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Evaluating the salt tolerance of seven fig cultivars (*Ficus carica* L.)

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Abstract: The growing demand for both fresh and dry figs worldwide is due to its richness in mineral compounds (i.e. iron and copper) and polyphenols. Considering the position of Iranian cultivars in global fig market, the present study examined the growth and photosynthetic rate of commercial fig cultivars (i.e. 'Sabz', 'Siyah', 'Shah Anjir', 'Atabaki', 'Kashki', 'Mati' and 'Bar Anjir') exposed to six salt treatments corresponding to the following electrical conductivities (EC): 0.5, 2, 4, 6, 8 and 10 dS m^{-1}. The results indicated a decrease trend of stem length, stem diameter and leaf number in salt-exposed plants. The electrolyte leakage and protein content in all cultivars followed an ascending trend. The specific leaf area, relative water content, photosynthetic indices and nitrogen content followed a decreasing trend according with increasing salinity. The 'Siyah' and 'Sabz', as the most salt-tolerant cultivars, had the maximum leaf abscission, the lowest transpiration rate and leaf water content under salt condition, compared to all other tested cultivars. Moreover, they had the most leaf succulence and leaf dry matter content and the lowest specific leaf area, which related to the balance between growth ratio and osmotic regulation under salt conditions. The 'Shah Anjir', as the most salt-sensitive cultivar, could not balance transpiration rate and leaf water content under salt treatment higher than 4 dS m^{-1}.

1. Introduction

The fig (*Ficus carica* L., 2n= 26) of the Moraceae family, is one of the first plants cultivated and consumed by human beings (Duenas *et al*., 2008). According to the FAO, the fig is harvested from 36,535 hectares of cultivated land, with an annual production of over one million tons (FAO, 2017). Iran is the third largest producer of dried figs in the world, as well as the fifth largest fresh fig producer in the world with a cultivated area of 53,101 hectares and a production of 70,730 tons per year of fresh figs (FAO, 2017).

The growing demand for the fig worldwide (Aksoy, 2005) is due to its richness in mineral compounds (i.e. iron and copper) and considerable amounts of vitamins A and C (Flaishman *et al*., 2008). The fig is consumed in fresh, dried, powdered, canned, chocolate-covered forms, and utilized in the preparation of jam, syrup and Muscat-Halvah (De Masi *et al*., 2005).

Significant genetic variation in the fig species, due to obligatory outcrossing, has led to the establishment of new genotypes with desirable properties. According to the latest reports, there are currently more than 600 known fruit-producing cultivars and genotypes, which are distinct in leaf morphology, growth vigor, internal and external color of the fruit, taste and quality index of the fruit, shape and thickness of the fruit, the diameter of the ostiole, and productivity period (Condit, 1955; Toribio and Montes, 1996; García-Ruiz *et al*., 2013).

Sabz or Verde (green), Siyah (black), Shah Anjir (king fig), Atabaki, Kashki and Mati are considered as the most important and marketable cultivars of Iranian figs for local markets or export. The 'Bar Anjir' is the most commonly-used caprifig (Condit, 1955; Pourghayoumi *et al*., 2016).

Several research centers have focused on different aspects of physiology and breeding of fig cultivars and genotypes. For example, some researchers emphasized on genetic diversity of fig using morphological (Khadivi *et al*., 2018) and molecular (Cabrita *et al*., 2001; Khadari *et al*., 2005; Giraldo *et al*., 2008) markers. Some others attempted to study the caprifigs (Dalkılıç *et al*., 2011), while others have considered the variety of the fruit and its qualitative features (Solomon *et al*., 2006; Polat and Caliskan, 2008; Ercisli *et al*., 2012).

In addition, the variation in the behavior of fig cultivars and genotypes to abiotic stress such as chilling (Karami *et al*., 2018), drought (Gholami *et al*., 2012) and salinity (Zarei *et al*., 2016) have attracted the researchers' attention.

Salinity is one of the most important environmental factors which reduces the growth, development and production of plants (Sevengor *et al*., 2011). While some researchers suggested reducing leaf area as the plants' responses to the salinity stress, others enumerate reduced stem length, root length, fresh and dry weights, and relative leaf water content (Yamasaki and Dillenburg, 1999; Bolat *et al*., 2006; Najafian *et al*., 2008; Adish *et al*., 2010; Khayyat *et al*., 2014; Khoshbahkt *et al*., 2014; Soliman and Abd Alhady, 2017). Other important processes that are negatively affected by salinity are protein synthesis (Taylor *et al*., 2004; Murcute *et al*., 2010) and nitrogen metabolism (Owais, 2015; Ashraf *et al*., 2017), whereas in other studies the inhibition of plant growth caused by salinity has been attributed to a decrease in photosynthesis (Garcia-Sanchez *et al*., 2006).

Fig is a moderate salt-tolerant crop (Golombek and Lüdders, 1990). The available studies on the response of fig commercial cultivars to different levels of salinity indicated a significant variation in morphological characteristics, growth parameters, physiological behavior, photosynthetic efficiency, gas exchange ratio, product quality, and productivity (Essam *et al*., 2013; Metwali *et al*., 2014; Alswalmeh *et al*., 2015; Zarei *et al*., 2016, 2017; Soliman and Abd Alhady, 2017).

Considering the position of Iranian cultivars in global fig market, the present study examined the growth and photosynthetic rate of commercial fig cultivars (i.e. 'Sabz', 'Siyah', 'Shah Anjir', 'Atabaki', 'Kashki', 'Mati' and 'Bar Anjir') exposed to six salt treatments corresponding to the following electrical conductivities (EC): 0.5, 2, 4, 6, 8 and 10 dSm^{-1} to identify the most salt-tolerant cultivar.

