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# EFFECTS OF DROUGHT STRESS ON GROWTH AND DEVELOPMENT FRANKENIA PLANT (*FRANKENIA LEAVIS*)

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## Abstract

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This research was conducted to investigate the effects of drought stress on *Frankenia Leavis*. Experiments carried out under a randomized complete blocks in horticulture farm in Ahwaz Shahid Chamran University-Iran, with three replication. The Irrigations treatments were 100% Field Capacity (FC) (control), 70% FC and 50% FC respectively. The results showed that control treatment to other had significant different (1%) at contents of proline, chlorophyll, soluble sugars, water use efficiency, fresh and dry weight of shoots and roots. Among the evaluated parameters, the highest accumulation of proline and soluble sugars were observed at 50% FC treatment. While the highest of chlorophyll, fresh and dry weight of shoots and roots were showed at control treatment (100% FC). The highest of water use efficiency showed at 70% FC treatment. At the other hand, there was not significantly difference between 100% FC and 70% FC treatments on water use efficiency. Finally, based on the obtained results, *Frankenia Leavis* can thrifty about 30% of irrigation content.

*Key words*: chlorophyll, Frankenia, proline, sugar soluble and water use efficiency

## Introduction

Drought is one of the environmental stresses, which have detrimental effects on most of plant growth stages, structure of organs and their activities. The amount of damage caused by water deficit in the plant depends on species, genotype, duration of exposure to stress, intensity of water deficit, plant's age and development stage and intrinsic properties (Safarnejad, 2004). Numerous examinations show that the stress resulted by water deficit would cause reduction of growth, leaf surface area and dry weights, cell membrane deterioration, destruction and reduction of proteins and enzymes, amino acid accumulation, reduction of growth intensifiers, damage to pigments and plastids, chlorophyll reduction and reduction of root growth. In general, reduction of water content in herbal tissues under drought conditions would cause limitation of plant growth and some physiological and morphological responses (Levitt, 1980).

Soluble sugars are a group of consistent Osmolytes, which are accumulated under drought conditions and act as a cause of osmotic protection. Sugars build up due to drought stress relates to osmotic adjustment, Turgescence preservation as well as the establishment of membranes and proteins (Bohnert, 1993). The results of studies performed on two species of Basic plant showed that increase of soil moisture stress would increase the concentration of soluble sugars (Khalid, 2006).

Amongst the soluble materials, the Proline accumulation in the cytoplasm is amongst the first responses of the plant to the drought stress. Proline acts as a protective factor against the stress. In this way, it has direct mutual effect on the macromolecules and so helps to preserve their natural shape and structure under stress conditions (Kuznetsov and Shevyakoa, 1999). Proline accumulation is regarded as a kind of plant defense reaction against a wide variety of environmental stresses. Due to water shortage, Proline would be accumulated in the cytoplasm with high rates. The Proline accumulation during water deficit would help to reduce the oxidative destruction in the plants (Yancey et al., 1982).

Photosynthesis durability and preservation of leaf's Chlorophyll under stress conditions are amongst the physiological indexes related to resistance against the stress. The drought stress would cause the generation of active oxygen together with reduction and decomposition of Chlorophyll. During

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the stress, the Chlorophylls are decomposed in the chloroplast and the Thylakoid structures are vanished (Sairam et al., 0000). The results of investigations have shown that a mild drought stress exerted on the Festuca and Poa plants has not any affect on the amount of Chlorophyll in these two cold climate plants, but would reduce the amount of Chlorophyll in these two plants (Hung).

The water use efficiency (WUE) index has many applications in agricultural sciences and ecology (Shan et al., 2000). Many researchers calculate the amount of crop and economical biomass generated by aerial part divided by the amount of water employed to produce this biomass in order to estimate the WUE index. In fact, the WUE index is the ratio between the amount of pure $CO_2$ and the amount of water absorbed by the plant (Tourner, 1990). With regard to the regions having drought and water-deficit problems, the WUE index is of paramount importance, because it is used to evaluate the amount of crop and better estimate the amount of water in order to obtain appropriate crop which is presentable to the market and generate much amounts of biomass by plants (Hatfield, 2001).

Frankenia (Frankenia Leavis) at family Frankeniaceae. Frankenia is ornamental, perennial, cover and halophyte plant. After the grass, Frankenia enjoys the highest wear tolerance amongst the cover and ornamental plants (Shushtarian and Tehranifar, 2009).

