0.58b   | 27.9 a           | 30.6 a                 | 15.56 ab             | 16.08 a             | 8.34 a              |
| E. japonicus var. aureo-marginatum | 430.9ab | 0.63ab  | 23.4 b           | 27.9 b                 | 14.35 b              | 14.49 b             | 7.34 b              |

Means with the same letters in each column do not differ significantly at the 5% level.
### Table 3. Mean comparison of effect of salinity on trial traits

| Salinity          | Na (mg/kg) | N (%) | Plant Height (cm) | Branch No | Plant Fresh Weight (g) | Plant Dry Weight (g) | Root Fresh Weight (g) | Root Dry Weight (g) | Shoot Fresh Weight (g) | Shoot Dry weight (g) |
|-------------------|------------|-------|-------------------|-----------|------------------------|----------------------|-----------------------|----------------------|------------------------|----------------------|
| Tap Water         | 298.2 b    | 0.59b | 31.2 a            | 7.29 a    | 34.55 a                | 17.26 a              | 16.15 a               | 9.05 a               | 18.36 a               | 8.15 a               |
| NaCl 100 mM       | 354.9 b    | 0.65a | 26.8 b            | 3.70 b    | 31.23 b                | 16.52 b              | 17.13 a               | 9.24 a               | 14.10 b               | 7.09 b               |
| NaCl 150 mM       | 317.4 b    | 0.57b | 22.12 c           | 2.37 c    | 26.72 c                | 14.23 b              | 15.35 db              | 7.78 b               | 11.49 c               | 6.34 b               |
| Caspian Sea Water | 719.9 a    | 0.66a | 20.17 d           | 0.59 d    | 25.28 c                | 13.21 b              | 13.80 b               | 6.92 b               | 11.41 c               | 6.19 b               |

Means with the same letters in each column do not differ significantly at the 5% level.
| Treatments                               | Na (mg/kg) | N (%)  | Plant Height (cm) | Plant Fresh Weight (g) | Plant Dry Weight (g) | Root Fresh Weight (g) | Root Dry Weight (g) |
|-----------------------------------------|------------|--------|-------------------|------------------------|----------------------|-----------------------|---------------------|
| **B. hycana × Tap Water**               | 304 b      | 0.61bc | 32.44 a           | 34.36 ab               | 17.74 a              | 15.73 abc             | 17.74 a             |
| **B. hycana × NaCl 100 mM**             | 375 b      | 0.82 a | 25.92 cd          | 29.18 b-f              | 16.35 ab             | 16.52 ab              | 16.35 ab            |
| **B. hycana × NaCl 150 mM**             | 330.8b     | 0.54 c | 19.80 ef          | 27.41 c-f              | 14.81 abc            | 16.46 ab              | 14.81 abc           |
| **B. hycana × Sea Water**               | 765.1a     | 0.63bc | 17.37 f           | 28.39 b-f              | 15.06 abc            | 16.25 ab              | 15.06 abc           |
| **E. japonicus Microphylla × Tap Water**| 265.4b     | 0.53 c | 32.61 a           | 37.86 a                | 18.77 a              | 18.02 a               | 18.77 a             |
| **E. japonicus Microphylla × NaCl 100 mM**| 325.3b     | 0.56 c | 29.37 b           | 33.80 abc              | 17.22 ab             | 17.95 a               | 17.22 ab            |
| **E. japonicus Microphylla × NaCl 150 mM**| 269 b      | 0.60 c | 25.39 d           | 27.36 c-f              | 14.76 abc            | 16.34 ab              | 14.76 abc           |
| **E. japonicus Microphylla × Sea Water**| 708.9a     | 0.62bc | 24.43 d           | 23.42 f                | 11.47 c              | 12.02 c               | 11.47 c             |
| **E. japonicus aureomarginatum × Tap Water**| 325.1b     | 0.62bc | 28.56 bc          | 31.42 a-d              | 15.22 abc            | 14.69 abc             | 15.22 abc           |
| **E. japonicus aureomarginatum × NaCl 100 mM**| 364.2b     | 0.58 c | 25.20 d           | 30.71 b-f              | 15.98 ab             | 16.91 ab              | 15.98 ab            |
| **E. japonicus aureomarginatum × NaCl 150 mM**| 352.4b     | 0.57 c | 21.17 e           | 25.39 def              | 13.12 bc             | 13.25 bc              | 13.12 bc            |
| **E. japonicus aureomarginatum × Sea Water**| 681.8a     | 0.75ab | 18.70 ef          | 24.02 ef               | 13.10 bc             | 13.13 bc              | 13.10 bc            |

