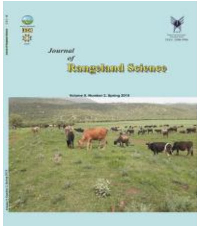
Contents available at ISC and SID

Journal homepage: www.rangeland.ir



Research and Full Length Article:

Effect of Drought and Salinity Stress on Morpho-physiological Variation of Iranian Endemic *Stachys Multicaulis* Benth. in Different Soil Textures

Habib Yazdanshenas[A], Mohammad jafari[B], Ali Tavili[C*], Hossein Azarnivand[D], Hossein Arzani[E]
[A] PhD Student of Range Management, Department of Reclamation of Arid and Mountainous Regions, Natural Resources Faculty, University of Tehran, Karaj, Iran.
[B,D,E] Professor, Department of Reclamation of Arid and Mountainous Regions, Natural Resources Faculty, University of Tehran, Karaj, Iran.
[C] Associate Professor, Department of Reclamation of Arid and Mountainous Regions, Natural Resources Faculty, University of Tehran, Karaj, Iran *(Corresponding Author). Email: atavili@ut.ac.ir

Received on: 25/04/2018
Accepted on: 17/12/2018

Abstract. Adaptation of plants under drought and salinity stress depends directly on the type of soil texture. Therefore, in this research, the morpho-physiological variations of *Stachys multicaulis*, an Iranian wild endemic plant species, were investigated in different soil textures under drought and salinity stress. For this purpose, plants were cultivated in three different light, medium and heavy soil textures under pot condition (outside the greenhouse near the plant original habitat) in 2016. Then, a set of drought stress (3 day intervals of irrigation; 3 to 15 days) and salinity stress (0, 5, 10, 15, 20 and 25 ds/m- NaCl) was used in two separate factorial experiments based on a completely randomized design with four replications. The results showed that both drought and salinity had significant effects on morpho-physiological properties of *S. multicaulis* ($p<0.01$) based on type of soil texture. All of traits had higher performance in heavy soil texture except trichome length. For 15 day interval of irrigation, higher values of plant biomass, plant greenness, leaf length/width ratio, leaf angle, and node distance as 8.25g, 28.1%, 4.17, 55°, 1.5cm respectively were obtained in heavy soil texture. Similarly, for salinity of 25 ds/m, higher values of same traits as 7.7g, 25%, 3.9, 50°, and 1.4cm, respectively were obtained in heavy soil texture. Both drought and salinity stress had no significant effect ($p<0.01$) on leaves trichome number, trichome length, floret number per plant and branch number per plant in all three soil textures. The morphological variations of the plant occurred with greater intensity in salinity stress and it was concluded that plant tolerance to salinity was lower than drought.

Key words: Salt stress, Soil properties, Pot culturing, Physiological properties, Greenness value

Introduction

Relationships between soil physical properties and crop yields have been reported previously (He *et al.*, 2011; Salem *et al.*, 2015; Jamali *et al.*, 2016). As the most important physical factor, soil texture is used to refer to the size distribution of the primary mineral particles in the soil (Dexter, 2004) which predominantly determines the hydraulic conductivity, water-holding capacity, porosity and aeration of a particular soil type (Jamali *et al.*, 2016). This factor has also been related to soil and plant water relations (Turner *et al.*, 2010; Poot and Veneklaas, 2013; Hamer *et al.*, 2016). However, soil texture is more important for plants in arid areas with drought and salinity stress in terms of food security and land management.

About one-third of the earth's land surface is arid and semi-arid (Lynch, 1995) in which drought and salinity stress are the most worldwide problems in the soil of these lands (Li *et al.*, 2015; Forni *et al.*, 2017; Radhakrishnan and Baek, 2017). Approximately 7% of the world's total land area are affected by salinity (Shabala and Cuin, 2008) along with drought which are the most factors limiting plant growth and crop productivity (Zhu *et al.*, 2012; Forni *et al.*, 2017; Ranjbar-Fordoei and Dehghani-Bidgoli, 2016). Therefore, the need to develop crops for higher salinity tolerance has increased strongly due to increased salinity and drought problems (Sivritepe *et al.*, 2003). Moreover, the direct selection of superior drought and salt-tolerant genotypes under field conditions can be a suitable solution to cope with these tensions. Higher soil salinity, for example can have adverse effects on many biological processes and decrease the growth of plant (Jiang *et al.*, 2014). But adaptation of plants under drought and salinity stress depends directly on the type of soil texture. Plants exposure to low level salinity activates an array of processes leading to an improvement of plant stress tolerance (Pandolfi *et al.*, 2012) but in higher stress, soil texture plays an important role in plant resistance.

Many researches had been published for plant species such as *Cichorium intybus* (Asghari, 2010), *Fortuynia bungei* (Tajamoliyan *et al.*, 2013), *Argania spinosa* (Chakhchar *et al.*, 2016), *Nitraria schoberi* (Ranjbar and Mousavi, 2015), *Reaumuria soongorica* (Shan *et al.*, 2015) and *Alhagi persarum* (Tanaomi *et al.*, 2018) under drought stress. Also, many researches have been done on the effect of the salinity on morpho-physiological properties of different plant species such as Kochia (Shelef *et al.*, 2010), Spring *Aeluropus Littoralis* (Kaleybar *et al.*, 2013), Tamarix (Li *et al.*, 2015) and *Nitraria schoberi* (Ranjbar-Fordoei and Dehghani-Bidgoli, 2016). However, the most mentioned studies were conducted only in a specific soil texture. Therefore, due to different environmental stresses and their longevity, soil condition and plant type, different effects may happen on plants morpho-physiological properties.

Adaptation to stress conditions is challenging because of complexity of target environments and the adaptive mechanisms adopted by plants when exposed to the stressful conditions (Reynolds *et al.*, 2005; Noori *et al.*, 2014). Plastic physiological or morphological responses to environmental stress are important adaptation among plants that live in extreme environments (Shan *et al.*, 2015) and this is valuable to find the most resistant endemic plant species for land rehabilitation. However, our knowledge is low for morphological and physiological variations for specific plant species in different conditions of salinity and drought as two main environmental stresses under soil properties.

Moreover, the effects of environmental factors on resistance and performance of native plants are more important and therefore, in this study, one of the Iranian endemic range species, *Stachys multicaulis* Benth. that is valuable in terms of ecologically forage production and its

Traditional medicinal values was studied. *S. multicaulis* species originated in Iran (Mozaffarian, 2007) is a wild endemic green bush with numerous stems having height of 20 to 40cm and covered with long simple trichome. *S. multicaulis* is valuable in terms of food, medicine (Erdemoglu *et al.*, 2006; Jamzad *et al.*, 2009), beauty and especially soil and water conservation in sloppy natural area.