## Materials and Methods

The current research was conducted in a research farm in the horticulture sciences department of Shahid Chamran University of Ahvaz in order to evaluate the water stress on the Frankenia plant. The cultivation of Frankenia was done through Scion in late Azar (9th month of the Iranian calendar) in the rectangular-shaped boxes, having dimensions 50 x 70 cm. To fill out the boxes, the one-third soil with equal portions of gravel, field soil and animal manure was used. To implement the water treatment, three water regimes, i.e. the control treatment (100% of field capacity), the 70% field capacity and the 50% field capacity were used within the design block randomized complete (RCBD) plan and with three replications. Table 1 shows the soil specifications with complete details.

Firstly, the usual irrigation was done to establish the plant completely. In order to implement the Regulated Deficit Irrigation (RDI) treatments, firstly the soil weight moisture percentages in the Field Capacity state (θFC) and Permanent Wilting Point (θPWP) were calculated using pressure plate machines (FC=10.7, PWP=5.4). To determine and calculate the soil moisture content, the daily sampling was performed in a soil depth of 0-30 cm from the control treatment using a cylindrical pipe with a diameter of 7 cm and the sample was placed in an oven with a temperature of 105°C for 24 hours in order to determine the moisture content. When the moisture percentage approached the (θPWP), the irrigation treatment was performed. For this purpose, the water depth required by the plant for control treatment was calculated using the formula Dn=(θFC - θPWP/100).Cs. Zr (Dn: irrigation depth, Cs: specific apparent weight and Zr: root depth in mm). Then, the water volume required for the irrigation was calculated using the formula V=Dn/1000.S (S is the surface area of desired containers and V is the water volume of control treatment in Liter). Moreover, for the irrigation treatments RDI70 and RDI50, the volumes of irrigation water were calculated and implemented using the equations (RDI70=0/7×V, RDI50= 0/5×V). The implementation time of water-deficit treatment was from March 2011 to June 2011. The measured parameters include wet weights of aerial part and the root, which were measured using digital balance. To calculate the dry weight, the oven with a temperature of 75°C was used for 48 hours. The amount of Proline index were calculated according to Bates et al (1973), chlorophyll, soluble sugars and the WUE index were calculated according to Bates et al (1973), Jao et al and ratio of generated biomass to consumed water, respectively.

After 90 days from the date of implementing the water treatment, the wet weight of the aerial part and the root were measured using the digital balance and then the sample was placed in a oven with a temperature of 75°C for 48 hours and the dry weight was calculated (In order to calculate the wet and dry weights of the root and the aerial part after 90 days from the date of treatment, all the plants inside the boxes were completely removed).

The analysis of data was done using the MSTAT-C software and the means were compared using the Duncan's multiple range test.

***Chlorophyll content***

Chlorophyll a and b were determined following the method of Arnon (1949). Fresh leaves were cut into 0.5 cm segments and extracted overnight with 80% acetone. The extract was centrifuged at 14 000 g for 5 min and the absorbance of

**Table 1**
**Soil specifications**

| EC, $ds.m^{-1}$ | PH | ESP, % | SAR | Loam, % | Sand, % | Clay, % |
|---|---|---|---|---|---|---|
| 11 | 7 | 28 | 27 | 22 | 58 | 20 |

the supernatant was read at 645 and 663 nm using a spectrophotometer.

***Free proline***

Proline was determined following Bates et al. (1973). Fresh plant material (1– 0.5 g) was homogenized in 10 ml of 3% sulfosalicylic acid and the homogenate filtered. The filtrate (2 ml) was treated with 2ml acid ninhydrin and 2ml of glacial acetic acid, then with 4ml of toluene. Absorbance of the colored solutions was read at 520 nm.

***Soluble sugars***

Soluble sugars were determined based on the method of phenol sulfuric acid (Dubois, 1956). 0.1 g dry weight of shoots was homogenized with ethanol, extract was filtered and the extract treated with 5% phenol and 98% sulfuric acid, mixture remained for 1h and then absorbance at 485 nm was determined by spectrophotometer. Contents of soluble sugar were expressed as mg.g$^{-1}$ dw.

## Results and Discussion

Regarding the results obtained from the analysis of variance in Tables 2 and 3, the following items are within a significance range of 1 percent: the Proline, Chlorophyll and soluble sugars, the fresh and dry weights of the root, shoot and WUE.

