Evaluating the physiological and hormonal responses of caper plant (*Capparis spinosa*) subjected to drought and salinity

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**Abstract**

In order to investigate the effect of drought and salinity stress on caper plant (*Capparis spinosa*), a factorial experiment including two factors consisting of drought and salinity levels based on randomized complete block design (RCBD) with five blocks were carried out at College of Agriculture, Shiraz University, Shiraz, Iran. After pretreatment, seeds were germinated in petri dishes and then transported to pots, to grow out of the glasshouse under natural conditions (same as environmental condition). Measuring morphological (Plant height, number of leaves, length of greatest leaf, root length, shoot fresh weight, shoot dry weight, root fresh weight and root dry weight, and chlorophyll (pad) and also physiological traits (relative water content (RWC) and water saturated deficit (WSD) for both root and shoot, root water content (RooWC) and leaf water content (LWC) showed that salinity and drought stresses as well as ABA concentration had negative effects on the plant. ABA content was significantly higher in salt-treated plants than in drought treated ones. The injury effect of salt stress was lower than drought. The results also indicated that the changes in response to the two stresses were low and so that this plant could be a suitable candidate for sowing and using in arid and semi-arid regions and also in saline condition.

**Keywords:** Chlorophyll; ABA; Arid regions; Root dry weight; Drought

1. Introduction

Adaptable and multipurpose plants can provide a valuable opportunity to enhance greenery and prevention of soil erosion in harsh climatic area. Due to the harsh climatic conditions in arid and semi-arid area, the erosion of the soil is a great problem. Caper Plant (*Capparis spinosa* L.) a multipurpose plant requires a semiarid or arid climate. Caper plant is a shrub native to the Mediterranean regions and tropics that grows wild on walls or in rocky coastal areas (Legua et al., 2013). This plant has a deep root system and is resistant to drought condition. It can tolerate the temperatures exceeding 40 °C (Suleiman et al., 2012). Because of its vegetative canopy, caper plant covers soil surfaces making soil water to be reserved (Saifi et al., 2011). It grows in a wide range of soils condition and different situation, and could be used as culinary, medicinal purposes, and ornamental shrub. Using its deep root system and high resistance in harsh condition, it could be used for the prevention of soil erosion in arid and semi-arid areas (Musallam et al., 2012). Caper plant as a shrub well adapted to water deficit conditions having less than 200 mm annual rainfall, but for commercial uses and plant production, this crop cannot be grown under such conditions without any irrigation (Legua et al., 2013).

Plants have developed different mechanisms to adapt to drought and salinity stress, involving complex physiological and biochemical changes. In the process of stress adaptation, hormones, especially abscisic acid (ABA), play important roles (Amjad et al., 2013). It has been proposed that ABA acts as a mediator and the major internal signal in plant response to abiotic stresses (Javid et al., 2011). ABA concentration increases proportionally with salt stress related to leaf water potential suggesting that increased ABA concentration is due to water deficit created by salts rather than a salt specific effect (Lovelli et al., 2012). This higher ABA concentration reduces the loss of water as transpiration by the closure of stomata under stressful conditions (Zhang et al., 2014; Hariadi et...
al., 2011). Due to the recent severe drought in Iran and most arid and semi-arid regions in the world, farmers have attempted to grow drought and saline resistant plant (such as caper) instead of plant with high water requirements. Caper plant is native in the Mediterranean landscape, from Portugal to Egypt and today is cultivated in southern parts of Iran, some regions of Italy as well as Morocco and Jordan as popular crop. There is a high interest for caper cultivation for several reasons among them, are the possible use of marginal lands, adapted to dry areas receiving less than 200 mm annual rainfall, low initial cost, higher profit margins as compared to other local crops, synergisms of crops with tourism activities and alternative use of capers in cosmetics and pharmacology but very little is known about its responses stress-related morpho-physiological and hormonal characteristics. This research aimed to evaluate changes in some morphological, physiological and hormonal properties of caper plant in response to drought and salinity stresses to measure tolerance and adoptability of this plant under these conditions.