Therefore, with respect to lack of research on the effect of drought and salinity stresses on plants morpho-physiological traits in different soil textures, the present study aimed to investigate morpho-physiological variation of *Stachys multicaulis* under salinity and drought stresses in three different soil textures.

Material and Methods

The experiment was done under pot condition outside the greenhouse and near the original habitat of the plant. Plant habitat (Ghasem Abad, Tiran and Karvan) covers approximately 3000 ha of area and is located between 50° 52′ to 50°59′ E longitude and 32° 41′ to 32° 46′ N latitude in 75 km far from Isfahan, Iran. In addition, laboratory experimental section was performed in soil lab at University of Tehran, Department of Natural Resources, Karaj, Iran in 2016.

In order to study the effect of salt and drought stress on morpho-physiological properties of the plant, cylindrical plastic pots in specific height and diameter (25×15 cm) were used. The soil samples were taken from the original habitat of the plant and mixed with the home garden soil for pot soil perpetration. Three different soil textures were prepared based on changes in soil constituents [i.e., percentage of sand, silt and clay] (Prakash *et al.*, 2010). The Plant habitat soil was used as the base of three different textures and therefore, chemical soil properties were similar except percent of clay, silt and sand. Therefore, different soil textures including light, medium and heavy were prepared using 5, 15 and 40% clay, respectively (Table 1).

Table 1. Summary of three different soils in terms of texture and physicochemical properties for pot culturing

Soil texture	Clay (%)	Silt (%)	Sand (%)	Texture	Bulk density (g/cm^3)
Light	5.00±0.00	25.00±0.00	70.00±0.00	Sandy loam	1.52
Medium	15.00±0.00	42.00±0.00	43.00±0.00	Loam	1.43
Heavy	40.00±0.00	30.00±0.00	30.00±0.00	Clay loam	1.35
N (Meq/L)	P (Meq/L)	K (Meq/L)	pH	OM (%)	EC(ds/m)
4.40±0.10	16.80±3.25	82.40±11.13	7.87±0.40	1.60±0.08	0.93±0.12

Seeds of *S. multicaulis* were collected from the plant habitat and after germination test, due to the problem in germination of *S. multicaulis* seed, plant scion was used for plant propagation in pots. For this purpose, at the initiating growth season, plant species stands were identified; then, plant scion was gathered and transferred to pots. A total number of 300 pots containing heavy, medium and light soil textures were prepared and due to the application of a set of salinity treatments (6 levels) and a set of drought treatments (5 levels) in 3 different soil textures and four replications, a total of 120 pots [3(5+5*4)] were prepared using two separate factorial experiments based on a completely randomized design. In fact, salinity and drought were examined separately. Pots were irrigated every 3 days. Then, 35 days after seed sowing, when plants have grown to the desired size, the salinity and drought treatments were applied to them. Drought stress included 3, 6, 9,12 and 15 days irrigation intervals and a set of salt treatments included 0, 5, 10, 15, 20 and 25 ds/m using NaCl (Zhang *et al.*, 2012) as one of the most common and most toxic environmental salts for plants concerning each soil texture.

At the end of the experiment (60 days), plant morpho-physiological properties were measured as follows: plant height, angle of leaves, leaf length/width ratio, distance between nodes, plant biomass, the relative greenness and leaf color (RGB), Leaves length and trichome density (using Zeiss microscope Model: 47 60 05-9901), number of branches and floret per plant.

Plant height, leaf length and width, and nodes distance were measured using a ruler (Promkhambut *et al.*, 2010). Areal dry matter of samples was weighted; relative greenness was measured using RGB based on image analysis and crating correlation to SPAD results (Yadav *et al.*, 2010). Image processing was performed based on RGB values using a digital camera (13 MP, 4128 × 3096 pixels resolution).

For trichome length and density measurement, leaves of control and treated plants were cut and observed with a stereomicroscope (Karray-Bouraoui *et al.*, 2009). In addition, number of branches and florets per plant were measured in pot based on observation.

At the end of the experiment, the collected data were tested for normality using Kolmogorov-Smirnov test, then analysis of variance and the post hoc test were performed using the Duncan method for grouping treats p≤0.05 using SPSS software.

Results

The analysis of variance in two separate factorial experiments showed significant differences between soil textures and between salinity and drought stresses (P<0.001) for all traits. There were no significant differences between stresses and soil texture interaction for all traits (Tables of ANOVA not shown).

The main effects of drought stress were significant for plant height (P≤0.01) and the plant height was generally decreased by increasing irrigation distance. However, there was no significant difference between 3 and 6 days irrigation duration. Similarly, the main effects of soil texture were significant and higher and lower plant heights were obtained in medium and heavy soil textures, respectively (Fig. 1A).

In salinity experiment, the similar result was obtained and plant height was decreased by increasing salt concentration. However, there was no significant difference between 10 ds/m and control. For the soil texture, higher plant height was obtained in both heavy and light soil textures (Fig. 1B).

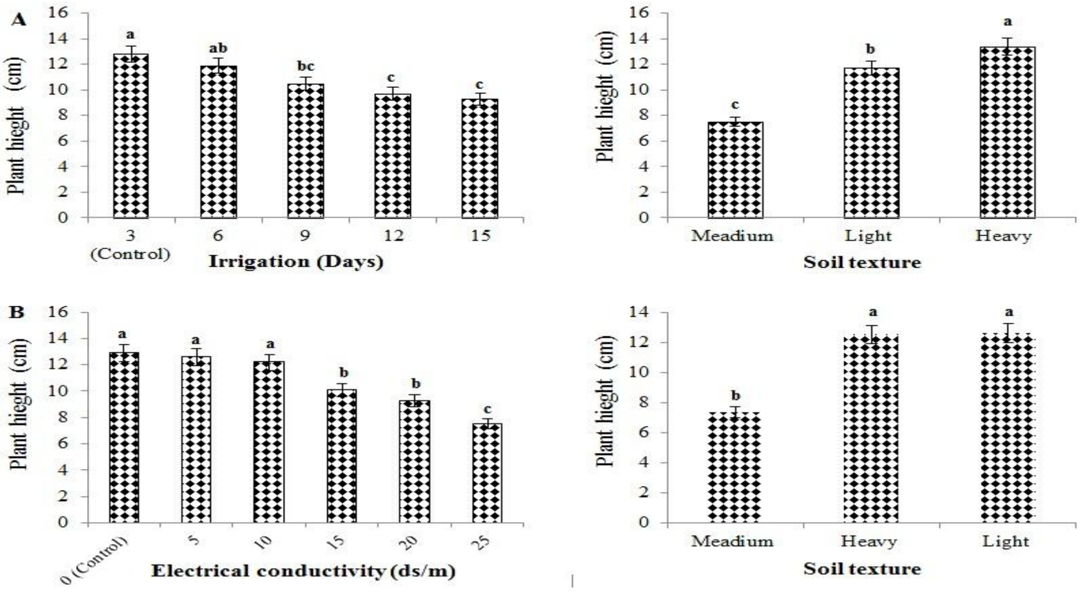


Fig. 1. Effect of salinity and drought stress on plant height of *S. multicaulis* in relation to soil texture