***Proline***

The results of comparison between the means in Table 4 and Figure 1 are indicative of a significant difference between the amounts of Proline in three moisture regimes (50, 70 and 100 percent). The highest amount of Proline accumulation was observed in 50 percent irrigation treatment, which its difference with two other levels was within a significance range of 1 percent. The lowest amount of Proline accumulation was in control treatment and the highest rate of Proline accumulation was found in 50 percent treatment followed by 70 percent treatment. The Proline accumulation during the stress helps the plant to reduce the oxidative destruction and it is necessary to be survived under drought stress (Von Willeret, 1983). In the corn plant, the Proline accumulation was increased by increase of intensity and duration of water-deficit treatment (Anjum, 2011). Shahrokhi et al. (2011) have reported that in the Festuca grass, the drought stress resulted in Proline accumulation. Bohnet et al. (1995) observed that un-

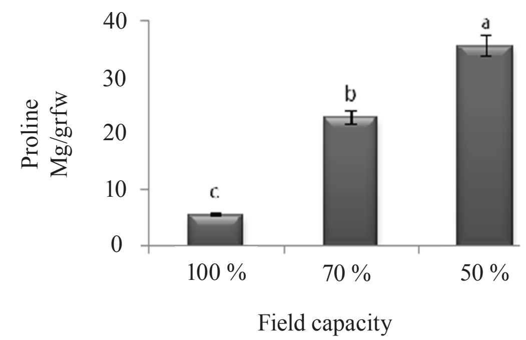


**Fig. 1. Effects of drought stress on total proline content (mg.g$^{-1}$ FW) in the shoots of frankenia. Results are shown as mean ± standard error (p<0.01), obtained from 3 replicates**

**Table 2**
**Analysis of variance for biochemical traits and the WUE of the Frankenia under drought stress**

| Source of variation | DF | Chlorophyll a | Chlorophyll b | Total chlorophyll | Proline | Soluble sugars | Water use efficiency |
|---|---|---|---|---|---|---|---|
| Treatment | 2 | 0/076** | 0/0024** | 0/183** | 179/22** | 369/78** | 0/388** |
| Error | 4 | 0/001 | 0/001 | 0/002 | 1/379 | 1/017 | 0/005 |
| Total | 6 | | | | | | |
| Cv% | | 6 | 4 | 6/81 | 9/73 | 12/67 | 7/6 |

**Significantly difference at 1%

**Table 3**
**Analysis of variance for physiological traits of the Frankenia under drought stress**

| Source of variation | DF | Fresh weight shoot | Dry weight shoot | Fresh weight root | Dry weight root |
|---|---|---|---|---|---|
| Treatment | 2 | 244/512** | 189/89** | 55/14** | 108/12** |
| Error | 4 | 27/32 | 8/85 | 0/263 | 9/8 |
| Total | 6 | | | | |
| Cv% | | 10/84 | 5/53 | 5/29 | 9/69 |

**Significantly difference at 1%

der water-deficit conditions in the Petunia plant, the Proline accumulation was increased compared to control plant. The current research findings are consistent with these results.

### *Soluble sugars*

Regarding the Table 4 and Figure 2 comparison of means indicates a significant difference between the amounts of accumulation of soluble sugars in three levels of irrigation regime and the highest amount of soluble sugars was observed in 50 percent field capacity stress which its difference with two other treatments became significant in the level of 1 percent and the lowest amount of soluble sugars was observed in the control treatment. After the 50 percent treatment, the second rank was dedicated to 70 percent treatment. In general, the increase of soluble sugars during stress can be attributed to the stop of growth or synthesis in these compounds from non-photosynthesis routes and the destruction of insoluble sugars can also be explained by the increase of soluble sugars (Ghorbanali, 2003). Paradix et al. (2006) reported that the change for carbohydrates depends on intensity and duration of drought implementation and the kind of species. The pea plant showed the highest level of carbohydrates in the highest level of drought stress (Mafakheri et al., 2011). In the Salvia leriifolia plant, the amounts of soluble sugars were increased by increase of drought stress (Tarahomi et al., 2009). In an experiment conducted by Sauchbert et al. (2005), the increase of water stress in the pea plant caused the increase of soluble sugars. In Ahvaz chicken plant, it was observed that the amount of soluble sugars increases by increase of duration of drought stress (Mohsenzadeh, 2006). The results of current research were consistent with these results.

### *Chlorophyll*

Regarding Table 4 and Figures 3 and 5 comparison of means indicates significant differences between amounts of a, b and total chlorophylls. The highest amounts of a, b and total chlorophylls are observed in control treatment, which its difference with other two treatments is significant. The lowest chlorophyll amount was found in 50 percent irrigation treatment.

