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Morpho-Physiological Responses of Some Iris Cultivars under Drought and Salinity Stresses

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ABSTRACT

The effects of drought and salinity stresses on morpho-physiological characteristics of three Iris (*Iris* spp.) cultivars ('Purple Blue Magic', 'White Madonna' and 'Blue Deep River') were investigated. Drought stress experiment included three drought levels (60, 75, and 90% of field capacity), and the salinity stress experiment included four concentration of NaCl (0, 50, 100 and 150 mM). Different drought and salt treatments had significant effects on the morphological characteristics (leaf surface, main root diameter, number of branched roots and corm dry weight) and the physiological characteristics (Relative Water Content= RWC, Carotenoid, Lipid Peroxidation= MDA, and Electrolyte Leakage= EL) of the three iris cultivars. The best vegetative growth characteristics and physiological conditions were recorded under the control treatments [most favorable moisture conditions (90% FC) and without using salt in irrigation water] and the poorest were under the most severe stress conditions (60% FC and 150 mM NaCl in irrigation water). With increasing drought stress in 60% FC level and increasing NaCl salt treatments in 100 and 150 mM, no flower appeared in the 'Madonna' and 'Blue Magic' cultivar, respectively. In this aspect, only 'Deep River' cultivar could reach flowering phase and complete life cycle in both drought and salinity stresses. We concluded that the process of flowering in some iris cultivars were sensitive to drought stress and salinity. However, by selection, resistant or tolerant cultivars or genotypes could be identified and promoted under these abiotic stress conditions.

Keywords: Deep River cv., Drought tolerant, Purple Blue Magic cv., Salt tolerant, White Madonna cv.

INTRODUCTION

Iris spp. is one of the important ornamental bulbous plants in temperate regions whose species and cultivars grow well in most parts of the world. This plant is widely used for decoration of parks and for cut flowers (Naseri and Ebrahimi Geravi, 1999). Iris as perennial grassland is a good choice with a beautiful appearance and high adaptation with a large number of cultivars (Guo *et al*., 2013). Drought and salinity are a well-known challenge to plant growth and cause a growing threat to the development of agriculture (Golldack *et al*. 2014). One of the tough environmental conditions the plants face is salinity stress, which is usually along drought stress. All plants, regardless of their tolerance degree, react against environmental stress factors through activation of a series of conserved responses, which are common to different types of abiotic stress. These responses encompass diverse physiological, biochemical, and cellular processes in a specific environmental context (Mbarki *et al*., 2018). They include, in most cases, inhibition of photosynthesis and plant growth (Zhu, 2016; Sun *et al*., 2016). The concept of salinity is usually raised in relation to its effect on

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plant growth and development (Nielson and Nielson, 1998). With increase in the level of minerals, the growth rate of the plant decreases (EL-Darier and Youssef, 2000). Zifeng (2009) examined the resistance of six *Iris* spp. cultivars to drought stress, and divided them into four categories in terms of resistance, among which the German cultivar had the highest resistance against drought, and *Iris flavescens* and *Iris germanica* had the lowest tolerance. Maleki *et al*. (2010) examined the effects of drought stress on growth and biochemical compounds in Saffron corms. In this study, the content of proline, soluble carbohydrates, total carbohydrates, carotenoids, and MDA increased under drought stress. The results of the study by Guo *et al*. (2013) on 10 Iris cultivars showed that prediction of drought tolerance by determining the electrical conductivity, chlorophyll content, soluble sugar and MDA can be used to evaluate the drought tolerance of other *Iris* spp.

Yildirim *et al*. (2017) reported the Pepper (*Capsicum annuum* L. cv. California Wonder) in the fully irrigated treatment water was more efficient than the excess and deficit irrigation treatments (Yildirim *et al*., 2017). Plesa *et al*. (2018) investigated the effects of drought and salinity on European Larch (*Larix decidua* Mill.) seedlings. In all cases, salinity appeared to have stronger effects on the seedlings than water deficit. Salt stress inhibited growth of all seedlings in European larch, by the relative reduction of stem length and fresh weight, and induced significant changes in the needle levels of several biochemical stress markers (Plesa *et al*., 2018). Al-Harbi *et al*. (2018) evaluated two greenhouse tomato cultivars. Results showed plant height, stem diameter, leaf area, and total yield decreased, whereas proline and total yield water use efficiency (TYWUE) increased with increasing water stress (Al-Harbi *et al*., 2018). Dugasa *et al*. (2019) studied the response of wheat genotypes to single and combined drought and salinity stresses by physiological and biochemical characteristics. Results showed that in two genotypes, Salinity and Drought (S+D) severely reduced plant growth, biomass, and net photosynthetic rate, with a greater effect observed in Yangmai20 (salt-sensitive) than Jimai22 (salt tolerant). Results suggest that high tolerance of Jimai22 in both D+S stresses is closely associated with larger root length and less MDA contents (Dugasa *et al*., 2019).