Means with the same letters in each column do not differ significantly at the 5% level.
3.4. The number of axillary branches

Analysis of variance revealed that salinity significantly affected the number of axillary branches \((p < 0.01)\) and the impact of other treatments was not significant. The number of axillary branches of the studied shrubs is seemingly one of the traits that is not affected by different trial treatments, and only various levels of salinity negatively influence it (Table 1). According to means comparison, among various levels of salinity, irrigation with tap water and with Caspian Sea water resulted in the highest and lowest number of axillary branches \((7.29\) and \(0.59\), respectively) (Table 3).

3.5. Fresh and dry weight

As analysis of variance showed, the influence of hedge shrub, salinity and hedge shrub × salinity was significant for plant fresh weight and the influence of the remaining treatments was insignificant. Means comparison revealed that among the studied shrub types, \(E. japonicus\) var. microphylla and \(E. japonicus\) var. aureo-marginatum had the highest and lowest plant fresh weight \((30.61\) and \(27.88\) g, respectively). Means comparison of the data for the effect of salinity on plant fresh weight indicated that plant fresh weight was decreased with salinity and tap water produced the highest plant fresh weight \((34.55\) g). Caspian Sea water and \(150\) mM NaCl produced the lowest fresh weight \((25.28\) and \(26.72\) g, respectively). Also, the data of the interaction of hedge shrub × salinity for plant fresh weight showed that \(E. japonicus\) var. microphylla irrigated with tap water produced the highest plant fresh weight of \(37.86\) g. The lowest fresh weight \((23.42\) g) was related to \(E. japonicus\) var. microphylla irrigated with Caspian Sea water.

Analysis of variance showed that the effect of hedge shrub type and salinity and the interaction of hedge shrub × salinity were significant on root fresh weight \((p < 0.01)\). This trait was not significantly affected by the interaction of shrub × drought, drought × salinity and shrub × salinity × drought (Table 1). The interaction of shrub × salinity for root fresh weight showed that the highest fresh root weight was related to \(E. japonicus\) var. microphylla × tap water \((18.02\) g) and \(E. japonicus\) var. microphylla × \(100\) mM NaCl \((17.95\) g). The lowest root fresh weight of \(12.02\) g was obtained from \(E. japonicus\) var. microphylla plants irrigated with Caspian Sea water which showed to be inappropriate for this as compared to other treatments (Table 4). The data for the effect of shrub type on root fresh weight revealed that the highest root fresh weight of \(16.34\) g was related to \(B. hyrcana\) with no significant difference with that of \(E. japonicus\) var. microphylla \((16.08\) g). The lowest root fresh weight of \(14.49\) g was related to \(E. japonicus\) var. aureo-marginatum (Table 2). According to means comparison for the effect of salinity, the treatment of \(100\) mM NaCl resulted in the highest root fresh weight of \(17.13\) g with no significant difference with the treatment of tap water. The lowest root fresh weight \((13.80\) g) was related to the treatment of Caspian Sea water (Table 3).

As analysis of variance showed just salinity affected shoot fresh weight. Based on results, other simple treatments and all interactions had no significant effect on shoot fresh weight (Table 1). Means comparison of the effect of salinity on shoot fresh weight showed that shoot fresh weight decreased with increased salinity, so that the highest shoot fresh weight was produced under the treatment of tap water and the lowest one was produced under Caspian Sea water and \(150\) mM NaCl \((11.41\) and \(11.49\) g, respectively) (Table 3).