The reduction of photosynthesis during exposure to stress is a kind of defense mechanism used by plants. In wheat plant, the amount of photosynthesis reduced significantly due to drought stress (Jones, 1992). Reduction of chlorophyll surface is mostly due to lack of activity in photosynthesis system. Therefore, the drought stress causes the chlorophyll surface to be reduced and the chloroplast membrane to be destructed and finally it would result in reduction of photosynthesis pigments' concentrations. The drought stress resulted in reduction of total chlorophyll in *Festuca* and Kentucky bluegrass (Haung, 2001).

**Table 4**
**Comparing the means of biochemical traits and the WUE for Frankenia under drought stress**

| Treatment | Chlorophyll a | Chlorophyll b | Total chlorophyll | Proline | Soluble sugars | Water use efficiency |
|---|---|---|---|---|---|---|
| 100%FC | 1/2 a | 0/75a | 2/1a | 5/5a | 28/69a | 1/5a |
| 70%FC | 0/32b | 0/24b | 0/38b | 22/27b | 54/59b | 1/8b |
| 50%FC | 0/13c | 0/12c | 0/17c | 35/55c | 98/75c | 1/1c |

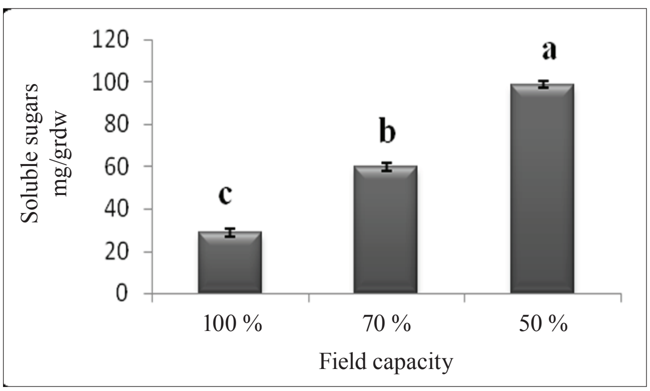


**Fig. 2. Effects of drought stress on soluble sugars content (mg.g$^{-1}$ DW) in the shoots of frankenia. Results are shown as mean ± standard error (p<0.01), obtained from 3 replicates**

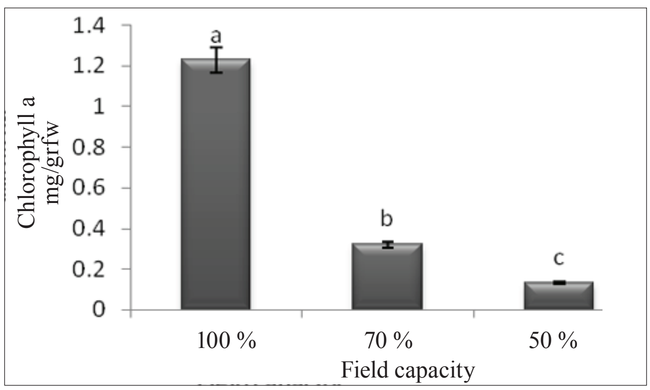


**Fig. 3. Effects of drought stress on chlorophyll a (mg.g$^{-1}$ FW) in the frankenia. Results are shown as mean ± standard error (p<0.01), obtained from three replicates**

***Water use efficiency***

The results obtained from comparison of means showed that no significant difference exists between 100 percent (control) and 70 percent irrigation treatments. However, the highest WUE index was observed in 70 percent treatment. The lowest WUE index was found in 50 percent treatment, which its difference with other two treatments is within 1 percent level of significance. Blum (2005) reported that in the grape plant, having performed the Regulated Deficit Irrigation (RDI) treatment, the WUE index was increased up to 72 percent. The cause of WUE increase is the reduction of water potential in the soil due to blockage of pores and the reduction of plant transpiration. The obvious reduction of photosynthesis speed and increase of WUE index in the Acacia plant is due to limitation resulted by the cavity blockage (Hugh, 2002). The irrigation regime, which has the highest WUE index under soil moisture stress, would mean superior yield and better irrigation regime (Blume, 2005). Based on the results of this research, the 70 percent treatment would be the best irrigation regime for the Frankenia plant because of having the highest WUE index (Figure 4).

***Fresh and dry weights shoot***

The results of comparison between means in Table 5 suggest that the highest fresh and dry weights were observed in control treatment, which had not significant difference with the 70 percent irrigation treatment. The lowest fresh and dry weights of the shoots part were found in the 50 percent treatment, which its difference with other two treatments was within a significance level of 1% (Figure 5).