2. Materials and Methods

2.1. Experimental procedure

The seeds of the caper plant were gathered from Farashband belonging to Fars province in Iran (Fig. 1). Voucher specimen (No. 32658) was deposited at the Herbarium of Fars Research Center for Agriculture, Shiraz, Iran. The seeds were separated, washed with deionized water, and sterilized with ethanol, and after that, they were placed in petri dishes consisting of filter paper and 5 mL polyethylene glycol 6000. For a period of four weeks, the petri dishes were kept in a germinator having a temperature of −4°C in order to cold stratification on seed dormancy. After germination, the seeds were transported to pots filled with soil (Error! Reference source not found.). Ten germinated seeds were sown in each pot. The experiment was carried out as a factorial arranged randomized complete block design with five replications. Total numbers of pots were 75 and the pots were kept out of the glasshouse at the natural temperature of the region in spring (2014). Drought stress had three levels of 100, 75, and 50 of FC (Field Capacity). 10 days after sowing salinity and drought treatments were started. Drought treatment levels were applied based on the weighting method by daily weighting of pots. Five levels of salinity containing 0, 4, 8, 12, and 18 ds m$^{-1}$ were also used. For salinity treatments, sodium chloride and calcium chloride with the same ratios were applied. Forty days after sowing, the leaf samples were cut from the plant and were frozen for transporting to the lab for measuring traits.

![Fig. 1. Used caper plant (Capparis spinosa) seeds in the experiment](image)

<table>
<thead>
<tr>
<th>Clay(%)</th>
<th>Silt(%)</th>
<th>Sand(%)</th>
<th>PH</th>
<th>OC(%)</th>
<th>soil texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.3</td>
<td>67.1</td>
<td>7.6</td>
<td>7.5</td>
<td>0.78</td>
<td>silty-loam</td>
</tr>
<tr>
<td>PWP</td>
<td>0.09</td>
<td>0.19</td>
<td>0.08</td>
<td>462</td>
<td>16.3</td>
</tr>
</tbody>
</table>

OC: Organic Carbon; PWP: Permanent Wilting Point in percent by volume; FC: Field Capacity in percent by volume

2.2. Measuring the traits

Morphological traits consist of plant height, number of leaves, length of greatest leaf; root length, shoot fresh weight, shoot dry weight, root fresh weight and root dry weight were measured in this study. Greenish index (Spad chlorophyll) was also measured as an index for chlorophyll content.
Physiological traits containing relative water content (RWC) and water saturated deficit (WSD) for both root and shoot and, root water content (RooWC) and leaf water content (LWC) were measured using following equations.

\[
\text{RWC} = \frac{\text{FW} - \text{TW}}{\text{TW}} \\
\text{WSD} = \frac{\text{TW} - \text{DW}}{\text{DW}}
\]

Means with the same letters in each column are not significantly different (least significant difference at 5% level of probability)

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\]

Means with the same letters in each column are not significantly different (least significant difference at 5% level of probability)

Table 2. Analysis of variance (ANOVA) for morphological measured traits

<table>
<thead>
<tr>
<th>Source</th>
<th>Degree of freedom</th>
<th>Plant height (cm)</th>
<th>Leaf number</th>
<th>Leaf length (cm)</th>
<th>Root length (cm)</th>
<th>Shoot fresh weight (gr)</th>
<th>Shoot dry weight (gr)</th>
<th>Root fresh weight (gr)</th>
<th>Root dry weight (gr)</th>
<th>Chlorophyll (Spad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought</td>
<td>2</td>
<td>2.469**</td>
<td>233.85**</td>
<td>19.98**</td>
<td>404.81**</td>
<td>0.37**</td>
<td>0.77**</td>
<td>0.9**</td>
<td>0.39**</td>
<td>1402.51**</td>
</tr>
<tr>
<td>Salinity</td>
<td>4</td>
<td>151.26**</td>
<td>109.15**</td>
<td>1.16**</td>
<td>121.35**</td>
<td>0.21**</td>
<td>0.27**</td>
<td>0.74**</td>
<td>0.26**</td>
<td>880.19**</td>
</tr>
<tr>
<td>Drought*</td>
<td>8</td>
<td>15.84**</td>
<td>6.1n</td>
<td>0.08n</td>
<td>7.82ns</td>
<td>0.02ns</td>
<td>0.01**</td>
<td>0.09ns</td>
<td>0.06ns</td>
<td>24.83ns</td>
</tr>
<tr>
<td>Error</td>
<td>60</td>
<td>3.1</td>
<td>5.15</td>
<td>0.11</td>
<td>16.09</td>
<td>0.05</td>
<td>0.003</td>
<td>0.08</td>
<td>0.06</td>
<td>251.79</td>
</tr>
</tbody>
</table>

**, *, and ns are representation of significant in 1% level, significant in 5% level, and not significant, respectively.

Table 3. Means comparison for some measured traits related to drought and salinity stress