Leaf length/width ratio (LR) as a photosynthetic surface area response to dry and saline treatments was significant. Higher leaf ratio was obtained in 15 day irrigation interval treatment. Regression analysis was performed to define linear relationships between Leaf length/width ratio and both drought and salinity levels. The relationships between drought stress and leaf length/width ratio were linear in three soil textures (Fig. 2). Higher R^2 was observed for heavy soil texture for both stresses. Probably due to environmental stress (salinity), the width of the leaf was decreased and therefore, the leaf length/width ratio was increased (Fig. 2).

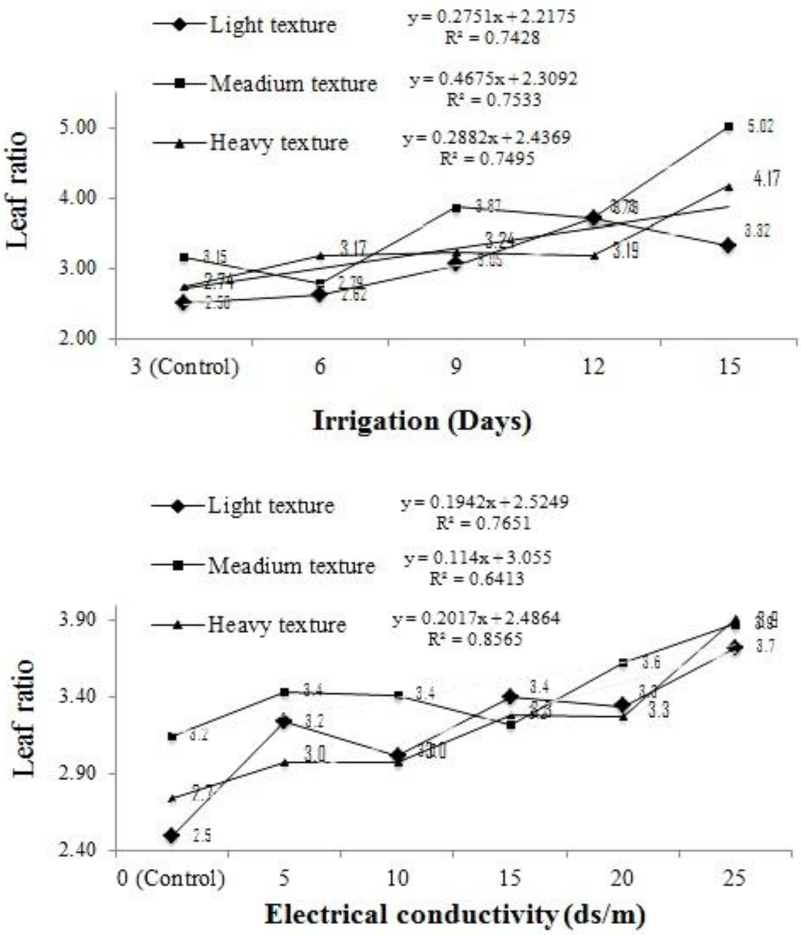


Fig. 2. Regression linear equations of leaf length/width ratio in *S. multicaulis* in relation to soil texture

The main effects of drought stress were significant for plant biomass ($P \leq 0.01$) and plant biomass was generally decreased by increasing irrigation duration. However, there was no significant difference between 6 and 9 day irrigation duration. Similarly, the main effect of soil texture was significant and higher biomass was obtained in heavy soil texture (Fig. 3A).

In salinity experiment, the similar result was obtained and plant biomass was sharply decreased by increasing salt concentration. Higher biomass was obtained in heavy soil texture (Fig. 3B).

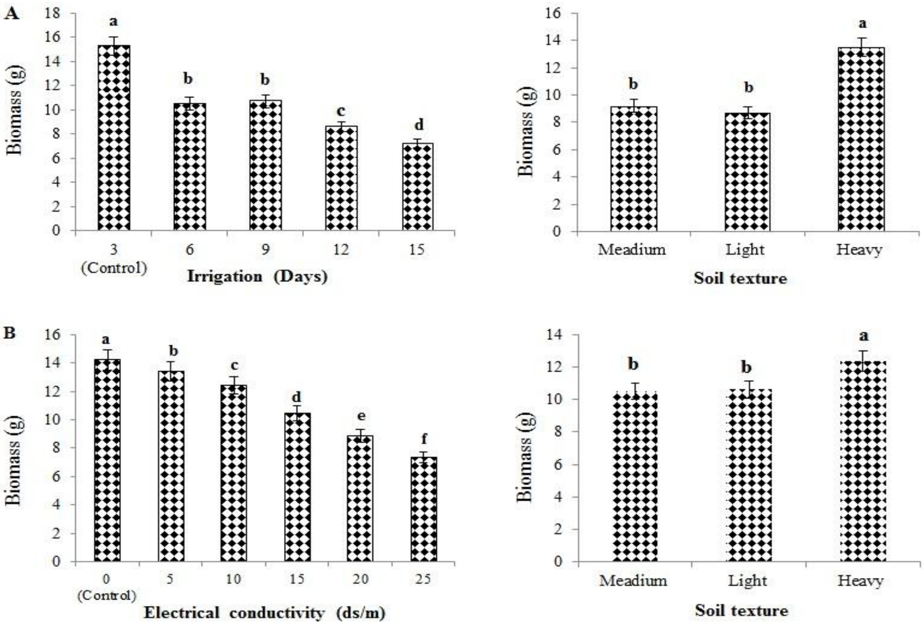


Fig. 3. Effect of salinity and drought stress on plant biomass production of *S. multicaulis* in relation to soil texture

The plant greenness values were decreased by increasing irrigation distance. Similarly, the main effects of soil texture were significant for plant greenness. The highest and lowest plant greenness was obtained in medium and heavy soil textures, respectively (Fig. 4A).