2. Materials and Methods

The present study was conducted in the plant breeding department, Faculty of Agriculture, University of Shiraz (36° 29' N and 32° 52' E), Iran during 2016-2018.

Plant materials

The plant materials were included six 20-years-old edible fig cultivars (Sabz, Siyah, Shah Anjir, Atabaki, Kashki, Mati), and a caprifig ('Bar Anjir') were located at Estahban fig Research Station (36° 29' N and 32° 52' E) (Table 1). The hard-wood cuttings, 20 cm in length and one cm in diameter, were collected from one-year-old branches on March 25, 2016. The cuttings were treated with a fungicide (Benomyl 2000 ppm) and a rooting hormone (IBA solution 3000 ppm). Then, the upper side of the cutting was covered to prevent the decay, and each cutting was placed in a dark plastic bag (25 x 18 cm^2), which was filled by sand. In the next stage, the bags were located in the shade-house conditions (Temperature: 28±2°C D/18±2°C N, RH=50%, and 50% shade) and were irrigated twice a day. In June 2017, rooted-cuttings were transplanted in pots filled with 500 g of gravel and 20 kg of the media described in Table 2.

Table 1 - The growth and bearing habit of studied fig cultivars (Sabet Sarvestani, 1999; Safai 2002; Jafari *et al.*, 2016)

Parameters	Cultivar						
	'Sabz'	'Siyah'	'Shah Anjir'	'Atabaki'	'Kashki'	'Mati'	'Bar Anjir'
Growth and bearing	Relatively high	High	Moderate	Moderate growth and low bearing	High growth and moderate bearing	Moderate growth and low bearing	Low- moderate growth and high bearing
Bud	Conical terminal buds with curved tip	Curved and pointed terminal bud	Terminal pointed bud	Terminal conical bud	Terminal conical, with tip	Terminal conical bud without tip	Terminal conical bud
Fruit	Medium, yellowish, no neck, thick pulp	Medium, dark purple, no neck, thin skin, flesh uniformly red, low pulp thickness	Large, necked, yellow, pink pulp, fully seed	Large, rounded, reddish-purple fruit, reddish pulp, reddish	Medium, green, , open ostiole necked, white pulp, low seedy	Large, no neck, open ostiole, dark and thick fruit, white, reddish pulp	Medium, with long neck, containing Blastophagous bees
Type of consumption	Dried Fruit	Fresh fruit	Both Fresh and dried fruit	Fresh fruit	Fresh and processed fruit	Fresh fruit	Caprifig
Yield	Very high	High	High	Moderate	Moderate	Moderate	Moderate
Taste	Excellent	Sweet-and-sour	Sweet	Sweet-and-sour	Sweet	Sweet-and-sour	Sweet
Bearing period	Early bearing	Early bearing	Mid-season bearing	Early bearing	Late bearing	Early bearing	Mid-season bearing

Table 2 - Physico-chemical properties of the soil

Soil texture	San (%)	Silt (%)	Clay (%)	EC (ds/m)	CEC (Me/100)	pH	Lime (%)
Sandy clay-loam	58±1.01	26±1	16±0.9	1.45±0.21	10.84±0.81	7.7±0.17	±351.33
Organic C (%)	N (%)	K (ppm)	P (ppm)	Cu (ppm)	Mn(ppm)	Fe (ppm)	Zn (ppm)
1.17±0.05	0.17±0.002	126±1.3	3.2±0.05	0.26±0.002	3.86±0.04	2.85±0.03	0.056±0.001

EC= Electrical conductivity;
CEC= Cation exchange capacity.

The media included the mixture of soil, leaf compost and sand (1:1:1), which was steam-disinfected. A pressure plate extractor (Model ADC, by Santa Barbara, United States) was used to measure the media water capacity. The pots were kept under shade-house condition (Temperature: 30±1°C D/18±0.5°C N, RH=50%, and 50% shade).

Salt treatment

The salt treatments were provided through the irrigation water. Treatments included low salt treatments (EC= 0.5 and 2 dS m^{-1}, A and B, respectively), intermediate salt treatments (EC= 4 and 5 dS m^{-1}, C and D, respectively) and high salt treatments (EC= 8 and 10 dS m^{-1}, E and F, respectively).

In order to avoid osmotic stress, salt treatments were introduced gradually, starting from 1/4 up to the final concentration. Then, irrigation frequency was calculated based on the media filed capacity and water requirement (Essam *et al*., 2013; Zarei *et al*., 2016). Salt treatment was performed within nine weeks from 23/7/2017- to 26/9/2017. In addition, all of the plants were irrigated by distilled water for four months (26/1/2018).

Stem length

The length of the stem was recorded at the beginning and end of the experiment. The difference between the two values was recorded as the difference in stem length (cm).

Stem diameter

The stem diameter was recorded at the beginning and end of the experiment by digital caliper (4 cm above the soil surface). The difference was recorded as the difference in stem diameter (mm).

Number of leaves

The number of expanded leaves was counted at the beginning and end of the experiment. The difference between the two values was recorded as the difference in the number of leaves.