---

Table 5. Mean comparison of effect of drought (irrigation intervals) on trial traits

| Treatments                  | Na (mg/kg) | N (%)  | Plant Height (cm) |
|-----------------------------|------------|--------|-------------------|
| Irrigation per 3 days       | 384.1 b    | 0.63 a | 25.97 a           |
| Irrigation per 7 days       | 440.4 a    | 0.65 a | 25.23 a           |
| Irrigation per 10 days      | 443.3 a    | 0.57 b | 24.04 b           |

Means with the same letters in each column do not differ significantly at the 5% level.
Table 6. Mean comparison of trial effect of “shrub type × salinity × drought” on trial traits

| Treatments                              | Na (mg/kg) | N (%) |
|-----------------------------------------|------------|-------|
| **Buxus hyrcana × Tap Water ×**         |            |       |
| Irrigation per 3 days                   | 285.3 def  | 0.83 abc |
| **B. hyrcana × Tap Water × Irrigation**|            |       |
| per 7 days                              | 349.7 de   | 0.47 def |
| **B. hyrcana × Tap Water × Irrigation**|            |       |
| per 10 days                             | 277 def    | 0.53 def |
| **B. hyrcana × NaCl 100 mM ×**          |            |       |
| Irrigation per 3 days                   | 360 de     | 0.85 ab  |
| **B. hyrcana × NaCl 100 mM ×**          |            |       |
| Irrigation per 7 days                   | 399.3 de   | 0.87 a  |
| **B. hyrcana × NaCl 150 mM ×**          |            |       |
| Irrigation per 3 days                   | 365.7 de   | 0.72 a-f |
| **B. hyrcana × NaCl 150 mM ×**          |            |       |
| Irrigation per 10 days                  | 338 def    | 0.50 de |
| **B. hyrcana × Sea Water × Irrigation**|            |       |
| per 3 days                              | 765 ab     | 0.58 a-f |
| **B. hyrcana × Sea Water × Irrigation**|            |       |
| per 7 days                              | 782.7 a    | 0.71 a-e |
| **B. hyrcana × Sea Water × Irrigation**|            |       |
| per 10 days                             | 759.7 ab   | 0.60 a-f |
| **E. japonicus Microphylla × Tap Water**|            |       |
| × Irrigation per 3 days                 | 169 f      | 0.52 def |
| **E. japonicus Microphylla × Tap Water**|            |       |
| × Irrigation per 7 days                 | 299.7 def  | 0.69 a-f |
| **E. japonicus Microphylla × Tap Water**|            |       |
| × Irrigation per 10 days                | 327.7 def  | 0.39 f  |
| **E. japonicus Microphylla × NaCl 100** |            |       |
| mM × Irrigation per 3 days              | 318.7 def  | 0.60 a-f |
| **E. japonicus Microphylla × NaCl 100** |            |       |
| mM × Irrigation per 7 days              | 336 def    | 0.46 a-f |
| **E. japonicus Microphylla × NaCl 100** |            |       |
| mM × Irrigation per 10 days             | 321.3 def  | 0.45 ef |
| **E. japonicus Microphylla × NaCl 150** |            |       |
| mM × Irrigation per 3 days              | 244.3 ef   | 0.53 def |
| **E. japonicus Microphylla × NaCl 150** |            |       |
| mM × Irrigation per 7 days              | 282.7 def  | 0.56 b-f |
| **E. japonicus Microphylla × NaCl 150** |            |       |
| mM × Irrigation per 10 days             | 280 def    | 0.72 a-e |
| **E. japonicus Microphylla × Sea Water**|            |       |
| × Irrigation per 3 days                 | 626.3 ab   | 0.56 b-f |
| **E. japonicus Microphylla × Sea Water**|            |       |
| × Irrigation per 7 days                 | 736 ab     | 0.71 a-e |
| **E. japonicus Microphylla × Sea Water**|            |       |
| × Irrigation per 10 days                | 764.3 ab   | 0.58 a-f |
| **E. japonicus aurea-marginatum ×**     |            |       |
| Tap Water × Irrigation per 3 days       | 320.3 def  | 0.60 a-f |
| **E. japonicus aurea-marginatum ×**     |            |       |
| Tap Water × Irrigation per 7 days       | 341 def    | 0.69 a-f |