In salinity experiment, a similar result was obtained; with an increase in salt concentration, plant greenness was decreased. Heavy and medium soil textures showed the highest and lowest greenness, respectively (Fig. 4B).

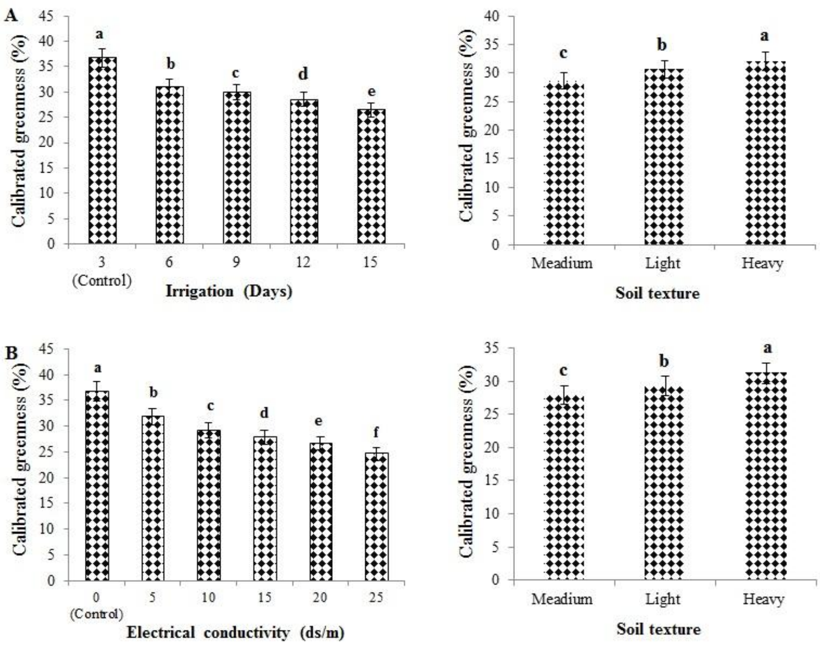


Fig. 4. Effect of salinity and drought stress on plant greenness of *S. multicaulis* in relation to soil texture

Leaf angle which is a physiological and morphological index of variation to receive the sunlight has a regular trend for different levels of salinity or drought stress. Fig.5 shows the variation of the plant leaf angle under drought and salinity stress in different soil textures.

By an increase in irrigation intervals, leaf angle was decreased. Similarly, the difference between soil textures was significantly decreased for leaf angle and higher value was obtained in heavy soil texture (Fig. 5A). In salinity stress experiment, the similar result was obtained and leaf angle was decreased by increasing salt concentration. Higher values of leaf angle were obtained in heavy and medium soil textures, respectively (Fig. 5B).

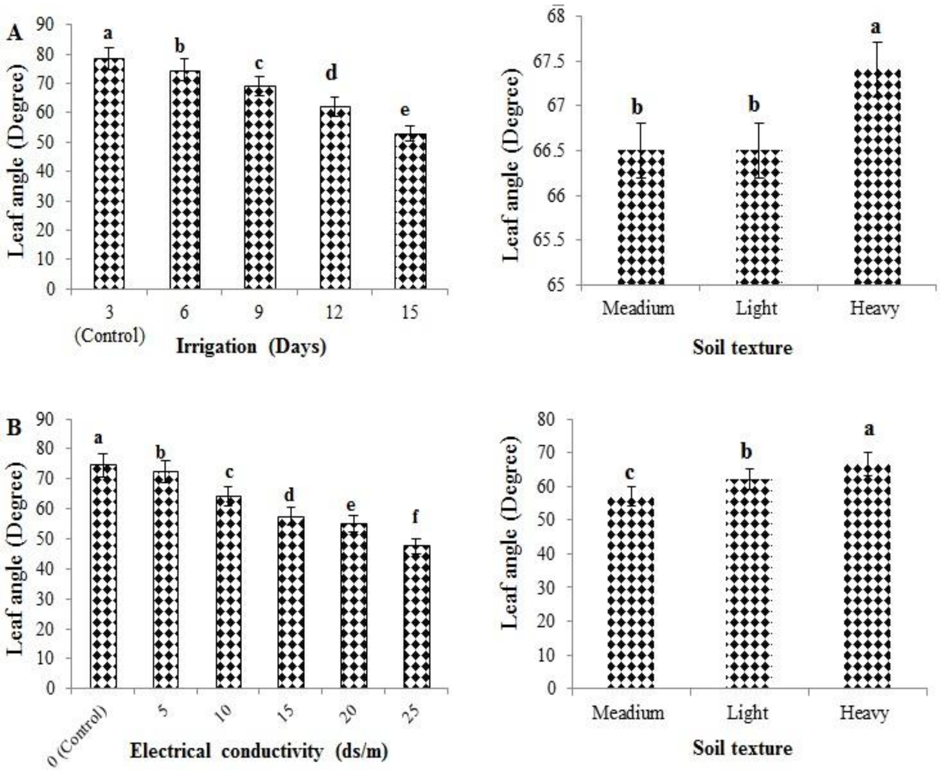


Fig. 5. Effect of salinity and drought stress on leaf angle of S. *multicaulis* in relation to soil texture

The Effects of drought and salinity stress on leaf morphological traits of *S. multicaulis* are presented in Tables 1 and 2. Both drought and salinity stresses had no significant effect ($p<0.01$) on leaves trichome number, trichome length, floret number per plant and branch number per plant in all three soil textures.

For the floret number and nodes distance, higher values were obtained in 3 day interval irrigation and their values were dropped by increasing irrigation distance. In contrast, for trichome length, higher value was obtained in 15 day drought stress. Two other traits such as branch number and trichome number had no response to drought stress (Table 2). In soil texture comparison, higher values of floret number, nodes distance, branch number and trichome number were obtained in heavy soil texture (Table 2).

In salinity experiment, both floret number and nodes distance values were decreased by increasing salinity effects. In contrast, for trichome length, higher values were obtained in 25 ds/m EC. Two other traits such as branch number and trichome number had no response to salinity stress (Table 3). In soil texture comparison, lower values of floret number and nodes distance were obtained in medium soil texture (Table 2). In contrast, lower trichome length was obtained in heavy soil (Table 3).

