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Growth and Flowering of Two Tuberose (*Polianthes tuberosa* L.) Cultivars under Deficit Irrigation by Saline Water

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ABSTRACT

Tuberose (*Polianthes tuberosa* L.) is one of the most important bulbous ornamental crops of tropical and subtropical areas. The objective of the present study was to determine the interaction effects of salinity and irrigation intervals on growth and flowering of two important commercial cultivars ('Mahallati' and 'Dezfuli') of tuberose (*Polianthes tuberosa* L.). Irrigation treatments consisted of four irrigation intervals 2, 4, 6, and 8 days, and salinity treatments in the irrigation water were *EC* values of 0.7 (control), 1.9, 3.1, and 4.3 dS m^{-1}. This research was carried out in a complete randomized design with factorial arrangement. It can be concluded that tuberose is sensitive to water and salinity stress. In both cultivars of tuberose, vegetative and reproductive parameters were unfavorably affected by these stresses. However, 'Mahallati' was more sensitive to those stresses than 'Dezfuli'. Further investigations are needed to clarify in depth the mechanism of tuberose sensitivity to the studied environmental stresses at both molecular and ultra-structural levels.

Keywords: Abiotic stress, Bulbous plant, Cut flower, Water management.

INTRODUCTION

The amount of water consumed by ornamental plants depends on the particular species and cultivar, the cultivation system, and the plant growing season. It has been estimated that, on average, 100-350 kg of water is needed to produce 1 kg of plant dry matter (Jiménez and Caballero, 1990). Arid and semiarid regions are characterized by limited fresh water resources, while there is increasing evidence of large aquifers of saline water lying beneath many desert regions (Shillo *et al*., 2002). Salinity and drought stresses retard plant growth because osmotic stress conditions restrain water availability at the soil level (Bartels and Sunkar, 2005). Water deficit affects negatively the process of flowering in many plant species by reducing the fertility of newly formed flowers (Slawinska *et al*., 2001). The growth of salt-treated plants is often limited by the ability of roots to extract water from the soil and transport it to the shoot due to the osmotic component of salinity (Rodríguez *et al*., 1997). Sepaskhah and Yarami (2009) indicated that saffron (*Crocus sativus* L.) flower and corm were the most and the least sensitive organ to soil water depletion, respectively. Furthermore, Shillo *et al.* (2002) reported two bulb species, namely, *Hippeastrum*×*hybridum* Hort. and *Ornitathogalum arabicum* L. that were very sensitive to salinity; and the degree of damage was correlated to the salinity level and this response was expressed as weight reduction in all the plant organs. Moftah and Al-Humaid (2006) indicated that plant biomass, number of leaves, length, and weight of marketable inflorescences and bulb yield of tuberose

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(*Polianthes tuberosa* L.) were significantly reduced by water deficit.

Tuberose (*Polianthes tuberosa* L.) is in great demand for its attractive and fragrant flowers. It is one of the most important bulbous ornamentals of tropical and subtropical areas. It is commercially cultivated for cut flower trade, and also for extraction of its highly valued natural flower essential oil (Jawaharlal *et al*., 2006). In India and France, tuberose is widely cultivated as a source of essential oils for the perfume industry. *Polianthes* is also a common garden plant in the spring; they flower during the summer and early autumn (De Hertogh and Le Nard, 1993). The effect of water salinity and drought stresses on growth and development of ornamental plants, especially in bulbous plants, has been investigated to a much lesser extent than other crops. In the present study, the effects of irrigation with saline water and deficit irrigation on the two cultivars 'Dezfuli' and 'Mahallati' of tuberose (*Polianthes tuberosa* L.) were investigated. To the best of our knowledge, this is the first report on application of water salinity and drought stresses on tuberose plants. Furthermore, this is the first report on using these stresses together on one ornamental plant.