Water stress and salinity are among the limiting factors in the production of agricultural products, such as ornamental plants, in the world and Iran. The effect of these stresses on the growth and development of ornamental plants, especially in bulbous plants, is much less than other products. A major objective of this investigation was to show the effects of water and salinity stresses on iris cultivars. Studying the physiological and morphological reactions of *Iris* spp. cultivars under salinity and water scarcity conditions will help us know the reaction of the cultivars and use it in the cultivation and maximization of iris growth and production in the arid and semi-arid lands.

MATERIALS AND METHODS

This research was conducted in two pot experiments at the Horticultural Science Research Greenhouses, College of Agriculture, Lorestan University, Iran, in 2017.

Preparation of Plant Material

The experiment was conducted in greenhouse at Lorestan University, Khorramabad, Iran. Bulbs of three iris (*Iris* spp.) cultivars including ‘Purple Blue Magic’, ‘White Madonna’ and ‘Blue Deep River’ were obtained from IFOP (Institute of Flowers and Ornamental Plants, Mahallat, Iran). Two iris bulbs were sown in separated pots (40 cm high and 30 cm diameter) that contained the desired soil texture with ratio of 2:1:1 of soil: animal manure: sand. On the 25th Day After Emergence (DAE), one iris per pot was kept and subsequently subjected to two growth conditions (drought and salinity stress).

Drought Treatment

In control condition, the soil Volumetric Water Content (VWC) in the pot was retained at 90% Field Capacity (FC), whereas irrigation was reduced for Drought (D) treatment during 45 days until the soil VWC in the pot was around 75and 60% FC, respectively.

Salinity Treatment

For Salinity (S) treatment, bulbs were irrigated with 1.5 L of distilled water (control), 50, 100 and 150 mM NaCl per pot on the 25th DAE.

The two experiments were organized using completely randomized design with three replications. The volumetric water content of soil in pots was monitored daily using a TDR 100 Device (Spectrum Company, USA). Samples were collected after 45 days of treatment for measurements of morphological and physiological characteristics under two growth conditions.

Measurement of Morphological Characteristics

At the end of both experiments, at the flowering stage, morphological characteristics including leaf surface, main root diameter, number of branched roots, corm fresh, dry weight, and number of days to flowering were measured/recorded. The leaf surface was measured by leaf surface meter (Delta-T Model, England) and the main root diameter was measured by the caliper.

Measurement of Physiological Characteristics

To determine the EL of leaf cells, the same size discs of expanded young leaves were taken by puncher and washed with deionized water. Leaf discs were placed in closed vials containing 10 mL of deionized water and incubated at 25°C on a rotary shaker for 24 hours. Subsequently, the Electrical Conductivity of the solution (EC_1) was measured. Samples were then autoclaved at 120°C for 20 minutes and the final Conductivity (EC_2) was measured after equilibration at 25°C. The EL was defined as follows (Lutts *et al*., 1996):

$$EL(\%)=(EC1/EC2) \times 100 \quad (1)$$

To measure the RWC (Ritchie and Nguyen, 1990), excised leaves of each plant were measured and weighed (Fresh Weight: F_W), and were immersed in distilled water for 24 hours and weighed again (Saturation Weight: S_W) and then were dried at 80°C inside an oven for 48 hours (Dry Weight: D_W). RWC was calculated using the following equation:

$$RWC= (FW\text{-}DW/SW\text{-}DW) \times 100 \quad (2)$$

Chlorophyll and carotenoid content was determined using Lichtenthaler (1987) method. To measure chlorophyll content, 0.1 g of fresh leaves in liquid nitrogen in a porcelain mortar was ground and about 10 mL of acetone 80% was gradually added. One mL of the prepared extract after centrifugation was placed in a spectrophotometer cell and the amounts of light absorbed by chlorophylls a, b, total and carotenoid were read at 645, 662 and 470 nm wavelengths, respectively. The amount of chlorophyll a, b, total, and carotenoid were determined by the following formulas:

$$Ch_a= 11.24\times(OD_{662})-2.04\times(OD_{645}) \quad (3)$$

$$Ch_b= 20.13\times(OD_{645})–4.19\times(OD_{662}) \quad (4)$$

$$Ch_{(a+b)}= 7.05\times(OD_{662})+18.9\times(OD_{645}) \quad (5)$$

$$C_{(x+c)}= 1000\times[(OD_{470})– 1.90\ C_A–63.14\ C_B]/214 \quad (6)$$

Where, Ch is Chlorophyll a, b, total (a+b) and $C_{(x+c)}$ is carotenoid concentration in mg g^{-1} fresh leaf and OD is the light absorption rate at corresponding wavelengths.

Lipid peroxidation was determined by measuring MDA content (Buege and Aust, 1978). To this end, 0.5 g of fresh leaves samples were homogenized in 5 mL of TCA solution (20% w/v) containing 0.5% thiobarbituric acid and the aliquots of filtrates were placed and heated inside a

Bain-marie at 40°C for 30 minutes and then cooled in ice bath. The absorbance of solution was recorded at 532 nm followed by correlation for the nonspecific absorbance at 600 nm. The amount of was determined according to extinction coefficient of 155 mM^{-1} cm^{-1}.

According to µmol g^{-1} fresh weight of leaf, MDA was calculated using Equation (7):

(7) MDA (µmol g^{-1} FW)= $[(A_{532} – A_{600})/155]×1000$

Data Analysis

All data are presented as mean value for each treatment. Data analysis was performed by Minitab version 16 software using ANOVA followed by the Duncan's Multiple Range Test (DMRT) to evaluate treatment effects ($P< 0.05$). The Microsoft Excel 2013 software was used to prepare graphs.

RESULTS

The results were evaluated under three separate groups as morphological, physiological parameters and number of days to flowering for both drought and salinity.

Effect of Drought and Salinity Stresses on Morphological Characteristics

This study showed variable responses of three iris cultivars to drought and salt treatments. Drought and salt in irrigation water induced a reduction of growth (Table 1) and even an inhibition of flowering (Figure 1). Different drought and salt treatments in both experiments had a significant effect on the morphological characteristics (leaf surface, main root diameter, number of branched roots and corm dry weight) of the three iris cultivars (Table 1). The best vegetative growth (plant height, stem diameter, and leaf surface) characteristics were recorded under the most favorable moisture conditions of the full-water regime (90% FC) and without using salt in irrigation water (control treatment) conditions. However, the poorest vegetative growth were obtained under the most severe

Table 1. Mean separation of the effect of different drought, salinity levels, and cultivars on some morphological traits of the three iris cultivars.

S.O.V [a]	Leaf surface (cm^2)		Main root diameter (g)		Number of lateral roots		Corm dry weight (g)	
	Drought	Salinity	Drought	Salinity	Drought	Salinity	Drought	Salinity
Cultivars (C)								
Deep river	51.72a	48.83a	1.12a	1.52a	22.2c	20.7b	0.75c	1.06b
Madonna	51.71a	40.47b	1.21a	1.08c	24.2b	21.8a	4.37a	1.06b
Blue magic	55.16a	38.17b	1.14a	1.22b	27.1a	18.3c	1.12b	3.24a
Drought (D)								
Control (90% FC)	68.22a		1.32a		27.5a		2.12a	
75% FC	52.46b		1.12b		26.1b		1.92a	
60% FC	37.90c		1.02b		19.8c		2.21a	
Interactive Effect (C×D)	NS		*		**		**	
Salinity (S)								
Control (0 mM)	59.13a		1.656a		24.5a		2.07a	
50 mM	45.49b		1.360b		21.4b		1.87b	
100 mM	36.66c		1.147c		18.8c		1.65c	
150 mM	29.06d		0.928d		16.3d		1.57c	
Interactive Effect (C×S)	**		NS		**		**	

[a] Sources of variance; NS: Non Significant. *Significant at $P< 0.05$, and **Significant at $P< 0.01$.