Table 2. Effect of drought stress on leaf morphological traits of *S. multicaulis* species in relation to soil texture

Factor (s)	Soil texture	Drought (Irrigation periods-days)				
		3	6	9	12	15
Number of floret per plant	Light	3 ± 1.0^{Ab}	2 ± 1.0^{Bb}	1 ± 1.0^{Cb}	1 ± 1.0^{Cb}	1 ± 1.0^{Ca}
	Medium	2 ± 1.0^{Ac}	1 ± 1.0^{Bc}	1 ± 1.0^{Bb}	1 ± 1.0^{Bb}	0 ± 0.0^{Cb}
	Heavy	5 ± 1.0^{Aa}	5 ± 1.0^{Aa}	5 ± 1.0^{Aa}	2 ± 1.0^{Ba}	1 ± 1.0^{Ba}
Number of branch per plant	Light	3 ± 1.0^{Aa}	2 ± 1^{Bb}	2 ± 1.0^{Ba}	2 ± 1.0^{Ba}	2 ± 1.0^{Bb}
	Medium	2 ± 1.0^{Bb}	3 ± 1^{Aa}	2 ± 1.0^{Ba}	2 ± 1.0^{Ba}	2 ± 1.0^{Bb}
	Heavy	3 ± 1.0^{Aa}	3 ± 1^{Aa}	2 ± 1.0^{Ba}	2 ± 1.0^{Ba}	3 ± 1.0^{Aa}
Distance between nodes (cm)	Light	2.3 ± 0.5^{Aa}	1.9 ± 0.4^{Ba}	1.6 ± 0.3^{Bb}	1.3 ± 0.2^{Cb}	0.9 ± 0.2^{Cb}
	Medium	1.5 ± 0.4^{Ab}	1.43 ± 0.2^{Ab}	1.3 ± 0.2^{Bb}	1.2 ± 0.2^{Bb}	0.9 ± 0.3^{Bb}
	Heavy	2.3 ± 0.7^{Aa}	1.8 ± 0.5^{Ba}	1.8 ± 0.3^{Ba}	1.7 ± 0.4^{Ba}	1.5 ± 0.3^{Ba}
Number of Trichome per unit	Light	3 ± 0.01^{Aa}	3 ± 0.01^{Aa}	3 ± 1.0^{Aa}	3 ± 0.01^{Ab}	3 ± 1.0^{Ab}
	Medium	3 ± 0.01^{Aa}	3 ± 0.01^{Aa}	3 ± 0.01^{Aa}	3 ± 0.01^{Ab}	3 ± 0.01^{Ab}
	Heavy	2 ± 0.01^{Cb}	3 ± 0.01^{Ba}	3 ± 0.01^{Ba}	4 ± 1.0^{Aa}	4 ± 1.0^{Aa}
Trichome length (mm)	Light	1.5 ± 0.5^{Bb}	2.3 ± 0.4^{Aa}	2.3 ± 0.3^{Aa}	2.8 ± 0.2^{Aa}	2.3 ± 0.2^{Aa}
	Medium	1.5 ± 0.4^{Cb}	1.8 ± 0.2^{Bb}	1.5 ± 0.2^{Cc}	2.0 ± 0.2^{Ac}	2.3 ± 0.3^{Aa}
	Heavy	1.8 ± 0.7^{Ca}	1.8 ± 0.5^{Cb}	2.0 ± 0.3^{Bb}	2.5 ± 0.4^{Ab}	2.3 ± 0.3^{Aa}

Similar uppercase letters in each row had no significant difference based on Duncan Test ($p<0.05$).
Similar lowercase letters in each column for each trait had no significant difference based on Duncan Test ($p<0.05$).

Table 3. Effect of salinity stress on leaf morphological traits of *S. multicaulis* species in relation to soil texture

Factor (s)	Soil texture	Salinity (ds/m)					
		0	5	10	15	20	25
Number of floret per plant	Light	3 ± 1.0^{Bb}	2 ± 1.0^{Cb}	4 ± 2.0^{AA}	4 ± 1.0^{AA}	2 ± 1.0^{Cb}	1 ± 1.0^{Cb}
	Medium	1 ± 1.0^{Ac}	1 ± 1.0^{Ac}	1 ± 1.0^{Ab}	1 ± 1.0^{Ab}	1 ± 1.0^{AC}	0 ± 0.0^{BC}
	Heavy	5 ± 1.0^{Aa}	4 ± 2.0^{Ba}	4 ± 1.0^{Ba}	4 ± 2.0^{Ba}	3 ± 1.0^{Ca}	3 ± 1.0^{Ca}
Number of branch per plant	Light	3 ± 1.0^{Aa}	2 ± 1.0^{Bb}	3 ± 1.0^{Aa}	3 ± 2^{Aa}	2 ± 1.0^{Ba}	2 ± 1.0^{Bb}
	Medium	2 ± 1.0^{Ab}	2 ± 1.0^{Ab}	2 ± 1.0^{Ab}	2 ± 1.0^{Ab}	2 ± 1.0^{Aa}	2 ± 1.0^{Ab}
	Heavy	3 ± 1.0^{Ba}	4 ± 2.0^{Aa}	3 ± 1.0^{Ba}	2 ± 1.0^{Cb}	2 ± 1.0^{Ca}	$3\pm2^{.0Ba}$
Distance between nodes (cm)	Light	2.3 ± 0.5^{Aa}	2.1 ± 0.3^{Aa}	1.7 ± 0.4^{Ba}	1.6 ± 0.3^{Ba}	1.3 ± 0.2^{Bb}	1.0 ± 0.2^{Bb}
	Medium	1.5 ± 0.4^{Ab}	1.4 ± 0.2^{Ac}	1.1 ± 0.2^{Bb}	1.1 ± 0.1^{Bb}	1.0 ± 0.2^{Bb}	0.7 ± 0.2^{Bb}
	Heavy	2.3 ± 0.7^{Aa}	1.7 ± 0.3^{Bb}	1.3 ± 0.3^{Cb}	1.1 ± 0.2^{Cb}	1.5 ± 0.4^{Ba}	1.4 ± 0.3^{Ca}
Number of Trichome per unit	Light	3 ± 0.0^{Aa}	3 ± 1.0^{Aa}	3 ± 1.0^{Aa}	3 ± 1.0^{Aa}	3 ± 1.0^{Aa}	3 ± 1.0^{Aa}
	Medium	3 ± 0.0^{Aa}	3 ± 1.0^{Aa}	3 ± 1.0^{Aa}	2 ± 1.0^{Bb}	2 ± 0.0^{Bb}	3 ± 0.0^{Aa}
	Heavy	2 ± 0.0^{Bb}	2 ± 0.0^{Bb}	3 ± 1.0^{Aa}	2 ± 1.0^{Bb}	3 ± 1.0^{Aa}	3 ± 1.0^{Aa}
Trichome length (mm)	Light	1.5 ± 0.5^{Bb}	1.5 ± 0.4^{Bb}	2.0 ± 0.3^{Aa}	2.2 ± 0.2^{Aa}	2.0 ± 0.3^{Ab}	2.0 ± 0.3^{Ab}
	Medium	1.5 ± 0.4^{Bb}	1.5 ± 0.3^{Bb}	2.0 ± 0.2^{Aa}	2.3 ± 0.2^{Aa}	2.3 ± 0.2^{Aa}	2.3 ± 0.3^{Aa}
	Heavy	1.8 ± 0.7^{Ba}	1.8 ± 0.4^{Ba}	1.8 ± 0.2^{Bb}	1.8 ± 0.1^{Bb}	1.8 ± 0.2^{Bc}	2.0 ± 0.3^{Ab}