(Continued)
According to analysis of variance, salinity levels and hedge shrub type and their interaction influenced significantly plant dry weight. Plant dry weight was not significantly affected by other treatments (Table 1). The data for the effect of the shrub type on plant dry weight revealed that *B. hyrcana* and *E. japonicus* var. aureo-marginatum had the highest and lowest shoot dry weight (15.99 and 14.35 g), respectively (Table 2). Based on results, shoot dry weight decreased with

| Treatments                                                                 | Na (mg/kg) | N (%) |
|---------------------------------------------------------------------------|------------|-------|
| *E. japonicus* aureo-marginatum × Tap Water × Irrigation per 10 days     | 314 def    | 0.56 b-f |
| *E. japonicus* aureo-marginatum × NaCl 100 mM × Irrigation per 3 days   | 357.7 de   | 0.61 a-f |
| *E. japonicus* aureo-marginatum × NaCl 100 mM × Irrigation per 7 days   | 383.3 de   | 0.54 c-f |
| *E. japonicus* aureo-marginatum × NaCl 100 mM × Irrigation per 10 days  | 351.7 de   | 0.58 a-f |
| *E. japonicus* aureo-marginatum × NaCl 150 mM × Irrigation per 3 days   | 339 def    | 0.56 b-f |
| *E. japonicus* aureo-marginatum × NaCl 150 mM × Irrigation per 7 days   | 346 def    | 0.62 a-f |
| *E. japonicus* aureo-marginatum × NaCl 150 mM × Irrigation per 10 days  | 372.3 de   | 0.51 def |
| *E. japonicus* aureo-marginatum × Sea Water × Irrigation per 3 days     | 593.3 bc   | 0.77 a-d |
| *E. japonicus* aureo-marginatum × Sea Water × Irrigation per 7 days     | 690.3 ab   | 0.84 abc |
| *E. japonicus* aureo-marginatum × Sea Water × Irrigation per 10 days    | 761.7 ab   | 0.64 a-f |

Means with the same letters in each column do not differ significantly at the 5% level.
salinity, so that the highest shoot dry weight of 17.24 g was related to irrigation with tap water. The lowest plant dry weight was related to the irrigation with Caspian Sea water (13.21 g) and 150 mM NaCl (14.23 g) (Table 3). It seems that the studied shrubs could tolerate NaCl-induced salinity up to the concentration of 100 mM. Results indicated that *E. japonicus* var. microphylla and *B. hyrcana* irrigated with tap water produced the highest plant dry weight (18.77 and 17.74 g, respectively). The lowest plant dry weight of 11.47 g was related to *E. japonicus* var. microphylla treated with Caspian Sea water which was not considered to be an appropriate treatment (Table 4).

The effect of hedge shrub type, salinity levels and the interaction of shrub × salinity was significant on root dry weight. However, this trait was not significantly affected by shrub × drought, salinity × drought and hedge shrub × salinity × drought interaction (Table 1). The highest root dry weight was related to *B. hyrcana* (9.06 g) with no significant difference with that of *E. japonicus* var. microphylla (8.34 g). The
lowest root dry weight (7.34 g) was related to *E. japonicus* var. aureo-marginatum (Table 2). Means comparison for the effect of salinity on root dry weight revealed that the treatment of 100 mM NaCl resulted in the highest root dry weight. It exhibited no significant difference with that of tap water (9.05 g). The lowest root dry weight was produced under the irrigation with Caspian Sea water with no significant difference with 150 mM NaCl (7.78 g) (Table 3). *E. japonicus* var. microphylla irrigated with tap water produced the highest root dry weight. The lowest root dry weight (5.67 g) was produced by *E. japonicus* var. microphylla irrigated with Caspian Sea water (Table 4).

As analysis of variance indicated, shoot dry weight was significantly influenced by salinity ($p < 0.01$). However, no significant differences were observed in shoot dry weight under all other simple treatments and their interaction (Table 1). It was shown that shoot dry weight was decreased with salinity so that the highest shoot dry weight (8.15 g) was related to irrigation with tap water and the lowest one (6.19 g) was related to the irrigation with Caspian Sea water without significant difference with 100 and 150 mM NaCl treatments (Table 3).

4. Discussion

The highest Na concentration was related to shrubs irrigated with Caspian Sea water. As it is known, the concentration of Na and Cl ions is much higher than trace and macroelements saline condition. Therefore, Na$^+$ uptake by plants is higher in these conditions because of the disruption of ion balance which is mainly brought about by the interference between Na$^+$ and K$^+$ ions (Aliasgharzadeh, Saleh Rastin, Towfigh, & Alizadeh, 2002; Jalili Marandi, 2010).