Specific leaf area (SLA), leaf dry matter content (LDMC) and leaf succulence

The fourth top leaf was harvested after ending the experiment. The leaf area was recorded using a Leaf Area Meter (CI-202 Portable Laser Leaf Area Meter). The leaves were then dried in an oven (75°C, 48 hrs.) and the dry weight was recorded (LDW). The specific leaf area (in cm^2 g^{-1}) was calculated by using the Eq. (1). LDMC and leaf succulence were calculated using Eq. (2) and (3).

$$SLA = LA/LDW \quad (1)$$

where LA is leaf area (cm^2) and LDW is leaf dry weight (g), according to Hunt *et al.*, 2002.

$$LDMC = LDW/LFW \quad (2)$$

where LDW and LFW are leaf dry weight (g) and leaf fresh weight (g) respectively (Garnier *et al.*, 2001).

$$\text{Leaf succulence} = LFW/LA \quad (3)$$

where LFW is leaf fresh weight (g) and LA is leaf area (cm^2), according to Agarie *et al.*, 2007.

Relative water content (RWC)

Mature leaves were collected nine weeks after salt application at mid-day, and were transferred immediately to the lab. Then, five similar leaf discs without any vein were separated from each sample and weighted (W_1). Further, the disc samples were placed in distilled water (4 hrs) under laboratory conditions (24 ± 1°C). Subsequently, the samples were surface dried and re-weighed (W_2). Furthermore, the discs were placed in an electric furnace (Model: Memmert, made by Karl Klob factory, Germany) (90°C, 60 min) and reweighted (W_3). Finally, the relative water content was calculated using the Eq. (4) (Barrs and Weatherley, 1962).

$$RWC = \frac{(W1 - W3)}{(W2 - W3)} \times 100 \quad (4)$$

Electrolyte Leakage (EL)

The top expanded leaf was harvested and 5 leaf discs without any vein were prepared. The samples were rinsed three times with distilled water, and incubated in 10 ml of distilled water (at 40°C for 30 min). After cooling, the electrical conductivity was measured using an Electrical Conductivity Meter (H18633 model) (C_1). The samples were then autoclaved (at 120°C for 15 min). After cooling, the electrical conductivity was re-measured (C_2). The Electrolyte Leakage was calculated via Eq. (5) (Sairam *et al.*, 1997).

$$EL = (C1/C2) \times 100 \quad (5)$$

Leaf protein content

First, the fresh leaf sample (0.2 g) was powdered with liquid nitrogen. Then, two ml of Potassium Phosphate buffer (38.5 ml NaH_2PO_4, 68.5 ml of Na_2HPO_4, 0.074 g EDTA and 1 g of PVP), pH = 7.15 was added and well-homogenized. The extract was centrifuged at 13000 rpm for 15 min at 4°C, and the supernatant was used to measure protein content. About 20 µl of the extract, 80 µl of potassium phosphate buffer (pH= 7.15) and 5 ml of Coomassie Brilliant Blue (C47H48N3NaO7S2) was stirred for 2 min. In addition, the absorbance was read at 595 nm by using a spectrophotometer (Biowave II model) after incubating 5 min at room temperature. The extraction buffer was used as Blank. The protein content (in mg g^{-1} FW) in the sample was calculated according to the sample absorption using the Bovine albumin serum (C123H193N35O37) standard curve (Bradford, 1976).

Leaf nitrogen content

The Kjeldahl method was used to determine the nitrogen content in fresh leaf samples (Kjeldahl, 1883).

Photosynthetic indexes

The photosynthetic indices were recorded using a compact-portable-photosynthesis-system (LCI, UK). The device was put on attached leaf (third expanded leaf) at midday, then transpiration rate (in mol H_2O m^{-2} s^{-1}) and stomata conductance (in mol CO_2 m^{-2} s^{-1}) were recorded after two min (Evans and Von Caemmerer, 1996).

Experimental design and data analysis

The present experiment was conducted in a Complete Randomized Design. The factors included fig cultivars (seven cultivars) and NaCl treatments (six concentrations), with five replications. SAS Version 9.1.3 (SAS®, 1990) was used for the statistical analysis. Shapiro-Wilks test confirmed the normality of the data. In addition, Leven's test confirmed the variance homogeneity. Further, Tukey test was conducted for mean comparisons ($P<0.01$). Finally, Pearson coefficient was used for analyzing the relationship between the parameters.

3. Results

The results of variance analysis indicated that the studied cultivars had a significantly different behavior under salt conditions, due to salt concentration and cultivar variation (Table 3).

Stem length

With increasing salinity level, stem length decreased significantly in all cultivars. The greatest effect was observed in 'Bar Anjir' cultivar, which decreased from 78.84 cm (under 0.5 dS m^{-1} salinity) to 28.44 cm (under 10 dS m^{-1} salinity). The lowest effect was observed in the 'Siyah' cultivar, which reduced from 51.3 cm (in 0.5 dS m^{-1} salinity) to 35.8 cm (in 10 dS m^{-1} salinity) (Table 4). The decrease in stem length for all the tested cultivars was between low (0.5 dS m^{-1}) and high (10 dS m^{-1}) NaCl-treated plant. This decrease for most of the cultivars (including 'Sabz', 'Shah Anjir', 'Mati' and 'Bar Anjir') was more than 200%.

Stem diameter

By raising salinity, the stem diameter decreased significantly in all cultivars. The highest reduction in stem diameter was observed in the 'Mati' cultivar, which decreased from 6.35 mm (under 0.5 dSm^{-1} salinity level) to 3.41 mm (under 10 dSm^{-1}). The lowest effect was observed in 'Siyah' cultivar, reducing from 5.37 mm at the lowest salinity level to 3.2 mm at the highest salinity level (Table 4). In addition, the decrease in stem diameter of low and high salt treated plants varied between 157.93 to 219.89% ('Kashki' and 'Bar Anjir' cultivars, respectively).