Anjum (2011) has discussed that the number of pores is reduced during drought stress. This issue affects the synthesis rate of fresh and dry materials in aerial member and causes the fresh and dry weights to be reduced. The drought stress has negative effects on many growth indexes such as stem length, number of leafs, leaf surface area and fresh and dry weights (Janick, 2001; Tooumi et al., 2007). Similar results were observed in this research. Reduction of plant's fresh and dry weights is amongst the disadvantages of drought stress (Fraqoo, 2009). In the white poplar plant, the drought caused the reduction of photosynthesis rate and hence the leaf growth and development (Wulscheger, 2005). Nabati (1994) reported that in the Kentucky bluegrass plant, the drought stress caused the pores to be blocked and the photosynthesis and growth rate reduced significantly. The results of current research are consistent with these results.

***Fresh and dry weights root***

Regarding the results of comparison between the means, the highest fresh and dry weights of the root were observed in the control treatment, which its difference with 70 percent treatment was not within significant range. The lowest

**Table 5**
**Comparing the means of physiological traits for Frankenia under drought stress**

| Treatment | Fresh weight shoot | Dry weight shoot | Fresh weight root | Dry weight root |
|---|---|---|---|---|
| 100%FC | 229/1a | 66/75a | 12/86a | 6/23a |
| 70%FC | 180/87a | 58a | 12/13a | 5/53a |
| 50%FC | 52/61b | 25/71b | 4/93b | 3/32b |

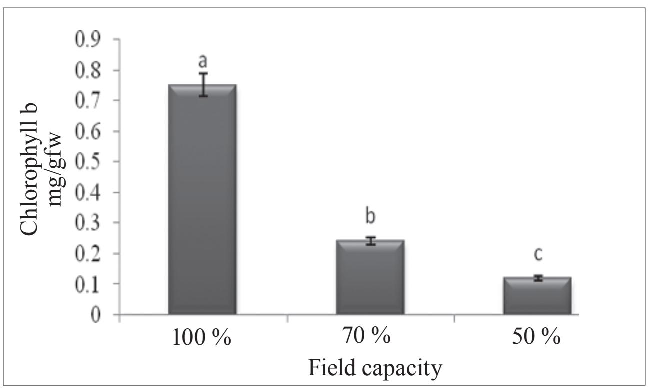


**Fig. 4. Effects of drought stress on chlorophyll b (mg.g$^{-1}$ FW) in the frankenia. Results are shown as mean ± standard error (p<0.01), obtained from three replicates**

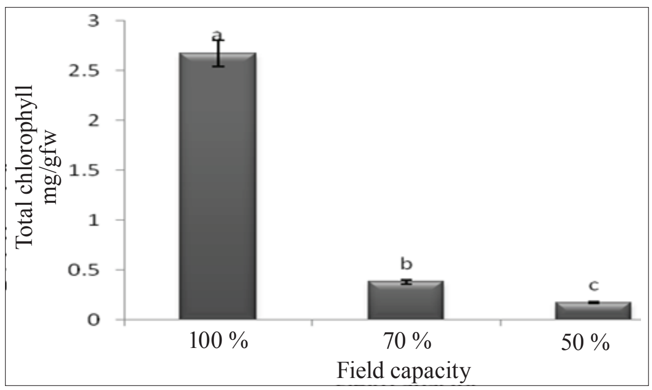


**Fig. 5. Effects of drought stress on total chlorophyll content (mg.g$^{-1}$ FW) in the frankenia. Results are shown as mean ± standard error (p<0.01), obtained from three replicates**

fresh and dry weights of the root were found in the 50 percent irrigation treatment, which its difference with other two treatments was significant. In grass plant, the fresh and dry weights of the root were reduced significantly due to drought stress (Mafakheri et al., 2011) and in the corn plant, a meaningful reduction was occurred in fresh and dry weights of the root caused by drought stress (Batlang, 2006).

## Conclusions

The results in this article showed that amount of proline and soluble sugar in 70 percent FC irrigation treatment were significantly higher than control treatment. It has to be seen that Frankenia increases its solution compound for adapting itself in drought, which most important of this solution compound are proline and soluble sugar. In addition, there were no considerable differences between 70 percent irrigation treatment and control treatment in dry and fresh weight in shoots and roots. On the other hand, the most water use efficiency was obtained in 70 percent FC treatment. Therefore, using this 70 percent FC treatment can save at least 30 percent of irrigation.

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