In a study on *Ricinus communis* L., Mohammadkhani, Attar, Salehi, and Houshmand (2013) found that a saline environment around the root zone resulted in higher Na concentration in shoot and root which is in agreement with the present study. The accumulation of Na in different tissues of hedge shrubs was increased with drought stress. Jalili Marandi (2010) reported that drought increases the accumulation of such cation as K$^+$ especially, Na$^+$ and Ca$^{2+}$ in plant tissues which is consistent with our results.

Singh and Pal (1995) believed that N and Na contents of plant tissues increase in saline conditions. In the present study, the highest N content was related to *B. hyrcana* × 100 mM NaCl × 7-day irrigation interval. Afshinmehr, Alizadeh, Jafari Haghighi, and Zare (2013) believed that as salt concentration increases, the water potential of soil becomes negative leading to physiological drought. In addition, higher soil pH disrupts the uptake and mobilization of nutritional ions. Najafo and Mirmasoomi (1999) reported the increase in N accumulation in soybean leaves under saline conditions which is in agreement with the present study. Majidi, Jazayeri, and Mohammadinejad (2009) reported that the constraints of water resources limited the uptake of all macronutrients. Since plants absorb the nutrients of the soil solution, water deficit limits the uptake of all nutrients. The Interactive effect of salinity and nutrients on the plant growth may be associated with the nutrient status in the plant tissues (Hu & Schmidthalter, 1997). Accumulation of Na and Cl ions in leaves through the transpiration flow is a general and long-term process occurring in salt-stress plants (Munns & Tester, 1986).

It was shown that plant height was decreased with salinity and that *E. japonicus* var. microphylla and *B. hyrcana* irrigated with tap water produced taller plants. It is believed that the salinity-induced loss of stem length is associated with the impact of NaCl, as it is reported that salinity stress reduces the production and mobilization of hormones inducing cell division and cell elongation (cytokinin and gibberellin), and instead, it increases ABA which results in the stomatal closure and the loss of photosynthesis. Consequently, the disruption of hormone balance is known as one reason for the loss of plant height under salinity conditions (Afshinmehr et al., 2013; Lazof & Bernstein, 1998). Salami, Safarnejad, and Hamidi (2006) reported that more intense salinity stress resulted in shorter stems in valerian and cumin. As the present study showed, drought stress reduced the height of all studied hedge shrubs, which can be related to inadequate water supply, the loss of growing cells' turgor pressure and its influence on cell elongation (Munns & Tester, 1986).
Safikhani et al. (2007) reported that drought stress decreased the plant height of *Dracocephalum moldavica* which is in agreement with our findings. The number of axillary branches was reduced with increased salinity level. It is believed that when the NaCl concentration increases in rhizosphere, the plant growth is decreased, and consequently, the production of axillary branches is slowed down or stopped (Afshinmehr et al., 2013; Munns & Tester, 2008; Sarmadnia, 1993). Omidbaigi, Hassani, and Sefidkon (2003) argued that the uptake of water and nutrients is decreased under stress resulting in the loss of plant growth and development. Ogbonnaya, Nwalozie, Roy-Macauley, and Annerose (1998) suggested that the loss of branching in kenaf (*Hibiscus cannabinus*) is a defense mechanism by which the plant attempts to maintain the water for the next growth stages.

Inhibition of water uptake resulting in physiological drought stress is reported as one destructive impact of salinity stress on plants. In fact, water and nutrient uptake decrease under saline conditions over time, resulting in the disruption of photosynthesis and inhibition of leaf expansion, stem branching and stem elongation. These factors, altogether, lead to the loss of plant fresh weight. In addition, salinity affects fresh weight by reducing stomatal conductance, transpiration and relative water content of plant parts (Sabet Teimouri, Khazaei, Nezami, & Nassiri Mahallati, 2007; Sarmadnia, 1993). Shao, Chu, Lu, and Kagn (2008) reported the development of drought stress and resulting in loss of water potential are the reasons for the loss of plant fresh and dry weight. The loss of shoot fresh weight under drought stress was reported by Higgs and Jones (1990) for olive plants which is in agreement with the present study.