MATERIALS AND METHODS

This experiment was conducted at the Horticultural Science Research Farm, College of Agriculture, Shiraz University, located in Bajgah, 15 km northeast of Shiraz, with a latitude of 29° 36′ North and longitude of 52° 32′ East, 1,810 m above the sea level. Bulbs of two tuberose (*Polianthes tuberosa* L.) cultivars 'Mahallati' and 'Dezfuli' with 2.5-3.0 cm diameter were obtained from two commercial production centers of tuberose in Iran, located at Mahallat and Dezful cities. After treatment with Benomyl fungicide (0.2%), the bulbs were planted in plastic pots with 35 cm high and 25 cm diameter filled with 5 kg of air-dried soil with a 2 cm thick gravel filter (2-4 mm gravel) at the bottom. Holes were drilled in the bottom of pots for drainage, containing soil sample of the research farm with the following characteristics: pH= 7.41, *EC*= 1.16 dS m^{-1}, silty loam soil texture with Clay= 14.4%, Silt= 51.96% and Sand= 33.3% with field capacity (FC) of 23% and permanent wilting point (PWP) of 16%, OM= 3.5%, K= 21.26 mg kg^{-1}, P= 19 mg kg^{-1}, Ca= 7.8 meq kg^{-1}, Na= 19.12 mg kg^{-1} and Cl= 0.4 meq kg^{-1} of soil. The irrigation treatments consisted of four irrigation intervals: 2 (W0), 4 (W1), 6 (W2) and 8 (W3) days. Salinity treatments in the irrigation water were 0.7 dS m^{-1} (control) the salinity level of usual water used in the studied area (S0), 1.9 dS m^{-1} (S1), 3.1 dS m^{-1} (S2) and 4.3 dS m^{-1} (S3). Some physical and chemical parameters of irrigation water used in the study (control) are given in Table 1. *SAR* values of irrigation water of S1, S2, and S3 were 2.02, 2.97 and 3.75 meq l^{-1}, respectively.

To prepare the saline water, NaCl and $CaCl_2$ were disolved in water at 1:1 ratio. The soil salinity in the beginning and the end of the experiment was: S0W0= 2.56 dS m^{-1}, S0W1= 2.11 dS m^{-1}, S0W2= 2.64 dS m^{-1}, S0W3= 2.91 dS m^{-1}, S1W0= 6.18 dS m^{-1}, S1W1= 7.24 dS m^{-1}, S1W2= 6.97 dS m^{-1}, S1W3= 3.70 dS m^{-1}, S2W0= 11.48 dS m^{-1}, S2W1= 7.50 dS m^{-1}, S2W2= 7.59 dS m^{-1}, S2W3= 6.18 dS m^{-1}, S3W0= 7.06 dS m^{-1}, S3W1= 9.71 dS m^{-1}, S3W2= 8.21 dS m^{-1}, S3W3= 11.48 dS m^{-1}. This research was carried out in a complete randomized design

Table 1. Some physical and chemical characteristics of irrigation water used in the study.

EC (dS m^{-1})	pH	Cl (meq l^{-1})	Na (meq l^{-1})	Ca (meq l^{-1})	Mg (meq l^{-1})	SAR (meq l^{-1})	HCO_3 (meq l^{-1})
0.7	7.87	2.00	0.98	3.80	4.10	0.49	6.16

with factorial arrangements including three factors (cultivar, water salinity, and irrigation interval) with 3 replications, and taking 3 samples in each pot. The pots were placed in greenhouse and plants allowed to grow and attain a large enough size to apply the treatments (4 weeks after planting). Then, pots were transferred to outdoor under field condition and weighted; then, irrigated to field capacity with saline water according to their irrigation intervals. In this experiment, treatments lasted 93 days. Total watering times (days) and total water used (ml) for each irrigation interval was as follows:

(W0) Irrigation interval 2 days= 47 d= 45942.5 ml

(W1) Irrigation interval 4 days= 24 d= 46920 ml

(W2) Irrigation interval 6 days = 16 d= 46920 ml

(W3) Irrigation interval 8 days = 12 d= 46920 ml

Dry weights (DW) of roots, shoots, fresh weight (FW) of flower stalk, relative water content (RWC), and cell membrane injury (CMI) of leaves, chlorophyll, and proline contents of leaves, the Na and Cl content of roots and leaves, and height and diameter of inflorescence were measured. Immediately after harvest, flowering stalks were weighed as fresh weight and at the end of treatments, shoot and root were harvested and dried at 70°C inside an oven (Korl Kolb 112SL, Germany) for 48 hours and weighed as dry weight. Chlorophyll content was determined by spectrophotometeric method (Saini *et al*., 2001). Proline content was determined according to Bates *et al.* (1973) method. To measure the *RWC*, 6 discs were taken from excised leaves of each plant, the discs were weighed (Fresh weight: FW), and were immersed in distilled water for 4 hours and weighed again (Turgid weight: TW) and then were dried at 70°C inside an oven for 24 hours (Dry weight: DW). *RWC* was calculated using the following equation (Whethereley, 1950):