Number of leaves

With an increase in salinity levels, the number of leaves in all cultivars followed a decreasing trend. The greatest effect of salinity was observed in 'Bar Anjir', which difference in the number of the leaves in the lowest and highest salinity levels was 10.2 leaves. The lowest effect of salinity on leaf number was observed in 'Shah Anjir', and the difference was 3 leaves in the lowest and highest salinity levels in this cultivar. In addition, 'Sabz' and 'Atabaki' cultivars had the lowest number of leaves under intermediate salt conditions (4 and 6 dSm^{-1}) (Table 4). The leaf number of 'Atabaki' cultivar under higher salt condition was significantly lower than 0.5 dS m^{-1} of EC.

Specific leaf area, leaf dry matter content and leaf succulence

The specific leaf area followed a decreasing trend due to an increase in salt concentration in the 'Sabz', 'Siyah', 'Shah Anjir' and 'Kashki' cultivars. In 'Atabaki' cultivar, under EC of 6 and 10 dSm^{-1} the reduction was observed. In 'Bar Anjir' cultivar, there was no significant difference between 2-10 dsm^{-1} salt levels (Table 4). Except for 'Mati' and 'Bar Anjir' cultivars showing 32.21 and 60.55% increase in SLA, the rest of the cultivars had descending trend of SLA during the experiment. Leaf dry matter content of salt-exposed fig cultivars followed a descending trend. The difference in LDMC of seven cultivars under low salt concentration (0.5 and 2 dsm^{-1}) was not remarkable. Under moderate salt condition (4 dsm^{-1}), most of the cultivars had similar values but under higher salt (6 dsm^{-1} and more), 'Shah Anjir' and 'Siyah' cultivars showed an ascending trend. Leaf succulence displayed slight rising trend. 'Bar Anjir' had the highest value under low salt conditions, while 'Siyah' Showed the highest value under moderate and high salt condition. The values of this parameter was unchanged under moderate salt conditions and the decrease started when NaCl reached 8 dsm^{-1} and more (Table 4). Leaf succulence of 'Sabz', 'Shah Anjir' and 'Siyah' under EC of 10 dS m^{-1} were 1.64, 1.64 and 1.61 times higher than their value under EC of 6 dSm^{-1}.

Relative water content of leaf

Salinity had a significant effect on reducing leaf

Table 3 - The interaction of cultivar and salinity on growth and physiological parameters of seven fig (the mean square value is given)

Physiological parameters	Cultivar	Salinity	Cultivar x salinity
Difference in stem length	1273.11 *	5916.23 *	223.68 **
Difference in stem diameter	9.61 **	30.78 *	1.34 **
Difference in leaf number	107.80 **	220.38 *	11.25 **
Specific Leaf Area	174.37 **	27.628 NS	11.23 **
Relative water content	1540.57 **	264.34 **	289.57 **
Electrolyte Leakage	21.31 **	239.41 **	11.23 **
Leaf protein	37007542 **	268172052 **	4586351 **
Leaf nitrogen	0.93 **	5.94 **	0.071 **
Transpiration rate	4.46 **	90.58 **	3.89 **
Stomata conductance	0.099 **	1.025 **	0.074 **

NS, * and **= not significant, significant at 5 and 1% respectively (by Tukey mean comparison test).

Table 4 - The influence of saline water on stem length, stem diameter, leaf number, specific leaf area, LDMC and leaf succulence of fig cultivars

Genotype	Treatments	Stem length (cm)	Stem diameter (mm)	Leaf number	Specific leaf area (cm^2 g^{-1})	LDMC	Leaf succulence
Sabz	A	59.72 b	4.53 c	8.20 c	11.53 b	0.68 b	0.13 i
	B	48.00 c	3.19 d	6.80 d	13.38 a	0.70 b	0.11 i
	C	38.64 c	3.29 d	6.00 d	11.60 b	0.52 d	0.17 h
	D	27.90 d	2.34 e	4.00 e	11.76 b	0.57 c	0.15 h
	E	30.75 d	2.51 e	3.20 f	10.22 c	0.57 c	0.17 h
	F	27.30 d	2.39 e	2.60 f	7.85 e	0.52 d	0.24 g
Siyah	A	51.30 c	5.37 b	5.80 d	4.79 f	0.74 a	0.28 e
	B	38.80 c	4.91 c	4.60 d	3.64 g	0.73 a	0.38 d
	C	30.24 d	3.24 d	2.50 f	3.94 g	0.61 c	0.41 c
	D	36.50 d	3.87 d	3.40 f	3.76 g	0.60 c	0.44 c
	E	28.66 d	3.49 d	1.00 g	3.77 g	0.60 c	0.44 c
	F	35.80 d	3.20 d	2.50 f	2.04 g	0.69 b	0.71 a
Shah anjir	A	49.72 c	4.72 c	4.00 d	11.27 b	0.70 b	0.13 i
	B	52.40 c	5.27 b	6.40 d	11.04 b	0.54 d	0.17 h
	C	29.30 d	3.68 d	5.40 d	10.35 c	0.62 c	0.16 h
	D	32.90 d	3.60 d	2.60 f	9.73 c	0.74 a	0.14 h
	E	33.04 d	3.15 d	1.60 f	9.52 c	0.76 a	0.14 h
	F	23.06 d	2.54 e	1.00 g	6.40 e	0.69 b	0.23 g
Atabaki	A	76.50 a	4.75 c	7.60 c	11.89 b	0.71 b	0.12 i
	B	59.20 b	5.17 b	7.20 c	8.49 d	0.68 b	0.17 h
	C	53.74 c	4.56 c	6.60 d	7.76 e	0.61 c	0.21 g
	D	40.50 c	3.99 d	5.00 e	5.64 f	0.49 d	0.36 e
	E	25.30 d	1.45 f	3.00 f	8.82 d	0.44 e	0.26 g
	F	44.08 c	2.46 e	3.60 f	6.01 e	0.49 e	0.34 e
Kashki	A	78.00 a	5.18 b	12.40 a	9.55 c	0.61 c	0.17 h
	B	53.62 b	5.50 b	7.00 c	9.23 d	0.62 c	0.18 h
	C	50.14 c	3.77 d	8.00 c	9.08 d	0.52 d	0.21 g
	D	38.88 c	2.97 d	4.40 e	7.88 e	0.57 c	0.22 f
	E	46.02 c	3.26 d	3.80 f	6.75 e	0.57 c	0.26 g
	F	45.46 c	3.28 d	6.60 d	6.65 e	0.52 d	0.29 f
Mati	A	68.22 b	6.35 a	9.80 b	5.95 f	0.68 b	0.25 g
	B	64.80 b	5.80 b	9.60 b	8.55 d	0.62 c	0.19 h
	C	52.10 c	4.65 c	5.80 d	5.21 f	0.45 e	0.43 c
	D	38.30 c	4.19 c	3.20 f	4.64 f	0.45 e	0.48 c
	E	33.80 d	4.24 c	5.20 e	4.20 f	0.45 e	0.53 b
	F	30.90 d	3.41 d	2.40 f	7.86 e	0.44 e	0.29 f
Bar anjir	A	78.84 a	3.98 c	13.60 a	5.60 f	0.35 f	0.51 b
	B	58.00 b	4.02 c	11.00 b	8.36 d	0.29 f	0.41 c
	C	48.00 c	3.67 d	8.40 c	8.74 d	0.30 f	0.39 d
	D	43.56 c	3.19 d	7.40 c	8.98 d	0.32 f	0.35 e
	E	32.20 d	2.90 d	4.20 e	8.68 d	0.28 f	0.42 c
	F	28.44 d	1.81 e	3.40 f	8.99 d	0.30 f	0.38 e