The researchers believe that the toxicity induced by over-accumulation of ions, especially Na⁺, in plant parts results in the loss of dry matter production (Flowers & Yeo, 1995; Shannon, 1997). Kafi (2000) argues that shoot dry weight is affected by the loss of vegetative growth, leaf area and photosynthesis. Salinity disrupts the uptake of water and nutrients by plants through the increasing osmotic potential of the environment resulting in the loss of vegetative growth and plant dry weight (Afshinmehr et al., 2013; Sarmadnia, 1993). Mirmohammadi Meibodi and Qareyazi (2002) argue that root continues its growth at high salinity, but stems cannot continue their normal growth, and consequently, root dry weight is less affected by salinity than shoot dry weight. The loss of dry matter production with the increase in drought stress can be associated with lower water and nutrient uptake, lower photosynthesis and the loss of vegetative growth as well as the allocation of more photosynthates to roots than to shoot (Sreevalli et al., 2001). Deficit irrigation is necessary in a situation where land is available but water is limited. It reduces crop yield than that of full irrigation. Therefore, this technique is suitable for the successful utilization of limited water for increasing crop production both in normal and saline soil (Mila, Ali, Akanda, Rashid, & Rahman, 2017).

Finally, given the decrease in precipitation and frequent droughts and the increase in saline water and soil in the world, it is necessary to find cultivars which are more resistant to environmental stresses. Therefore, *B. hyrcana* and *E. japonicus* var. microphylla were found to be appropriate for regions with saline and limited water resources and their planting is recommended in these regions under irrigation management. However, further research is required to prove these recommendations.

5. Conclusions

(1) Although the trial shrubs (*Buxus* and *Euonymus*) are resistant to salinity, high salinity levels reduce plant height and fresh and dry weight. Drought stress at high levels, especially 10-day interval, resulted in the loss of these traits, too.

(2) Though having the highest Na⁺ concentration, *B. hyrcana* was found to be the best treatment or not to have a significant difference with the best treatment in the most studied traits, which can be an evidence of its higher resistance to drought and salinity. Therefore, it can be said that *B. hyrcana* is more resistant than *E. japonicus* var. microphylla and *E. japonicus* var. aurea-marginatum to drought and salinity.
Funding
The authors declare that there is no funding for this study.

Author details
Sharam Sedaghathoor1
E-mail: sedaghathoor@yahoo.com
ORCID ID: http://orcid.org/0000-0002-2438-2299
Seyedeh Khadijeh Abbasnia Zare1
1 Faculty of Agriculture, Department of Horticulture, Rasht branch, Islamic Azad University, Rasht, Iran.

Cover image
Source:

Competing Interests
The authors declare no competing interests.

Citation information
Cite this article as: Interactive effects of salinity and drought stresses on the growth parameters and nitrogen content of three hedge shrubs, Sharam Sedaghathoor & Seyedeh Khadijeh Abbasnia Zare, Cogent Environmental Science (2019), 5: 1682106.