Similar uppercase letters in each row had no significant difference based on Duncan Test ($p<0.05$).
Similar lowercase letters in each column for each trait had no significant difference based on Duncan Test ($p<0.05$).

Discussion

Water stress is a major limitation to crop productivity worldwide and possible global climate change scenarios suggest a future increase in the risk of drought (IPCC 2001, Ali *et al.*, 2009). Water resources and protection of resources are the basic strategies to achieve sustainable development (Kolahchi *et al.*, 2011). Also, salinity along with water shortage affect plant life and therefore, resistant plant species should be identified to ensure food security around the world. However, the physical properties of the soil had a major impact on the resistance and sustainability of plants in areas under stress, and this should be considered in the remediation and rehabilitation projects based on cultivated plant species.

According to this research, the most variation of *S. multicaulis* height considering all soil textures occurred in salinity than that for drought stress. Plant height in medium soil texture was lower than two other soil textures. [Height=15, 8.8, 15.5cm for light, medium and heavy soil texture, respectively] (Fig.1). It seems that *S. multicaulis* has high performance in light or heavy soil texture. The trend of plant height under severity of the drought stress also had a significant difference. Also, the plant height under 5 ds/m salinity or 6 day irrigation stress was no significant with control.

There was a significant difference between plant biomass production under drought and salinity stresses in relation to different soil textures for *S. multicaulis* (Fig. 3). Although plant biomass decreased along with the drought and salinity stress, the heavy soil showed higher performance in all treatments rather than medium and light soil textures. Greenness (Cblibredted greeness based on RGB) which is related to photosyntess showed that the plant greenness values were decreased by increasing irrigation distance and salt concentration (Fig. 4). Ranjbar and Mousavi (2015) in *Nitraria schoberi* found that plant is capable to maintain its physiological activities when subjected to relatively high levels of drought. Also, decrease of photosynthesis activity was reported by Zhu *et al.* (2012) study for *Zea mays* under drought stress in sandy soil texture.

Noori *et al.* (2014) also disclosed negative effect of salinity on morpho-physiological characteristics of tested plant under sandy soil condition and reported that salinity treatments decreased biomass and other plant morpho-physiological characteristics. However, for sandy soil texture, Li *et al.* (2015) reported saline water irrigation did not influence the normal growth of adaptive plants in *Tamarix*. Moreover, Wang *et al.* (2016) found that long term saline water irrigation in silty loam texture may result in significant yield losses even for low concentrations of salt in spring maize. Such results have also been reported for *Glaucium flavum* (Cambrollé *et al.*, 2011).

Leaf angle and Leaf length/width ratio which are physiological and morphological traits had a regular trend for different soil textures in both salinity and/or drought stresses. Figs. 2 and 5 show the variation of the plant leaf angle and leaf ratio in different soil textures under drought and salinity stress. In Fig. 2, leaf length/width ratio increased to 5 units for severe drought stress in medium soil texture. In this regard, Tajamoliyan *et al.* (2013) reported that increasing water deficit stress led to decreasing in water potential and specific leaf area in *Fortuynia bungei*. Kaleybar *et al.* (2013) reported that salinity stress reduced the shoot growth, shoot/root length ratio and chlorophyll content with increasing salinity in *Aeluropus Littoralis* which is a durable plant for stressful environments.

As seen in Table 1, higher values of the plant factors were observed under different levels of drought stress in heavy soil texture. For example, distance between nodes decreased from 2.3 to 1.5 and number of trichomes per unit increased from 2 to 4 in heavy soil. The light soil texture had the least influence on the plant parts under stress. In addition, the number of florets per plant had no regular and stable changes (Table 2). Amir-Ahmad *et al.* (2017) also reported a positive effect of loam and sandy loam soil textures on plant shoot in *Phaseolus vulgaris*.

Similar to drought, salinity also had a negative effect on measured plant parts (for example; trichome length) but the variation of some attributes such as trichome number per unit, and branch number per plant was not clear for all soil textures. The most variation occurred in light soil texture for distance between nodes (2.3 to 1) and number of florets per plant (Table 2 and 3).

In control treatments, the density and size of leaf surface trichomes varied with leaf side (abaxial or adaxial) and developmental stage. Salinity stress was affecting trichome distribution and size on both sides. Previous study indicated that salinity increased the densities of the two types of glandular trichomes (Karray-Bouraoui *et al.*, 2009). However, there was no significant trend for number and density of the plant trichomes under stress in different soil textures.

Conclusion

Morpho-physiological variation of the *S. multicaulis* under environmental stress (drought and salinity) directly depended on soil texture. Also, under all soil textures, plant factors including biomass, greenness, leaf ratio, floret number per plant, branch number per plant, and nodes distance were affected directly by severity of drought and salinity stress and showed a stable trend. Other factors such as leaf angle, trichome number and trichome length did not show regular changes in all soil textures. In general, plant characteristics were affected by the combination of soil texture and severity of stress. The morphological variations of the plant occurred with greater intensity in salinity stress and it seems that plant tolerance to salinity was lower than drought.

Acknowledgment

We would like to appreciate the laboratory of the supporting institute (laboratory of Isfahan University of Technology and laboratory of Natural resources Department of Tehran university) and also special thanks to anyone who helped us during research time and special thanks to Mr. Hamid Yazdanshenas, Amir Ali Kardan and Abolfazl Shafiee who helped us in preparing cultivation requirements and watering pots during the research period.

References

Ali, M.A., Abbas, A., Niaz, S., Zulkiffal, M., Ali, S., 2009. Morpho-physiological criteria for drought tolerance in sorghum (*Sorghum bicolor*) at seedling and post-anthesis stages. Int. J. Agric. Biol; 11(6): 674-680.