Data are average of five replications. In each column means with a common letter have no significant difference at 1% of Tukey test. Treatments A, B, C, D, E and F are 0.5, 2, 4, 6, 8, and 19 dS m^{-1} of EC, respectively.

relative water content in all cultivars. The highest decrease was observed in the 'Siyah' cultivar, which reduced from 90.83% in the lowest salinity level to 53.03% in the highest salinity level. The lowest effect was observed on the 'Sabz' cultivar. The intermediate salt condition of 4 dSm^{-1} did not make a significant difference from 2 dSm^{-1}, except in 'Sabz' (Table 5). The 'Kashki' and 'Bar Anjir' cultivars had the lowest decline of RWC during the experiment (15.15 and 15.33%, respectively), while 'Siyah' showed the stronger decrease in RWC (41.62%).

Electrolyte leakage

Salinity had a significant ascending effect on electrolyte leakage in seven fig cultivars. The highest salinity increased the ionic leakage in 'Siyah' and 'Atabaki'

Table 5 - The influence of saline water on electrolyte leakage, protein, nitrogen, transpiration rate, stomata conductance and RWC of fig cultivars

Genotype	Treatments	RWC (%)	Electrolyte leakage (%)	Protein (mg. g^{-1}. Fw)	Nitrogen content (%)	Transpiration rate (mol H_2O $m^{-2}s^{-1}$)	Stomata conductance (mol CO_2 m^{-2} s^{-1})
Sabz	A	76.20 c	19.53 c	0.90 c	3.73 a	59.72 b	0.46 d
	B	74.80 c	20.75 c	0.93 c	3.55 b	48.00 d	0.13 g
	C	68.20 d	18.76 c	1.21 b	3.28 b	38.64 c	0.20 f
	D	62.55 d	17.80 d	1.79 b	3.13 b	27.90 c	0.20 f
	E	62.22 d	19.20 c	2.20 a	2.47 c	30.75 g	0.06 h
	F	61.88 d	22.01 c	2.45 a	2.31 c	27.30 g	0.05 h
Siyah	A	90.83 a	15.77 e	0.86 c	3.55 b	51.30 b	0.53 c
	B	76.78 c	16.42 d	0.86 c	3.59 b	38.80 c	0.78 a
	C	70.15 c	18.61 c	1.22 b	3.43 b	30.24 e	0.16 g
	D	67.55 d	19.91 c	2.17 a	3.21 b	36.50 e	0.14 g
	E	65.09 d	22.31 b	2.35 a	2.98 c	28.66 g	0.07 h
	F	53.03 e	24.73 a	2.60 a	2.97 b	35.80 g	0.04 h
Shah anjir	A	89.23 b	16.23 d	0.76 c	3.28 b	49.72 b	0.45 d
	B	88.79 b	15.17 e	0.92 c	3.28 b	52.40 b	0.48 d
	C	81.68 b	18.67 c	0.99 c	3.10 b	29.30 d	0.30 d
	D	77.66 c	21.24 b	1.01 b	2.50 c	32.90 d	0.15 g
	E	77.56 c	20.61 c	1.56 b	3.15 b	33.04 f	0.08 h
	F	72.15 c	22.22 c	1.36 b	2.92 c	23.06 e	0.11 g
Atabaki	A	81.16 b	14.37 e	0.91 c	3.13 b	76.50 a	0.67 b
	B	77.22 c	15.39 e	1.01 b	3.34 b	59.20 c	0.36 e
	C	75.33 c	16.56 d	1.15 b	3.16 b	53.74 d	0.38 d
	D	73.47 c	19.29 c	1.62 b	2.97 c	40.50 d	0.40 d
	E	71.09 c	22.75 b	2.04 a	2.43 c	25.30 g	0.06 h
	F	64.65 d	23.05 b	2.31 b	2.29 c	44.08 h	0.03 h
Kashki	A	85.34 b	16.51 d	0.74 c	2.98 c	78.00 b	0.40 a
	B	78.92 c	20.10 c	0.85 c	3.31 b	53.62 c	0.27 f
	C	75.33 c	20.04 c	1.08 b	3.13 b	50.14 e	0.13 g
	D	73.48 c	22.49 b	1.31 b	2.89 c	38.88 e	0.19 g
	E	73.29 c	23.20 b	1.84 b	2.75 c	46.02 e	0.14 g
	F	72.41 c	22.75 c	2.19 a	2.33 c	45.46 e	0.11 g
Mati	A	96.32 a	14.46 e	0.84 c	2.97 c	68.22 a	0.75 a
	B	88.58 b	17.27 d	0.94 c	3.50 b	64.80 b	0.43 d
	C	83.88 b	19.24 c	1.09 b	3.27 b	52.10 e	0.13 g
	D	78.39 c	21.22 b	1.23 b	3.09 b	38.30 e	0.23 f
	E	74.58 c	21.65 c	1.71 b	2.66 c	33.80 f	0.15 g
	F	70.23 c	22.38 c	2.01 a	2.60 c	30.90 g	0.04 h
Bar anjir	A	95.00 a	14.83 e	0.71 c	3.78 a	78.84 d	0.20 f
	B	93.68 a	15.30 e	0.75 c	3.32 b	58.00 d	0.34 e
	C	91.82 a	16.68 d	0.81 c	3.14 b	48.00 b	0.26 f
	D	88.52 b	19.72 c	1.04 b	2.82 c	43.56 b	0.09 h
	E	82.81 b	21.26 b	1.76 b	2.75 c	32.20 f	0.08 h
	F	80.44 b	21.96 c	1.96 b	2.30 c	28.44 g	0.04 h