References
Abadi Almus, D., Bagherikia, S., & Mohdavi, K. (2013). Effects of salt and water stresses on germination and seedling growth of Artemisia vulgaris L. International Journal of Agriculture and Crop Sciences, 6(11), 762–765.
Afshinmehr, R., Alizadeh, O., Jafari Haghhighi, B., & Zare, M. (2013). Evaluation of the effects of different salt stress levels on some morphological and physiological traits in some soybean (Glycine max L.) cultivars. Journal of Plant Ecophysiology, 5(14), 17–33.
Ahmadikiah, A. (2009). Crop response to abiotic environmental stresses. Gorgan, Iran: Gorgan Agriculture and Natural Resources University Press.
Alisaghorzadeh, N., Saleh Rastin, N., Towfigh, H., & Alizadeh, A. (2002). Effect of mycorrhization on yield and nutrient uptake by barley in saline conditions. 17th World congress of soil science (pp. 14–21). Bangkok, Thailand.
Asadi, H., Hosseini, S. M., Esmailzadeh, O., & Ahmadi, A. (2011). Flora, life form and chorological study of Box tree (Buxus hycanus Pojark.) sites in Khvbs protected forest, Mazandaran. Journal of Plant Biology, 3(8), 27–40.
Bokhsh Khanki, G. R. (2007). Iranian trees and shrubs. Tehran, Iran: Payam Noor University Press.
Brickell, C. (2008). Encyclopaedia of garden plants. Leo Paper Products Ltd. Hong Kong.
Emami, A. (1996). Plant analysis method (Vol. 2nd). Tehran, Iran: Soltan Water and Institute.
Flowers, T. J., & Yeo, A. R. (1995). Breeding for salinity resistance in crop plants: Where next? Aust Australian Journal of Plant Physiology, 22, 875–885. doi:10.1071/PP9950875
Higgs, K. H., & Jones, H. G. (1990). Response of apple rootstocks to irrigation in southeast England. Journal of Horticultural Science, 65, 125–141. doi:10.1080/00212159.1990.11516019
Hu, Y., & Schmidhalter, U. (1997). Interactive effects of salinity and macronutrient level on wheat. II. Composition. Journal of Plant Nutrition, 20, 1169–1182. doi:10.1080/01904169709563253
Jalili Marandi, R. (2010). Physiology of environmental stresses and resistance mechanisms in horticultural plants (fruit trees, vegetables, ornamental plants, and medicinal herbs (Vol. 1)). Oromie, Iran: Jadad-e Daneshghahi Press.
Jami Al Ahmadi, M., & Kafi, M. (2008). Kochia (Kochia scoparia): To be or not to be? In Crop and forage production using saline waters. In M. Kafi & M.A. Khan (Eds.), (pp. 119–162). New Delhi: Daya Publisher.
Kafi, M. (2000). Mechanisms of plant resistance to environmental stresses. Mashhad, Iran: Ferdowsi University Press.
Kafi, M., Borzou, A., Salehi, M., Kamandi, A., Masoomi, A., & Nabati, J. (2009). Physiology of environmental stresses in plants. Mashhad, Iran: Mashhd Jahad-e Daneshghahi Press.
Karimi, H. (2005). Encyclopedia of Iranian plants: 2nd Vol. Trees, shrubs, flowers and ornamental plants. Tehran, Iran: Parcham Press.
Lazof, D. B., & Bernstein, N. (1998). The NaCl-induced inhibition of shoot growth: The case for disturbed nutrition with special consideration of calcium nutrition. Advances in Botanical Research, 29, 115–190. doi:10.1016/S0065-2296(08)60311-0
Lebaschi, M. H., & Sharifi Ashoorabadi, E. (2004). Growth indices of some medicinal plants under different water stresses. Iranian Journal of Medicinal and Aromatic Plants Research, 20(3), 249–261.
Majidi, M. M., Jozayneri, M. R., & Mohammadinejad, G. (2009). Salt effects on germination and seedling growth of safinon (Onobrychis vicillicopa Scop.) genotypes. Iranian Journal of Rangelands and Forests Plant Breeding and Genetic Research, 17(2), 256–269.
Mila, A. J., Ali, M. H., Akanda, A. R., Rashid, M. H. O., & Rahman, M. A. (2017). Effects of deficit irrigation on yield, water productivity and economic return of sunflower. Cogent Food & Agriculture, 3(1), 1287619. doi:10.1080/23311932.2017.1287619
Mirmohammad Meibodi, S. M., & Qoreyzi, B. (2002). Physiological and breeding aspects of salinity stress in plants. Isfahan, Iran: Isfahan University of Technology Press.
Mohammadkhani, A., Attar, F., Salehi, M. H., & Housshmand, S. (2013). Effect of NaCl salinity on seed yield and the uptake and translocation of some elements in three landraces of castor (Ricinus communis L.). Journal of Water Research in Iran, 7(12), 99–109.
Munns, R., & Termaat, A. (1986). Whole plant responses to salinity. Functional Plant Biology, 13, 143–160. doi:10.1071/PP986143
Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. Annual Review of Plant Physiology, 59, 651–681. doi:10.1146/annurev.arplant.59.032607.092911
Najafi, H., & Mirmossoomi, M. (1999). A study on physiological responses of soybean under salinity stress conditions. Journal of Agriculture Science and Industries, 13(1), 34–39.
Ogbonnaya, C. L., Nwalozie, M. C., Roy-Macauley, H., & Annerose, D. J. (1999). Growth and water relations of kenaf (Hibiscus cannabinus L.) Under Water Deficit on a Sandy Soil. Industrial Crops and Products, 8, 65–76. doi:10.1016/S0926-6690(97)01011-5
Omidbaigi, R., Hassani, A., & Sefidkon, F. (2003). Essential oil content and composition of sweet basil (Ocimum basilicum) at different irrigation regimes. Journal of Essential Oil Bearing Plants, 6, 104–108. doi:10.1080/0972-060X.2003.10643335
Sabet Teimouri, M., Khazaei, H. R., Nezami, A., & Nassiri Mahallati, M. (2007). Effect of different salinity levels on antioxidant enzymes activity in leaf and physiological characteristics of sesame (Sesamum indicum). Agriculture and Security Water, Soil and Plant in Agriculture, 7(4a), 109–119.
Sabeti, H. (1995). Forests, trees and shrubs in Iran. Yazd, Iran: Yazd University Press.