<table>
<thead>
<tr>
<th>Drought (%FC)</th>
<th>Plant height (cm)</th>
<th>Leaf number</th>
<th>Leaf length (cm)</th>
<th>Chlorophyll (Spad)</th>
<th>Root length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>28.7</td>
<td>A</td>
<td>25.08</td>
<td>A</td>
<td>34.49</td>
</tr>
<tr>
<td>75</td>
<td>20.5</td>
<td>B</td>
<td>15.08</td>
<td>B</td>
<td>33.27</td>
</tr>
<tr>
<td>50</td>
<td>8.92</td>
<td>C</td>
<td>5.76</td>
<td>C</td>
<td>20.95</td>
</tr>
<tr>
<td>4</td>
<td>20.8</td>
<td>B</td>
<td>16.73</td>
<td>B</td>
<td>32.45</td>
</tr>
<tr>
<td>8</td>
<td>19.567</td>
<td>B</td>
<td>15.07</td>
<td>C</td>
<td>29.15</td>
</tr>
<tr>
<td>12</td>
<td>17.5</td>
<td>C</td>
<td>13.4</td>
<td>D</td>
<td>24.09</td>
</tr>
<tr>
<td>18</td>
<td>15.33</td>
<td>D</td>
<td>12.27</td>
<td>D</td>
<td>21.3</td>
</tr>
</tbody>
</table>

Means with the same letters in each column are not significantly different (least significant difference at 5% level of probability)
Mean comparison for shoot fresh and dry weight, root fresh and dry weight related to drought stress are presented in Table 4. The highest values for shoot fresh weight and shoot dry weight were observed in 100% FC and their lowest values were observed in 50% FC, while the lowest values for root fresh and dry weight were obtained in 100% FC and their highest values were obtained in 50% FC. Between 75 and 50% FC related to shoot fresh weight and root dry weight significant difference were not observed. Root fresh weight showed no significant difference between 100 and 75% FC.

Effects of salinity levels on shoot fresh and dry weight showed that salinity decreased these traits (Figure 2). For shoot fresh weight, no significant differences were observed among 0, 4, 8, and 12 ds m⁻¹, but 18 ds m⁻¹ showed a significant difference with other levels. The difference between 12 and 18 ds m⁻¹ were also not significant. Figure 3 shows root fresh and dry weight mean comparison for different salinity levels. Salinity decreased the weight of fresh and dry root. Between 0, 4, and 8 ds m⁻¹ related to both root fresh and dry weight significant difference were not observed.

Table 4. Mean comparison for some morphological and physiological measured traits related to drought stress

<table>
<thead>
<tr>
<th>%FC</th>
<th>Shoot fresh weight (gr)</th>
<th>Shoot dry weight (gr)</th>
<th>Root fresh weight (gr)</th>
<th>Root dry weight (gr)</th>
<th>Shoot RWC</th>
<th>Root W federal deficit</th>
<th>leaf water content</th>
<th>WSD-Shoot</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1.42</td>
<td>A</td>
<td>0.653</td>
<td>A</td>
<td>1.857</td>
<td>B</td>
<td>0.623</td>
<td>A</td>
</tr>
<tr>
<td>75</td>
<td>1.283</td>
<td>B</td>
<td>0.475</td>
<td>B</td>
<td>1.958</td>
<td>B</td>
<td>0.595</td>
<td>A</td>
</tr>
<tr>
<td>50</td>
<td>1.176</td>
<td>B</td>
<td>0.303</td>
<td>C</td>
<td>2.224</td>
<td>A</td>
<td>1.404</td>
<td>A</td>
</tr>
</tbody>
</table>

Means with the same letters in each column are not significantly different (least significant difference at 5% level of probability)

Fig. 2. Effect of salinity on shoot fresh/dry weight. Means with the same letters are not significantly different (least significant difference at 5% level of probability)

Fig. 3. Effect of salinity on root fresh/dry weight. Means with the same letters are not significantly different (least significant difference at 5% level of probability)

Results of ANOVA for physiological traits consist of root and shoot relative water content, root and shoot water saturated deficit, and root and leaf water content are presented in Table 5. Effect of drought and salinity were significant for shoot RWC, leaf water content, and shoot WSD, while they were not significant for root RWC, root water content, and root WSD. The interaction effect of
drought by salinity was not significant for all physiological traits (Table 5). The highest amounts of shoot RWC, leaf water content, and shoot WSD were obtained in 100% FC, while the lowest amounts were obtained in 50% FC (Table 4). Levels of 100 and 75% FC showed no significant difference for related to shoot RWC; on the other hand, shoot WSD of 75 and 50% FC was not significant. Figures 5 shows changes of shoot RWC, leaf water content, and shoot WSD in response to salinity levels. All of these mentioned traits decreased in line with increase in severity of salinity. For shoot RWC salinity levels of 0, 4, and 8; for leaf water content salinity levels of 0, and 4; and finally for shoot WSD salinity levels of 0, 4, and 8 showed no significant difference one another.