Data are average of five replications. In each column means with a common letter have no significant difference at 1% of Tukey test. Treatments A, B, C, D, E and F are 0.5, 2, 4, 6, 8, and 19 dS m^{-1} of EC, respectively.

cultivars (Table 5). The electrolyte leakage of 'Atabaki', 'Siyah' and 'Bar Anjir' cultivars showed the highest difference between the moderate and high salt conditions (39.19, 32.89 and 31.65% increases, respectively).

Leaf protein

The results indicated that salinity had a significant effect on leaf protein of studied fig cultivars. Increasing the stress to 4 ds^{-1} of EC increased the total protein content gradually. The highest amounts were observed in 'Siyah' (2.60 mg g^{-1} FW) and 'Sabz' (2.45 mg g^{-1} FW) cultivars and the lowest in 'Shah Anjir' (1.36 mg g^{-1} FW) and 'Bar Anjir' (1.96 mg g^{-1} FW) cultivars (Table 5). The increase in protein content was expected between moderate (4 ds^{-1}) and high (10 ds^{-1}) NaCl treated plant. This increase for most of the cultivars (including 'Sabz', 'Siyah', 'Atabaki', 'Kashki' and 'Bar Anjir') was more than 200%.

Leaf nitrogen

By increasing salinity levels in all seven fig cultivars, leaf nitrogen content decreased. The highest reduction was observed in 'Bar Anjir' cultivar at EC of 10 ds^{-1} (2.30%) and the lowest reduction was observed in 'Siyah' cultivar, which decreased from 3.55% at the lowest salinity level to 2.99% at the EC of 10 dSm^{-1} (Table 5). The 'Mati', 'Kashki' and 'Atabaki' showed 10.03, 5.04 and 0.88% increase in N content under moderate salt condition (4 dSm^{-1}), while the rest cultivars exhibited a decrease in N content (Table 5).

Photosynthetic indices

The interaction of salinity stress and cultivar on photosynthetic indices (transpiration rate and stomata conductance) was significant. With increasing NaCl levels, the rate of transpiration decreased in seven fig cultivars. The highest reduction was observed in 'Atabaki' cultivar (0.85 mol H_2O m^{-2} s^{-1} at 10 dSm^{-1} of EC). The lowest influence was observed in 'Kashki' (3.41 mol H_2O m^{-2} s^{-1} at 10 dSm^{-1} of EC). For all the studied cultivars this parameter did not differ significantly between 4 and 6 dSm^{-1} (intermediate salt conditions). High salt concentrations (8 and 10 dSm^{-1}) caused a noticeable difference among the genotypes, where 'Atabaki', 'Siyah', 'Mati' and 'Sabz' were fall to 12.18, 19.63, 22.16 and 23.40% of their initial values (Table 5). Stomata conductance decreased by increasing salt concentration in all cultivars, and reached its lowest level at the highest salinity level (10 dSm^{-1}). The lowest stomata conductance at of EC 10 dSm^{-1} was observed in 'Atabaki' (0.03 mol CO_2 m^{-2} s^{-1}) and the lowest in 'Kashki' (0.11 mol CO_2 m^{-2} s^{-1}) (Table 5). The 'Atabaki', 'Mati' and 'Siyah' cultivars displayed the highest decrease of stomata conductance from 05. to 10 dSm-1of EC (3.86, 5.91 and 7.95% decrease of their initial values, respectively)

Correlation analysis

Table 4 indicates the bivariate Pearson correlations among the parameters. The bold faces values indicate high correlated values (higher than 0.5). Difference in the number of leaves had high correlation with relative water content (0.583**), Transpiration rate (0.899**) and stomata conductance (0.915**). Specific leaf area and relative water content were positively correlated (0.680**). In addition, both photosynthetic indices showed high correlation (0.877**) (Table 6).