Amir-Ahmadi, N., Moosavi, M.R., Moafpourian, G., 2017. Effect of soil texture and its organic content on the efficacy of Trichoderma harzianum (MIAU 145 C) in controlling *Meloidogyne javanica* and stimulating the growth of kidney beans. Biocontrol science and technology, 27(1): 115-127.

Asghari, T., 2010. Effect of water deficit on some traits of *Cichorium intybus* L. at different densities. Journal of plant ecophysiology. 2 (3) 2-9.

Cambrollé, J., Redondo-Gómez, S., Mateos-Naranjo, E., Luque, T., Figureueroa, M.E., Physiological responses to salinity in the yellow-horned poppy, *Glaucium flavum*. Plant 2011. Physiology and Biochemistry, 49(2): 186-194.

Chakhchar A, Lamaoui M, Aissam S, Ferradous A, Wahbi S, El Mousadik A, Ibnsouda-Koraichi, S, Filali-Maltouf A, El., Modafar C. 2016. Differential physiological and antioxidative responses to drought stress and recovery among four contrasting *Argania spinosa* ecotypes. Journal of Plant Interactions, 11(1): 30-40.

Dexter, A.R., 2004. Soil physical quality: Part I. Theory, effects of soil texture, density, and organic matter, and effects on root growth. Geoderma,; 120(3-4): 201-214.

Erdemoglu, N., Turan, N.N., Cakõcõ, I., Sener, B., Aydõn, A., 2006. Antioxidant activities of some Lamiaceae plant extracts. Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives, 20(1): 9-13.

Forni, C., Duca, D., Glick, B.R., 2017. Mechanisms of plant response to salt and drought stress and their alteration by rhizobacteria. Plant and Soil, 410(1-2): 335-356.

Hamer, J.J., Veneklaas, E.J., Renton, M., Poot, P. 2016. Links between soil texture and root architecture of Eucalyptus species may limit distribution ranges under future climates. Plant and soil, 403(1-2): 217-229.

He, J., Li, H., Rasaily, R.G., Wang, Q., Cai, G., Su, Y., Qiao, X., Liu, L., 2011. Soil properties and crop yields after 11 years of no tillage farming in wheat–maize cropping system in North China Plain. Soil and Tillage Research, 113(1):48-54.

IPCC (Intergovernmental Panel on Climate Change) 2001. Climate Change 2001. Available at http://www.ipcc.ch; accessed on September 1, 2005.

Jamali, H., Quayle, W., Scheer, C., Rowlings, D., Baldock, J., 2016. Effect of soil texture and wheat plants on N2O fluxes: A lysimetric study. Agricultural and forest meteorology, 223:17-29.

Jamzad, M., Akbari, M.T., Rustaiyan, A., Masoudi, S., Azad, L., 2009. Chemical Composition of Essential Oils of Three Stachys Species Growing Wild in Iran: Stachys asterocalyx Rech. f., *Stachys obtusicrena* Boiss. and Stachys multicaulis Benth. Journal of Essential Oil Research, 21(2): 101-104.

Jiang, X., Qi, W., Xu, X., Li, Y., Liao, Y., Wang, B., 2014. Higher soil salinity causes more physiological stress in female of *Populus cathayana* cuttings. Acta Ecologica Sinica, 34(4):225-231.

Kaleybar, B.Sh., Nematzadeh, Gh., Hashemi, S.H.R., Askari, H., Kabirnataj, S., 2013. Physiologic and genetic reply of halophyte Aeluropus to salt. Journal of modified crop plants. (12): 29-12.

Karray-Bouraoui, N., Rabhi, M., Neffati, M., Baldann, B., Ranieri, A., Marzouk, B., Lachaâl, M., Smaoui, A., 2009. Salt effect on yield and composition of shoot essential oil and trichome morphology and density on leaves of *Mentha pulegium*. Industrial Crops and Products, 30(3): 338-343.

kolahchi, N., Mohseni Saravi, M., Tavili, A., Jafari, M., Assadian, G., 2011. Rangeland Ecohydrology, New Paradigm in Water Management of Arid and Semi-arid Lands. Journal of Rangeland Science, 1(4): 303-308.

Li, C., Lei, J., Zhao, Y., Xu, X., Li, S., 2015. Effect of saline water irrigation on soil development and plant growth in the Taklimakan Desert Highway shelterbelt. Soil and Tillage Research, 146: 99-107.

Lynch, J., 1995. Root architecture and plant productivity. Plant physiology, 109(1):1-7.

Noori, S.A., Izadi-Darbandi, A., Mehdi Mortazavian, S.M., 2014. Effect of Salinityon Morpho-Physiological Characteristics of Spring Wheat Genotypes. 4(1); 13-21.

Pandolfi, C., Mancuso, S., Shabala, S., 2012. Physiology of acclimation to salinity stress in pea (*Pisum sativum*). Environmental and Experimental Botany, 84: 44-51.

Poot, P., Veneklaas, E., 2013. Species distribution and crown decline are associated with contrasting water relations in four common sympatric eucalypt species in southwestern Australia. Plant Soil; 364:409–423.

Prakash, R., Singh, D., Pathak, N.P., 2010. The effect of soil texture in soil moisture retrieval for specular scattering at C-band. Progress in Electromagnetics Research, 108:177-204.

Promkhambut, A., Younger. A, Polthanee, A., Akkasaeng, C. 2010. Morphological and physiological responses of sorghum (*Sorghum bicolor* L. Moench) to waterlogging. Asian Journal of Plant Sciences, 9(4), 183.

Radhakrishnan, R., Baek, K.H., 2017. Physiological and biochemical perspectives of non-salt tolerant plants during bacterial interaction against soil salinity. Plant physiology and biochemistry, 116; 116-126.

Ranjbar, A. and Mousavi, S., 2015. Effects of drought stress on the efficiency of photosystem II and content of pigments in the leaves of *Nitraria schoberi* L. Journal of Plant Ecophysiology. 7(21): 97-85.

Ranjbar-Fordoei, A., Dehghani-Bidgoli, R., 2016. Impact of salinity stress on photochemical efficiency of photosystem II, chlorophyll content and nutrient elements of nitere bush (*Nitraria schoberi* L.) plants. Journal of Rangeland Science, 6(1): 1-9.

Reynolds, M., Mujeeb Kazi, A., Sawkins, M., 2005. Prospects for utilizing plant- adaptive mechanisms to improve wheat and other crops in drought and salinity prone environments. Annals of Applied Biology; 146:239-259.