Table 5. Analysis of variance (ANOVA) for physiological measured traits

<table>
<thead>
<tr>
<th>Source</th>
<th>Degree of freedom</th>
<th>Mean squares</th>
<th>Mean squares</th>
<th>Mean squares</th>
<th>Mean squares</th>
<th>Mean squares</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shoot RWC</td>
<td>leaf water content</td>
<td>Shoot-WSD</td>
<td>Root- RWC</td>
<td>Root water content</td>
<td>Root-WSD</td>
</tr>
<tr>
<td>Drought</td>
<td>2</td>
<td>0.12**</td>
<td>0.26**</td>
<td>0.12**</td>
<td>0.38ns</td>
<td>0.026ns</td>
</tr>
<tr>
<td>Salinity</td>
<td>4</td>
<td>0.09**</td>
<td>0.09**</td>
<td>0.09**</td>
<td>0.43ns</td>
<td>0.025ns</td>
</tr>
<tr>
<td>Drought*Salinity</td>
<td>8</td>
<td>0.02ns</td>
<td>0.01ns</td>
<td>0.02ns</td>
<td>0.33ns</td>
<td>0.039ns</td>
</tr>
<tr>
<td>Error</td>
<td>60</td>
<td>0.03</td>
<td>0.01</td>
<td>0.03</td>
<td>0.39</td>
<td>0.019</td>
</tr>
</tbody>
</table>

Coefficient of variation 22.88 12.82 23.37 24.66 21.03 24.81

**, *, and ns are representation of significant in 1% level, significant in 5% level, and not significant, respectively.

4. Discussion

In this research the injury effect of drought stress on capper plant was greater than salinity stress because rate of decreasing in morphological traits were higher under drought stress. These results indicate that capper plant can tolerate salinity more than drought. On the other hand, the difference between 100 and 75% FC for morphological traits were significant and, between 75 and 50% FC were not
significant. These results show that moderate drought stress have a little negative effect on morphological response of capper plant. Salinity levels of 0, 4, and 8 ds m$^{-1}$ have little effects on most of the morphological traits. Physiological responses of plants in different situations constitute stress are varied (Pessarakli, 2014; Saed-Mooshesive et al., 2014). All metabolic activities of plants are affected regularly by environmental changes (Auge et al., 2015). Drought stress when accompanied with very high constraint or fluctuations results in injury, abnormal physiological changes, etc. (Suzuki et al., 2014). The changed physiological condition tends to change the equilibrium and results in stress and strain (physical and chemical) (Nemali et al., 2014). Drought and salinity stresses decreased the amount of $c h a$ and the lowest $c h a$ was recorded for severe salinity stress (Pirasteh Anosheh et al., 2011).

ABA was indeed accumulates at higher amounts in salt-treated plants than in drought-treated ones. The same results have been found by Ben Hassine and Lutts (2010) who reported that salt treated Atriplex halimus contain more ABA concentration than in drought treated ones. In addition to hormonal compounds, the injury effect of drought stress was higher under drought stress with lower ABA content. Concerning to abscisic acid, many reports have shown its involvement in physiological and biochemical processes related to salinity tolerance of plants (Lovelli et al., 2012; Sadeghi and Robati, 2015). Our results suggested that ABA plays important roles in reducing the injury effect of salt stress in C. spinosa. Under salt stress, by increasing the salinity level, ABA levels increased dramatically (Figure 5), suggesting that ABA acts as a signal in caper salt response. ABA controls many stress adaptation responses, including stomatal closure, activation of genes involved in osmotic adjustment, ion compartmentation, regulation of shoot versus root growth and modifications of root hydraulic conductivity properties (Zhang et al., 2006; Antoni et al., 2011; Javid et al., 2011; Hu et al., 2006; Jiang et al., 2002).

5. Conclusion

Caper Plant is a multipurpose plant adapted to semiarid or arid climate. Physiological properties of caper plant root showed no significant differences for salinity and drought stress levels. Also, physiological response of shoot showed a bit changes in response to salinity and drought stress. All of these results are indicated that caper plant is a suitable plant for to be used in arid and semi-arid and also in saline condition to obtain different benefit from this plant such as greenery benefits and using its fruit for adorable foods.

References