4. Discussion and Conclusions

The negative effect of salinity leads to the changes in soil structure, competition in nutrients uptake in different parts of the plant and eventually inhibition of nutrients absorption (Gholami et al., 2012). Na+ reduces plant biomass by disrupting the protein synthesis, destroying chlorophyll, and decreasing the activity of the enzymes which are involved in biosyn-

Table 6 - The correlation analysis of physiological parameters of fig cultivars

Physiological parameters	Leaf nitrogen	Leaf protein	Electrolyte Leakage	Difference in stem length	Difference in the number of leaves	Difference in stem diameters	Specific leaf area	Relative water content	Transpiration rate	Stomata conductance
Leaf nitrogen	1									
Leaf protein	-0.170 *	1								
Electrolyte Leakage	-0.225 **	0.017	1							
Difference in stem length	-0.375 **	-0.006	0.068	1						
Difference in the number of leaves	0.331 **	-0.009	-0.055	-0.108	1					
Difference in stem diameters	-0.415 **	0.323 **	0.179 **	0.093	-0.287 **	1				
Specific leaf area	0.393 **	-0.239 **	-0.103	-0.079	0.199 **	-0.480 **	1			
Relative water content	0.351 **	-0.124	-0.122	-0.077	0.583 **	-0.499 **	0.680 **	1		
Transpiration rate	0.362 **	-0.111	-0.098	-0.079	0.899 **	-0.435 **	0.227 **	0.581 **	1	
Stomata conductance	0.195 **	0.025	-0.033	-0.036	0.915 **	-0.149*	-0.020	0.463 **	0.877 **	1

* and **= Correlation is significant at the 5 and 1% levels, respectively.

thesis (phosphoenolpyruvate carboxylase, Ribulose-l,5-bisphosphate carboxylase, pentose phosphate pathway enzymes and glycolysis pathway enzymes) (Demiral, 2005).

The major strategies of plants to overwhelm this stress included: reduction in Cl- and Na+ uptake, leaf loss, decrease in leaf specific area and relative leaf water content, synthesis of osmotic compounds, exclusion of toxic ions into vacuole, change in membrane stability, and increase in the activity of antioxidant enzyme (Mutsushita and Matoch, 1992; Sato *et al*., 2006).

Based on the results of the present study, the stem length in 'Siyah' and 'Sabz' was less affected by salt stress. In addition, under intermediate salt conditions 'Shah anjir', 'Siyah' and 'Sabz' had the lowest stem length. It has already reported that salt-sensitive fig cultivars such as 'Brown Turki' and 'Pius' displayed reduction in stem length under salinity conditions (Alswalmeh *et al.*, 2015; Zarei *et al*., 2016). A similar decrease in stem length under salt conditions was reported in almond (Najafian *et al*., 2008) and pistachio (Adish *et al.*, 2010).

The findings of Soliman and Abd Alhady (2017) and Zarei *et al.* (2016), indicated that the stem diameter in salt-exposed fig cultivars had a linear decrease. Furthermore, the decrease in stem diameter in salt-treated plums (Bolat *et al*., 2006), citrus (Khoshbahkt et al., 2014) and pomegranate (Khayyat *et al*., 2014) showed similar pattern. In the present study, stem diameter of 'Siyah' cultivar was less affected by salt.

Reducing the number of leaves in salt-exposed plants is due to limit leaf production or early leaf aging (Yeo *et al.*, 1991; Munns and Tester, 2008). Based on the results, the highest leaf loss was observed in 'Bar Anjir' cultivar. Similar results are available in almond (Momenpour *et al*., 2018), pistachio (Adish *et al.*, 2010) and fig cultivars (Essam *et al.*, 2013; Alswalmeh *et al*., 2015; Zarei *et al*., 2016; Soliman and Abd Alhady, 2017).

Reduction in the relative leaf water content under salinity stress indicates lower water uptake by plants. Limited access to water due to increase in osmotic potential reduces the cell development and decreases turgor pressure of the cells (Yamasaki and Dillenburg, 1999). In the present study, salinity reduced the relative content of leaf water in fig cultivars, except 'Bar Anjir'. In 'Siyah' cultivar, a dramatic decrease was observed in the relative leaf water content. Under various salt concentrations, the trend of this parameter stayed unchanged.

Under intermediate salt conditions the specific leaf area of 'Siyah' and 'Sabz' had not evident changes. According to Owais (2015), with increasing salt levels, the relative leaf water content in grape genotypes decreased, but this decrease was lower in tolerant cultivars. A similar decrease was observed in the relative leaf water content under salinity stress in fig (Zarei *et al.*, 2016; Soliman and Abd Alhady, 2017) and pomegranate (Khayyat *et al.*, 2014).

The values of SLA and LDMC reveal an important exchange in plant function between high SLA, low LDMC (cultivars with rapid production of biomass) and low SLA, high LDMC (cultivars with an efficient conservation of nutrients) (Poorter and Garnier, 1999). According to our results, 'Siyah' and 'Sabz' cultivars had the lowest SLA and the highest LDMC value, confirmed its production efficiency under various salt concentration. In addition, 'Bar Anjir' and 'Shah Anjir' had the highest SLA and the lowest LSDM under different NaCl concentration, due to their limited production efficiency under salt conditions.

Rising the salinity level, increased leaf succulence. This ability characterizes a balance between growth rate and the necessity of osmotic adjustments (Flowers and Yeo, 1986), which regulate low external water potential encouraged by salinity stress (Flowers and Colmer, 2008). Moreover, it explains the better carbon assimilation capacity per unit area (de Vos et al., 2013). Based on our findings 'Siyah' and 'Sabz' cultivars had the highest leaf succulence, which related to the balance between growth ratio and osmotic regulation under salt conditions.