Safikhani, F., Heydarye Sharifabadi, H., Syadat, A., Sharifi Ashorabadi, A., Syednedjad, M., & Abbaszadeh, B. (2007). The effect of drought on yield and morphological characteristics of Deracocephalum Moldavia L. Iranian Journal of Medicinal and Aromatic Plants, 23(2), 183–194.

Salemi, M. R., Safarnejad, A., & Hamidi, H. (2006). Effect of salinity stress on morphological characters of cumi-num cyminum and valeriana officinalis. Pajouhesh Sazandegi, 72, 77–83.

Salehi, M., Kafi, M., & Kiani, A. (2009). Growth analysis of kochia (Kochia scoparia L.) irrigated with saline water in summer cropping. Pakistan Journal of Botany, 41(4), 1861–1870.

Sarmadnia, G. (1993). The importance of environmental stresses in agronomy. 1st National conference of agronomy and plant breeding. Karaj, Iran.

Sefikhani, S., Chaparzadeh, N., & Zarandi, N. (2010). A study on some physiological indicators in different leaves of Euonymus japonicus (M.Sc. Thesis). Tarbiat Modleem University of Azerbaijan, Tabriz, Iran.

Shannon, M. (1997). Adaptation of plants to salinity. Advances in Agronomy Journal, 60, 75–120. doi:10.1016/S0065-2113(08)60601-X

Shao, H. B., Chu, L. Y., Lu, Z. H., & Kagn, C. M. (2008). Primary antioxidant free radical scavenging and redox signaling pathways in higher plants. International Journal of Biological Sciences, 2, 8–14. doi:10.7150/ijbs.4.8

Singh, L., & Pal, B. (1995). Effect of water salinity and fertility levels on yield and yield attributing charac-ters of blond psyllium (Plantago ovate). Indian Journal of Agricultural Sciences, 65, 503–505.

Sreevali, Y., Baskaran, K., Chandrashekara, R., Kuikkan, R., Sushil Hasan, S., Samresh, D., & Rakesh, T. (2001). Preliminary observations on the effect of irrigation frequency and genotypes on yield and alkaloid concentration in periwinkle. Journal of Medicinal and Aromatic Plant Sciences, 22, 356–358.

Zaman, S. (2003). Medicinal herbs: Planting, harvesting and illustrative description of 256 species. Tehran, Iran: Qognoos Press.

© 2019 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

You are free to:
Share — copy and redistribute the material in any medium or format.
Adapt — remix, transform, and build upon the material for any purpose, even commercially.
The licensor cannot revoke these freedoms as long as you follow the license terms.
Under the following terms:
Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made.
No additional restrictions
You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.

Cogent Environmental Science (ISSN: 2331-1843) is published by Cogent OA, part of Taylor & Francis Group.
Publishing with Cogent OA ensures:
• Immediate, universal access to your article on publication
• High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
• Download and citation statistics for your article
• Rapid online publication
• Input from, and dialog with, expert editors and editorial boards
• Retention of full copyright of your article
• Guaranteed legacy preservation of your article
• Discounts and waivers for authors in developing regions

Submit your manuscript to a Cogent OA journal at www.CogentOA.com