$$RWC= (FW-DW)/ (TW-DW)\times 100$$

CMI was measured using Sairam *et al*. (1997) method. Six discs were taken from excised leaves of each plant and washed with distilled water, then, they were immersed in a glass container containing 10 ml distilled water and were placed inside a benmary (Gemmy Ind. Corp, Taiwan) at 40°C for 30 minutes and *EC* was measured (EC_1). Later, they were placed inside a benmary at 100°C for 10 minutes, and *EC* was measured again (EC_2); and *CMI* was calculated using the following equation:

$$CMI=1-(EC_1/EC_2)\times 100$$

Contents of Na and Cl were measured according to Chapman and Pratt (1961) method. Data were analyzed by MSTATC software and means were compared using LSD test at 5% level.

RESULTS AND DISCUSSION

Salinity and Drought Stress Effects

Reproductive Variables

Both increased salinity and longer irrigation interval reduced reproductive growth of the two cultivars (Tables 2, 3, and 4). In 'Dezfuli' cultivar, with increase in salinity and drought stresse, height of inflorescence decreased significantly compared to 'Mahallati' cultivar (Tables 2, 3, and 4). Decrease in diameter and fresh weight of flowering stem in 'Mahallati' cultivar was more significant than 'Dezfuli' cultivar (Tables 2, 3, and 4). The means of salinity level at S2 and S3 and irrigation interval at W2 and W3 showed significant decrease in the height of inflorescence compared to the control plants (Table 4). Increase in salinity level significantly decreased the means of diameter and fresh weight of flowering stem compared to the control plants. Irrigation interval of W2 and W3 significantly decreased diameter of flowering stem and W3 had the same effect on fresh weight of flowering stem (Table 4). These results indicated that tuberose was

Table 2. Effect of water salinity and irrigation interval on different plant parameters of 'Dezfuli' cultivar of tuberose (*Polianthes tuberosa* L.).[a]

Irrigation interval (Days)	Salinity level (dS m^{-1})	Height of inflorescence (cm)	Diameter of flowering stem (cm)	Fresh weight of flowering stem (g)	Chlorophyll content of leaves (mg g^{-1})	Dry weight of roots	Dry weight of shoots	Proline (mg g^{-1}) of leaves	Relative water content (RWC) of leaves	Cell membrane injury (CMI) of leaves	Na content (µg g^{-1}) dry matter of shoots	Cl content (%) dry matter of shoots	Na content (µg g^{-1}) dry matter of roots	Cl content (%) dry matter of roots
2 (W0)	0.7 (S0)	20.67a*	0.60a	36.67a-d	5.36a-g	12.77ab	7.05a	02.57i	93.15a	36.96g-j	271.4e-k	1.27l	445.8ghi	1.15c-j
	1.9 (S1)	17.00a-d	0.49c-f	22.00c-h	6.10abc	10.10a-d	5.78abc	03.90hi	85.98b	53.20a-d	384.7 c-h	2.4hij	556.9c-i	1.39a-j
	3.1 (S2)	17.00a-d	0.52a-e	32.33b-e	5.59a-e	07.56cde	2.63f-l	06.79e-i	83.99bc	38.48g-j	505.9abc	3.68def	707.1a-d	1.11d-j
	4.3 (S3)	14.00b-f	0.58ab	28.00b-g	2.54hi	04.59ef	1.94g-l	24.14b-e	75.19efg	59.25ab	394.7c-g	2.80ghi	617b-g	1.41a-j
4 (W1)	0.7 (S0)	18.33a-d	0.57abc	36.67abc	6.16ab	07.91b-e	5.36bcd	03.53hi	85.69b	31.72ijk	226.3g-k	1.56kl	421.8ghi	0.78hij
	1.9 (S1)	16.67a-e	0.53a-d	28.00b-g	3.39e-i	05.36ef	5.45a-d	05.82f-i	74.86e-h	39.82f-i	292.6e-k	2.62hi	677a-f	2.27ab
	3.1 (S2)	16.67a-e	0.50b-f	28.67b-g	5.44a-f	04.67ef	3.11e-h	14.38c-i	73.64fgh	40.59f-i	433.8b-f	3.3fgh	846a	2.32a
	4.3 (S3)	14.67b-f	0.50b-f	22.33c-h	2.34i	05.13ef	1.76g-l	23.78b-f	67.71ij	39.52ghi	451.8b-e	5.58a	614b-g	1.23c-j
6 (W2)	0.7 (S0)	14.00b-f	0.51a-e	29.33b-g	4.61a-i	04.64ef	4.59cde	05.10ghi	66.09ijk	19.53lm	167.3jk	1.54kl	541.9c-i	0.96f-j
	1.9 (S1)	13.33c-f	0.57abc	26.67b-h	3.26e-i	06.83de	3.19e-h	09.20e-i	59.94lmn	26.55j-m	208.6h-k	2.67hi	538.9c-i	1.30c-j
	3.1 (S2)	14.00b-f	0.41f-i	31.00b-f	3.19f-i	05.12ef	3.04e-i	22.34b-g	52.39pq	31.00i-m	264.6f-k	2.86ghi	718.1abc	1.61a-i
	4.3 (S3)	14.00b-f	0.45d-i	25.33b-h	3.77c-i	04.33ef	1.90g-l	27.76bcd	50.45q	37.90g-j	439.8b-f	4.04b-e	674a-f	2.05abc
8 (W3)	0.7 (S0)	13.00def	0.46d-i	21.00e-h	2.38hi	04.07ef	2.20g-l	08.11e-i	61.07k-n	18.98m	232.5g-k	1.24l	379.7i	1.04e-j
	1.9 (S1)	11.33ef	0.43e-i	17.33fgh	3.72d-i	04.49ef	2.87f-j	10.17d-i	49.00q	22.74klm	349.7c-j	2.84ghi	499.9e-i	1.99a-d
	3.1 (S2)	05.33g	0.48c-g	23.00c-h	2.32i	04.24ef	2.64f-k	22.82b-g	42.45r	31.35i-l	289.7e-k	3.67def	523.3c-i	2.05abc
	4.3 (S3)	10.67f-g	0.47d-i	17.33fgh	2.36i	03.76ef	1.34g-l	32.82b	36.79s	26.52j-m	358.7c-i	3.58efg	704a-d	0.51j