Salem, H.M., Valero, C., Muñoz, M.Á., Rodríguez, M.G., Silva, L.L., 2015. Short-term effects of four tillage practices on soil physical properties, soil water potential, and maize yield. Geoderma, 237; 60-70.

Shabala, S., Cuin, T.A., 2008. Potassium transport and plant salt tolerance. Physiologia Plantarum, 133(4): 651-669.

Shan, L., Yang, C., Li, Y., Duan, Y., Geng, D., Li, Z., Zhang, R, Duan, G., Жигунов, А.В., 2015. Effects of drought stress on root physiological traits and root biomass allocation of *Reaumuria soongorica*. Acta Ecologica Sinica, 35(5): 155-159.

Shelef, O., Lazarovitch, N., Rewald, B., Golan- Goldhirsh, A., Rachmilevitch, S., 2010. Root halotropism: salinity effects on *Bassia indica* root. Plant Biosystems, 144(2): 471-478.

Sivritepe, N., Sivritepe, H.O. and Eris, A., 2003. The effects of NaCl priming on salt tolerance in melon seedlings grown under saline conditions. Scientia horticulturae, 97(3-4), pp.229-237.

Tajamoliyan, M., Irannezhad Parizi, M.H., Malekinezhad, H., Rad, M.H., Sodaiizadeh, H., 2013. Effects of water stress on some physiological characteristics of range plants pen (*Fortuynia bungei* Boiss.). "Journal of Genetics and Plant Breeding of pasture and woodland; 20(2): 273-283.

Tanaomi, N., Jonoubi, P., Chehregani, Rad A, Majd, A., Ranjbar, M., 2018. Embryological features of Alhagi persarum (Fabaceae): Adapt to environmental constraints. Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology, 152(1): 152-160.

Turner, NC, Schulze ED, Nicolle D., Kuhlmann I. 2010. Growth in two common gardens reveals species by environment interaction in carbon isotope discrimination of Eucalyptus. Tree Physiol 30:741–747.

Mozaffarian, V. 2007. Umbelliferae. In: Flora of Iran (eds. Assadi, M., Khatamsaz, M., Maassoumi, A. A.) No. 54. -Tehran (In

Persian).

Wang, Q., Huo, Z., Zhang, L., Wang, J., Zhao, Y., 2016. Impact of saline water irrigation on water use efficiency and soil salt accumulation for spring maize in arid regions of China. Agricultural Water Management, 163:125-138.

Yadav, S.P., Ibaraki, Y., Gupta, S.D., 2010. Estimation of the chlorophyll content of micro propagated potato plants using RGB based image analysis. Plant Cell, Tissue and Organ Culture (PCTOC), 100(2): 183-188.

Zhang, Z., Li, H., Qiao, S., Zhang, X., Liu, P., Liu, X., 2012. Effect of salinity on seed germination, seedling growth, and physiological characteristics of *Perilla frutescens*. Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology, 146(2), 245-251.

Zhu, X.C., Song, F.B., Liu, S.Q., Liu, T.D., Zhou, X., 2012. *Arbuscular mycorrhizae* improves photosynthesis and water status of *Zea mays* L. under drought stress. Plant Soil Environ; 58(4): 186-191.

اثر تنش خشکی و شوری بر تغییرات مورفوفیزیولوژیکی گونه انحصاری ایران *Stachys multicaulis* Benth، در بافت‌های مختلف خاک

حبیب یزدانشناس[الف]، محمد جعفری[ب]، علی طویلی[ج]* حسین آذرنیوند[د]، حسین ارزانی[ه]

[الف]دانشجوی دکتری علوم مرتع، گروه احیای مناطق خشک و کوهستانی، دانشکده منابع طبیعی، دانشگاه تهران

[ب،د،ه]استاد گروه احیای مناطق خشک و کوهستانی، دانشکده منابع طبیعی، دانشگاه تهران

[ج]دانشیارگروه احیای مناطق خشک و کوهستانی، دانشکده منابع طبیعی، دانشگاه تهران *(نگارنده مسئول)، پست الکترونیک atavili@ut.ac.ir

تاریخ دریافت: ۱۳۹۶/۱۲/۰۶

تاریخ پذیرش: ۱۳۹۷/۰۹/۲۶

چکیده. سازگاری گیاهان تحت تنش خشکی و شوری به طور مستقیم به نوع بافت خاک بستگی دارد. در این تحقیق، تغییرات مورفو فیزیولوژیک گونه *Stachys multicaulis*، گیاه انحصاری ایران کشت شده در بافت‌های مختلف خاک تحت تنش خشکی و شوری مورد بررسی قرار گرفت. برای این منظور قلمه‌های گیاه در سه بافت خاک سبک، متوسط و سنگین در گلدان خارج از گلخانه در نزدیک رویشگاه اصلی گیاه در بهار ۱۳۹۶ کشت شد. سپس یک مجموعه از تنش خشکی(دوره‌های ۳ روزه آبیاری، ۳ تا ۱۵ روز) و تیمار شوری(۰، ۵، ۱۰، ۱۵، ۲۰ و ۲۵ دسی‌زیمنس بر متر) در آزمایشی به صورت فاکتوریل در قالب طرح بلوک-های کامل تصادفی به صورت مجزا به کار برده شد. نتایج نشان داد که تنش خشکی و شوری در بافت‌های مختلف خاک اثر متفاوتی بر خصوصیات مورفو فیزیولوژیکی گیاه($p<0.01$) دارند. خصوصیات گیاهی مورد ارزیابی در بافت سنگین خاک در تمامی تیمارها عملکرد بالاتری داشتند. زیست توده، درصد سبزینگی، نسبت طول به عرض برگ، زاویه برگ، فاصله میان گره‌ها برای تنش خشکی ۱۵ روزه به ترتیب برابر ۸/۲۵(گرم)، ۲۸/۱(درصد)، ۴/۱۷، ۵۵(درجه)، ۱/۵(سانتیمتر) و برای تنش شوری ۲۵ دسی‌زیمنس بر متر برابر ۷/۷(گرم)، ۲۵(درصد)، ۳/۹، ۵۰(درجه)، و ۱/۵(سانتیمتر) در خاک سنگین بافت بود. همچنین تنش خشکی و شوری در تمام بافت‌های خاک بر تعداد و طول کرک، تعداد گل و تعداد شاخه‌زایی گیاه اثر معنی-داری نداشت($p<0.01$). در مجموع مقاومت این گیاه به شوری کمتر از خشکی بود.

کلمات کلیدی: خشکی، شوری، خصوصیات خاک، کشت گلدانی، خصوصیات فیزیولوژیکی