Peroxidation of lipids is regarded as an extra effect of salinity on plants (Demidehik *et al.*, 2002). The findings of the previous researchers on increasing ion leakage under salinity stress in fig (Abdoli Nejad and Shekhafandeh, 2014; Zarei *et al.*, 2016) and pomegranate (Khayyat *et al.*, 2014) confirms our results.

Proteins biosynthesis is an important biochemical process which is affected by salt stress. Expression of specific genes under NaCl stress assistances the plant to adapt to adverse conditions (Murcute *et al*., 2010). According to our findings, protein content increased under high salt condition, but this increase was greater under intermediate salt for 'Siyah' and 'Sabz' cultivars.

It has reported that sodium chloride treatment reduced leaf protein content in salt-sensitive grape (Alizadeh *et al*., 2010) and figs (Abdoli Nejad and Shekhafandeh, 2014).

In fact, salt inhibits the synthesis of nitrate reductase, glutamine synthase and glutamate synthase (which are involved in nitrogen metabolism), decreases nitrogen metabolism (Hossain *et al*., 2012), changes active forms of nitrogen, reduces amino acids synthesis, and finally increases the activity of degrading enzymes (De Souza *et al*., 2016). In saline conditions, Cl^- competes with nitrate (Abdelgadir *et al.*, 2005), leading to the decline of nitrogen in different parts of the plant (Yu *et al*., 2016; Hasan and Miyake, 2017). According to the Owais (2015) and Doulati Baneh *et al.* (2014), salinity had a decreasing effect on the leaf nitrogen content in fruit crops. Although the relationship between salinity and nitrogen metabolism is very complex, balanced nitrogen metabolism significantly affects salinity tolerance in plants (Teh *et al.*, 2016). In the present study, the impact of salinity on leaf nitrogen content of different fig cultivars was not the same.

Photosynthesis is another important plant phenomenon, significantly affected by abiotic stress. Reduction of photosynthesis under salinity stress is attributed to stomata factors (reduced CO_2 permeability, stomata closure, decrease in plants transpiration, stomata conductance reduction), and non-stomata factors (cell membrane dehydration, structural changes in the cytoplasm and chlorophyll degradation) (Brugnoli and Lauteri, 1991; Reza *et al.*, 2006; Tabatabaei, 2006). Salinity reduces stomata conductance in hybrids of fig, by decreasing the photo-conductivity of leaf cells (Golombek and Lüdders, 1990; Zarei *et al*., 2016), which is in agreement with the results of the present study. Similar results were reported in pistachio (Adish *et al.*, 2010). According to the results of the present study, 'Atabaki' and 'Kashki' cultivars showed the lowest and the highest stomata conductance under high salt condition, respectively.

Salinity reduces evaporation and transpiration in plants (Bhantana and Lazarovitch, 2010; Dudley *et al.*, 2008). The linear relationship among reduction of plant evapotranspiration, transpiration and increase in salinity levels was reported in pomegranate (Shani and Ben-Gal, 2005; Mohamed Ibrahim and Abd El-Samad, 2018) and date palm (Tripler *et al.*, 2007), which is coordinated with the results of the current study.

In addition, the maximum quantum efficiency of photosystem II, electron transfer, gas exchange, and carbon dioxide assimilation decrease under salt conditions (Joao-Correia *et al.*, 2006). In the present study, Atabaki cultivar had the highest transpiration rate at the low and mild salinity levels, and with increasing salinity, a greater decrease was observed (Table 5). The lowest effect of salinity on transpiration rate was observed in 'Kashki' (Table 5), the cultivar which was able to balance the transpiration level at mild and severe stress levels, probably due to having thicker cuticle.

The most important physiological process affected by this stress is photosynthesis (Sudhir and Murthy, 2004; Acosta-Motos *et al*., 2017). Reduction in photosynthesis efficiency is followed by a series of molecular events including cell membrane dehydration, stomata closure, decreased CO_2 entry, reduction in leaf permeability to CO_2, structural changes in the cytoplasm and subsequent alteration in the activity of enzymes (Tabatabaei, 2006).

On the other hand, nitrogen plays effective role in plant growth and construction of vital plant structures such as amino acids and proteins (Arghavani *et al.*, 2017). Nitrogen is necessary to generate cellular components such as Rubisco, which is responsible for assimilating carbon dioxide. Therefore, by limiting nitrogen uptake, salinity stress affects the photosynthesis efficiency, leading to a decrease in vegetative and reproductive growth (Coruzzi and Bush, 2001; Marschner, 2012; Zarata-Valdez *et al.*, 2015).

In the present research, salinity had a significant effect on growth parameters and photosynthetic indices in seven cultivars of fig. The differences in stem length, stem diameter and leaf number in all cultivars followed a downward trend. The stomata conductance of all fig cultivars was same up to 4 dS m^{-1} NaCl. Moreover, the transpiration rate did not exhibited variation unless in salt concentration higher than 8 dSm^{-1}. The 'Siyah' and 'Sabz' cultivars had the lowest decreases in stem length and diameter, the lowest leaf water content and transpiration rate, and the maximum leaf abscission. Additionally, 'Siyah' and 'Sabz' cultivars had the highest leaf succulence and LDMC and the lowest SLA, which related to the balance between growth ratio and osmotic regulation under salt conditions. The 'Mati', as an intermediate salt-tolerance cultivar, had the lowest leaf abscission under severe salinity levels. The 'Shah Anjir', as the most salt-sensitive cultivar, could not balance transpiration rate and leaf water content under salt treatment higher than 4 dSm^{-1}.

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