[a] Means in the same column followed by the same letter(s) are not significantly different using LSD test (5%).

Table 3: Effect of salinity and irrigation interval on different plant parameters of 'Mahallati' cultivar of tuberose (*Polianthes tuberosa* L.).[a]

Irrigation interval (Days)	Salinity level (dS m^{-1})	Height of inflorescence (cm)	Diameter of flowering stem (cm)	Fresh weight of flowering stem (g)	Chlorophyll content of leaves (mg g^{-1})	Dry weight of roots	Dry weight of shoots	Proline (mg g^{-1}) of leaves	Relative water content (RWC) of leaves	Cell membrane injury (CMI) of leaves	Na content (µg g^{-1}) dry matter of shoots	Cl content (%) dry matter of shoots	Na content (µg g^{-1}) dry matter of roots	Cl content (%) dry matter of roots
2 (W0)	0.7 (S0)	19.00ab	0.60a	48.00a	4.60a-i	12.77a	6.36ab	02.69i	93.62a	41.00e-i	299.3e-k	1.65jkl	460.8ghi	1.06e-j
	1.9 (S1)	18.60abc	0.53a-d	39.0ab	6.82a	07.18cde	3.40efg	03.90hi	86.7 b	48.54b-g	321.6d-k	3.05fgh	605b-h	1.96a-e
	3.1 (S2)	14.33b-f	0.48d-h	24.33b-h	5.97a-d	07.16cde	1.59h-l	06.67e-i	81.32bcd	52.96a-e	439.8b-f	4.02b-e	695.1a-e	1.42a-j
	4.3 (S3)	17.00a-d	0.51a-e	19.33e-h	3.81c-i	06.88de	1.30jkl	12.09di	79.27cde	63.14a	641.2a	4.38bcd	623b-g	1.72a-g
4 (W1)	0.7 (S0)	17.33a-d	0.48c-g	33.00b-e	4.55a-i	11.59abc	4.04def	03.77hi	83.48bc	31.26i-l	348.5c-j	2.12ijk	490.8f-i	0.91f-j
	1.9 (S1)	18.00a-d	0.53a-d	24.67b-h	3.71d-i	05.81def	2.22g-l	07.51e-i	76.31d-g	38.59ghi	290.5e-k	3.47efg	432ghi	1.31c-j
	3.1 (S2)	14.67b-f	0.58ab	24.67b-h	4.10c-i	04.05ef	1.56h-l	11.37d-i	69.48hi	45.43c-h	400.7c-j	3.78c-f	586.9b-h	1.06d-j
	4.3 (S3)	15.67a-f	0.51a-e	21.67d-h	4.28c-i	04.68ef	0.97 l	20.17b-i	60.52k-n	47.31b-g	487.8a-d	4.50bc	713.1a-d	1.69a-h
6 (W2)	0.7 (S0)	16.33a-e	0.48c-g	26.33b-h	5.34a-g	06.15def	3.41efg	04.62ghi	77.16def	34.92hig	184.5ijk	1.78jkl	403.7hi	0.65j
	1.9 (S1)	16.33a-e	0.46d-i	26.00b-h	4.07c-i	04.90ef	1.76g-l	14.74b-i	70.80ghi	42.10d-i	259.6f-k	3.93b-e	429ghi	1.08d-j
	3.1 (S2)	15.00b-f	0.52a-d	29.00b-g	4.42b-i	04.73ef	2.50f-l	18.36b-i	65.41i-l	51.56a-f	322.1d-k	4.42bcd	598.9b-h	1.73a-f