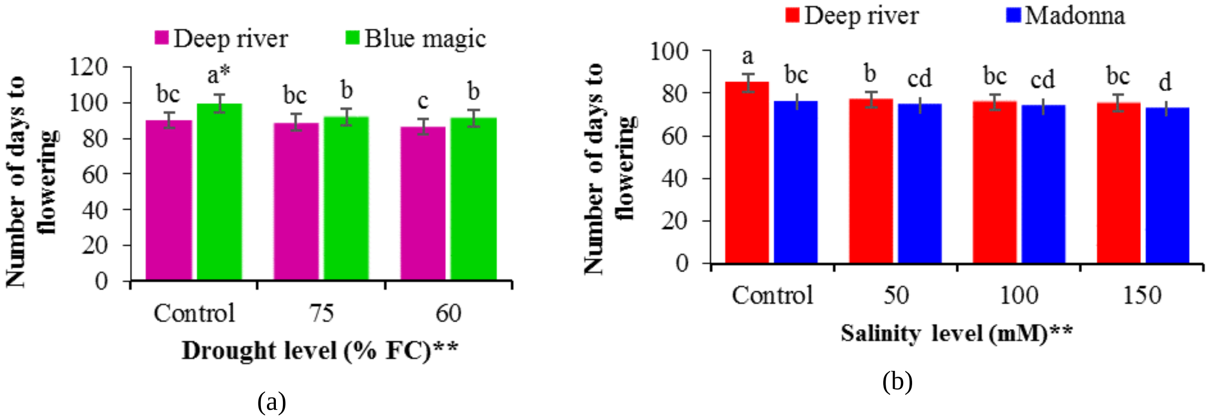

Figure 1. Mean comparison interaction effects of drought (a), salinity (b) and cultivars on number of days to flowering in two Iris cultivars. *Means with the same letter represent non-significant at 5% probability level. ** 'Madonna' at drought (60% FC) and 'Blue Magic' at salt treatments (100 and 150 mM NaCl) could not reach flowering phase and complete life cycle.

stress conditions of the low-water regime (60% FC) and high salinity (150 mM NaCl) treatments (Table 1).

The moderate drought treatment (75% FC) decreased leaf surface, main root diameter, and number of branched roots to a lesser degree than severe drought effect (60% FC) (Table 1). On the other hand, low (50 mM), moderate (100 mM), and high NaCl (150 mM) treatments decreased leaf surface, main root diameter, number of branched roots and corm dry weight as compared with their respective control (Table 1). The maximum number of branched roots at drought stress and NaCl treatments were observed in 'Blue Magic' (27.1) and 'Madonna' (21.8) cultivars, respectively (Table 1). The maximum main root diameter under drought stress and NaCl treatment were observed in 'Madonna' (1.21 cm) and 'Deep River' (1.52 cm) cultivars, respectively (Table 1). The minimum reduction of leaf surface was observed at severe (38.12%) drought stress and 150 mM (37.53%) salt in irrigation water in 'Blue Magic' and 'Deep River' cultivars, respectively (Table 3). Compared to other cultivars, 'Madonna' cultivar had the minimum reduction in corm fresh weight at severe drought (9.99%) and high NaCl concentration (17.49%) treatments (Table 3).

Effect of Drought and Salinity Stresses on Physiological Characteristics

Results of this study showed variable physiological responses of three iris cultivars to drought and salt treatments. In both experiments, drought and salt treatments had significant effects on the physiological characteristics (RWC, Carotenoid, MDA and EL) of the three iris cultivars (Table 2). Drought treatment and salt in irrigation water induced a reduction in RWC and total chlorophyll and increased MDA and EL (Table 2). The simple effects of cultivars and cultivar×drought interactions were not significant on total chlorophyll (Table 2).

The best physiological conditions (photosynthetic pigment content, RWC, MDA and EL) were recorded under the most favorable moisture conditions of the full-water regime (90% FC) and without using salt in irrigation water (control treatment). However, the poorest physiological condition were obtained under the most severe stress conditions of the low-water regime (60% FC) and high salinity (150 mM NaCl) treatments (Table 2). The minimum reduction in RWC was observed at moderate (12.67%) and severe (22.44%) drought stress in 'Madonna' and 'Blue Magic' (Table 3). The minimum reduction in RWC was observed at low (13.22%), moderate (19.86%), and high (30.96%) NaCl concentrations in, respectively, 'Deep River', 'Madonna' and 'Blue Magic' (Table 3). At moderate and severe drought treatments, EL was increased by, respectively, 14.89 and 41.93% as compared with their corresponding control (Table 3). The minimum increase in EL was observed at moderate (12.62%) and severe (37.49%) drought stress in 'Deep River' and 'Madonna', respectively (Table 3). The minimum increase in EL was observed at low (5.98%), moderate (18.32%), and high NaCl (41.34%) concentrations in 'Deep Rover' cultivar. At moderate and severe drought treatments, MDA was increased by, respectively, 20.90 and 41.97% as compared with their respective control (Table 3). The minimum increase in MDA was observed at moderate (10.72%) and severe (32.46%) drought stress in 'Madonna' cultivar (Table 3). At low, moderate, and high NaCl treatments, MDA was increased by, respectively, 32.65, 54.51 and 69.33% as compared with their respective control (Table 3). The minimum increase in MDA was observed at low (21.41%), moderate (44.66%) and high NaCl (55.34%) concentrations in 'Deep River' cultivar.

Effect of Drought and Salinity Stresses on Number of Days to Flowering

In this study, flowering in some iris cultivars was sensitive to water stress and salinity. With increasing drought stress at 60% FC level and NaCl salt treatments in 100 and 150 mM treatments, no flower appeared in the 'Madonna' and 'Blue Magic' cultivars. In this respect, only 'Deep River' cultivar could reach flowering phase and complete life cycle in both drought and salinity experiments. In the severe drought stress and high NaCl treatments, 'Deep River' and 'Madonna' cultivars had the minimum no. of days to flowering, respectively (Figure 1).

Table 2. Mean separation of the effect of different drought, salinity levels and cultivars on some physiological traits of the three Iris cultivars.[a]

S.O.V	RWC (%)		EL (%)		Chl T (mg g^{-1} fresh weight)		MDA (µmol g^{-1} fresh weight)	
	Drought	Salinity	Drought	Salinity	Drought	Salinity	Drought	Salinity
Cultivars (C)								
Deep river	59.17a	52.24a	35.11a	32.98ab	18.35a	17.76a	1.68a	1.36b
Madonna	57.54ab	49.78b	33.84ab	31.96b	18.28a	19.81a	1.59b	1.51a
Blue magic	57.49b	49.23b	33.474b	33.18a	19.19a	16.01a	1.44c	1.55a
Drought (D)								
Control (90% FC)	66.910a		28.707c		22.284a		1.302c	
75% FC	57.299b		32.970b		18.154b		1.570b	
60% FC	49.990c		40.744a		15.381c		1.839a	
Interactive Effect (C×D)	**		NS		NS		**	
Salinity (S)								
Control (0 mM)	60.758a		25.225d		20.841a		1.096d	
50 mM	51.868b		29.883c		21.912a		1.400c	
100 mM	47.617c		33.746b		15.700ab		1.636b	
150 mM	41.427d		41.975a		12.990b		1.775a	
Interactive Effect (C×S)	**		**		NS		NS	

[a] RWC: Relative Water Content; EL: Electrolyte Leakage; Ch T: Total Chlorophyll; Car: Carotenoid; MDA: MalonDiAldehyde, S.O.V.: Sources of variance; NS: Non Significant. * Significant at P< 0.05 and ** Significant at P< 0.01.

Table 3. Interactive effect of drought/salinity levels and cultivars on some morpho-physiological and biochemical traits of iris.

Cultivars		Experiment 1: Drought				Cultivars		Experiment 2: Salinity					
		Leaf Surface						Leaf Surface					
		75% FC		60% FC				50 mM		100 mM		150 mM	
	Control (90% FC)	NO	%	NO	%		Control (90% FC)	NO	%	NO	%	NO	%
Deep River	66.65	52.24	21.62	36.26	45.60	Deep River	62.64	49.68	20.68	43.88	29.95	39.13	37.53
Madonna	67.91	53.15	21.74	34.08	49.82	Madonna	59.10	44.31	25.03	33.67	25.03	24.80	58.04
Blue Magic	70.11	52.00	25.83	43.38	38.12	Blue Magic	55.65	42.50	23.64	31.25	23.64	23.27	58.19
Average	68.22	52.46	23.06	37.91	44.52	Average	59.13	45.50	23.12	36.27	23.12	29.07	51.25
Cultivars		Experiment 1: Drought				Cultivars		Experiment 2: Salinity					
		RWC						RWC					
		75% FC		60% FC				50 mM		100 mM		150 mM	
	Control (90% FC)	NO	%	NO	%		Control (90% FC)	NO	%	NO	%	NO	%
Deep River	67.19	58.44	13.03	51.88	22.80	Deep River	62.97	54.64	13.22	48.83	22.46	42.55	32.43
Madonna	67.26	58.68	12.67	46.69	30.58	Madonna	60.17	49.83	17.19	48.22	19.86	40.91	32.01
Blue Magic	66.27	54.78	17.34	51.41	22.44	Blue Magic	59.14	51.14	13.54	45.81	22.54	40.83	30.96
Average	66.91	57.30	14.38	49.99	25.27	Average	60.76	51.87	14.65	47.62	21.62	41.43	31.80
Cultivars		Experiment 1: Drought				Cultivars		Experiment 2: Salinity					
		EL						EL					
		75% FC		60% FC				50 mM		100 mM		150 mM	
	Control (90% FC)	NO	%	NO	%		Control (90% FC)	NO	%	NO	%	NO	%
Deep River	29.51	33.24	-12.62	42.57	-44.26	Deep River	28.33	30.03	-5.98	33.52	-18.32	40.05	-41.34
Madonna	28.76	33.22	-15.50	39.54	-37.49	Madonna	23.15	29.69	-28.25	34.86	-50.56	40.12	-73.28
Blue Magic	27.85	32.46	-16.54	40.12	-44.06	Blue Magic	24.19	29.93	-23.73	32.86	-35.83	45.76	-89.17
Average	28.71	32.97	-14.89	40.74	-41.93	Average	25.22	29.88	-19.32	33.75	-34.90	41.98	-67.93
Cultivars		Experiment 1: Drought				Cultivars		Experiment 2: Salinity					
		MDA						MDA					
		75% FC		60% FC				50 mM		100 mM		150 mM	
	Control (90% FC)	NO	%	NO	%		Control (90% FC)	NO	%	NO	%	NO	%
Deep River	1.37	1.74	-26.15	1.92	-39.19	Deep River	1.05	1.27	-21.41	1.67	-44.66	1.86	-55.34
Madonna	1.39	1.54	-10.72	1.85	-32.46	Madonna	1.14	1.44	-26.16	1.68	-46.72	1.79	-56.88
Blue Magic	1.13	1.43	-25.83	1.75	-54.27	Blue Magic	1.10	1.49	-35.41	1.72	-56.86	1.91	-73.41
Average	1.30	1.57	-20.90	1.84	-41.97	Average	1.10	1.45	-32.65	1.69	-54.51	1.85	-69.33

DISCUSSION

Significant differences were obtained for the two stresses regarding some parameters. For example, salinity had more severe effects on the morphological characteristics (leaf surface and main root diameter) than drought; whereas total chlorophyll was less affected under salinity conditions than under drought. By limiting cell growth, the size of the limb becomes limited, which is why the first tangible effect of water deficit on plants can be identified by the smaller size of the leaves (Haishen *et al*., 2009). Dry matter production in plants shows a positive correlation with leaf surface and leaf photosynthetic rate; thus, for achieving higher rates of dry matter production, it is necessary to increase the photosynthesis rate by maintaining a high leaf surface area at all growth stages. It seems that the decrease in leaf surface area in plant is due to the reduction in water absorption capability of the plant due to osmotic stress caused by salinity. The result was similar to Sabet Teimuri *et al*. (2010) findings that lack of sufficient moisture in root caused a significant decrease in fresh and dry weight, leaf thickness and width, but leaf number was not affected by drought treatments. Also, at higher salinity levels, the leaf area strongly decreases in rice (Asch *et al*., 2000). Our results on corm fresh weight support the results of Bahadoran and Salehi (2015). These authors were able to show that the effects of increase in irrigation water salinity and interval on dry weights of roots and shoots of two tuberose (*Polianthes tuberosa* L.) cultivars were statistically significant. Singh *et al*. (2000) claimed that plants with better root development have more tolerance to drought and drought stress compared to other plants, among which ‘Blue Magic’ had more branched roots. Root is the first organ that reacts to drought. Sabet Teimouri *et al*. (2010) reached similar results in studying the effect of drought stress on Saffron (*Crocus sativus* L.), where applying drought stress caused a significant decrease in root number and, consequently, root weight. Root is the first organ of the plant exposed to soil salinity and, in many cases, plays an important role in preventing the transfer of salt to leaves. Additionally, the appropriate reaction of the root zone to salt stress is effective in its subsequent growth (Yildirim and Guvenc, 2006). Moftah and Al-Humaid (2006) indicated that plant biomass, number of leaves, length and weight of marketable inflorescences, and bulb yield of tuberose *Polianthes tuberosa* L. were significantly reduced by water deficit. Our results showed these three cultivars of Iris had a different reaction at moderate and severe drought stress to changes in leaf RWC. Sharif *et al*. (2017) reported that drought stress conditions led to significant reduction in RWC. In our study, drought stress at 60% FC and 150 mM NaCl reduced leaf surface area and RWC more severely than at 75% FC and 100 mM salt, respectively. The obtained results of this study are in agreement with the results of Watson *et al*. (2003). Leaf moisture content changes are used as a short-term response to stress and a measure of the ability to maintain source power under drought stress conditions (Ahmadi *et al*., 2010). The result was consistent with the results of the research on saffron, which showed that under the drought stress, the RWC of leaves decreased and the highest and lowest RWC of leaves were observed at 100% FC and drought stress (Sabet Teimouri *et al*, 2010). Salinity stress led to physiological drought in plant by negative effect of osmotic potential and decreasing water availability. The reduction of leaf RWC is one of the most visible reactions observed in plants under these conditions. Other researchers have confirmed a negative relationship between salinity and RWC of the plant, and with increasing salt stress, the RWC of the plant decreases (Parida and Das, 2005). Similar results were attained in study of Rostami *et al*., (2015), where increased salinity caused the leaf RWC to decrease linearly.

In general, drought and salinity stresses increase the electrolyte leakage from the cell membrane in plants including *Iris* spp. The results of other researchers have also indicated that, under drought stress conditions, electrolyte leakage increased and the relative water content of leaves decreased (Beltrano and Ronco, 2008), consistent with the results of this study. MDA and EL increased in leaf of three iris cultivars due to water deficit and salt treatment, but a higher increase was observed in 'Blue Magic' than other cultivars in both experiments. Salinity induces secondary oxidative stress and, by generating an increased level of active oxygen species, can degrade the membrane and increase EL (Bhattacharjee and Mukherjee, 2002). In saffron plant, it has also been observed that with increasing drought stress, MDA content increases (Mzabri *et al*., 2017). In our study, total chlorophyll was less affected under salinity conditions than under drought stress. Lawlor and Cornic (2002) stated that one of the most important reasons for the reduction of chlorophyll content in drought stress is their destruction by active oxygen species. In the study by Maleki *et al*. (2010), significant reduction of chlorophyll a and b was observed under severe stress, which was consistent with result of this study on drought stress. These results might be due to the increased thickness of leaves and compacted mesophyll cells of stressed-leaves, consequently, more chloroplasts per unit area, as often is the case under stress conditions (Delperee *et al*., 2003). The results of Rostami *et al*. (2015) on saffron were different and salinity did not have a significant effect on chlorophyll a and b content. In the experiment by Gholami Touran Poshti *et al*. (2005) the concentration of chlorophyll was not affected by irrigation water salinity. However, according to Hassani and Omid Beigi (2001), salinity stress reduces chlorophyll a, b and total chlorophyll content in saffron plants. In the present experiment, the reduction in chlorophyll and carotenoids was not consistent with the above result. Although the general effect of salinity stress on pigments is their reduction, which depends on the plant species (Parida and Das, 2005), total chlorophyll in the three iris cultivars was not affected by drought and salinity stress. Lack of effect of drought and salinity stress on the plant pigments is in contrast to what has been observed earlier in most crop species in which considerable reduction in chlorophyll contents due to water deficit and salinity was reported (Dugasa *et al*., 2019; Yildirim *et al*., 2017; Plesa *et al*., 2018).

Our results also showed that with increasing salinity, the number of days to flowering decreased. We conclude that flower appearance in iris is sensitive to water stress for 60% FC level and high salinity (100 and 150 mM) treatments, but depending on the cultivar ('Blue Magic' and 'Madonna' in this study), it may not reach the flowering stage. Sepaskhah and Yarami (2009) indicated that saffron flower and corm were the most and the least sensitive organs to soil water depletion, respectively.

CONCLUSIONS

Our results indicate the importance of drought, salinity, and type of cultivar on the growth and development of iris (*Iris* spp.) vegetative and flowering. The results of this study suggest that the effect of drought and NaCl treatments on three iris cultivars decreased properties such as the morphological characteristics (leaf surface, main root diameter, number of branched roots and corm dry weight) and the physiological characteristics (RWC, Carotenoid, MDA, and EL), and affect flowering of different iris cultivars. In conclusion, cultivar 'Deep River' (drought and salt tolerant) showed a higher degree of drought and salt tolerance than 'Madonna' (drought sensitive) and 'Blue Magic' (salt sensitive). Drought and salt tolerance of 'Deep River' was found to be associated with a smaller reduction in leaf surface area, leaf RWC, less EL and MDA contents, and smaller number of days to flowering phase and shorter life cycle in both drought and salinity experiments. As flowering in iris is important as an ornamental plant, it should be noted that *Iris* spp. can tolerate under-irrigation for up to 75% FC and 100 mM NaCl in irrigation water without affecting flowering. In addition, there is an early flowering under shortage of water. From the behavior of cultivars in the present study, it is considered that 'Deep River' is a promising cultivar for cultivation in areas with salty and dry soil, in contrast to 'Madonna' and 'Blue Magic'.

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پاسخ‌های مورفو- فیزیولوژیکی برخی ارقام زنبق به تنش خشکی و شوری

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چکیده

اثر تنش خشکی و شوری بر ویژگی های مورفو- فیزیولوژیکی سه رقم زنبق ('بلومجیک ارغوانی'، 'مدونا سفید' و 'دیپ‌ریور آبی') بررسی شد. آزمایش تنش خشکی در سه سطح (۶۰، ۷۵ و ۹۰ درصد ظرفیت زراعی (FC)) و آزمایش تنش شوری در چهار غلظت شوری (صفر، ۵۰، ۱۰۰ و ۱۵۰ میلی مولار NaCl) اجرا گردید. تیمارهای خشکی و شوری اثر معنی داری بر صفات مورفولوژیک (سطح برگ، قطر ریشه اصلی، تعداد ریشه ای جانبی و وزن خشک برگ) و صفات فیزیولوژیک (محتوی نسبی آب، کاروتنوئید، مالون دی آلدئید و نشت الکترولیت) سه رقم مورد بررسی داشتند. بهترین و ضعیف‌ترین صفات رشدی و شرایط فیزیولوژی به ترتیب تحت تیمار شاهد (شرایط بهترین وضعیت از نظر رطوبت (۹۰ درصد ظرفیت زراعی) و بدون استفاده از نمک در آب آبیاری) و شرایط تنش شدید (۶۰ درصد ظرفیت زراعی و ۱۵۰ میلی مولار شوری در آب آبیاری) حاصل شد. با افزایش تنش خشکی در سطح ۶۰ درصد ظرفیت زراعی و افزایش شوری ۱۰۰ و ۱۵۰ میلی مولار به ترتیب در ارقام 'مدونا' و 'بلومجیک' گل تشکیل نشد. از این نظر، رقم 'دیپ‌ریور' در هر دو تنش خشکی و شوری توانست سیکل زندگی خود را با ورود به فاز زایشی و گلدهی کامل کند. ما نتیجه گرفتیم که فرایند گلدهی در برخی ارقام زنبق تحت تاثیر تنش خشکی و شوری قرار می‌گیرد، اما با گزینش می‌توان ارقام یا ژنوتیپ‌های متحمل یا مقاوم به این فاکتورهای تنش‌های غیر زنده را شناسایی و توصیه نمود.