	4.3 (S3)	13.67b-f	0.38i	16.00gh	3.86c-i	02.37f	1.13kl	21.37b-h	56.60nop	55.93abc	611ab	4.58b	764.1ab	0.68ij
8 (W3)	0.7 (S0)	16.67a-e	0.53a-d	24.33b-h	3.80c-i	07.37cde	2.66f-k	08.11e-i	63.22j-m	32.04ijk	163.5k	2.37hij	405.4hi	1.67a-h
	1.9 (S1)	15.67a-f	0.47d-i	19.00e-h	4.70a-h	04.34ef	1.74h-l	20.53b-i	58.68mno	41.13e-i	298.7e-k	4.44bcd	511.7d-i	0.83f-j
	3.1 (S2)	14.00b-f	0.39hi	25.00b-h	3.07ghi	04.79ef	1.96g-l	24.50b-e	56.39nop	42.95d-i	250.6g-k	4.01b-e	598.9b-h	1.34b-j
	4.3 (S3)	10.3fg	0.40ghi	12.00 h	4.64a-i	04.54ef	1.43i-l	31.73bc	54.19opq	44.49c-h	379.7c-h	3.87b-e	481.8f-i	0.79g-j

[a] Means in the same column followed by the same letter(s) are not significantly different using LSD test (5%).

Table 4. Means of salinity, irrigation interval, and cultivars effects based on height of inflorescence (cm), diameter (cm) and fresh weight of flowering stem of tuberose (*Polianthes tuberosa* L.).[a]

	The means of salinity level				The means of irrigation interval				The means of cultivar	
	0.7 (S0)	1.9 (S1)	3.1 (S2)	4.3 (S3)	2 (W0)	4 (W1)	6 (W2)	8 (W3)	"Mahallati"	"Dezfuli"
The height of inflorescence (cm)	16.92 A	15.88 A	13.88 B	13.75 B	17.20 A	16.50 A	14.58 B	12.13 B	15.79 A	14.42 A
Diameter of flowering stem (cm)	00.53 A	00.50 B	00.48 B	00.47 B	00.53 A	00.52 A	00.47 B	00.45 B	00.49 A	00.50 A
Fresh weight of flowering stem (g)	31.88 A	25.33 BC	27.25 B	20.25 C	31.17 A	27.46 A	26.21 A	19.88 B	25.77 A	26.58 A

[a] Means in the same column followed by the same letter are not significantly different using LSD test (5%).

sensitive to both salinity and water stresses. Therefore, when saline water is used to irrigate tuberose, more frequent irrigation intervals should be used. Our results were the same as Sepaskhah and Yarami (2009) who reported that water stress acquired by reducing the quality of water per application decreased flower yields of saffron, and Moftah and Al-Humaid (2006) who concluded that all elements of the marketable inflorescences of tuberose were reduced significantly in plants grown under water deficient condition. Furthermore, Shillo *et al*. (2002) reported that water salinity stress reduced flowering stalk length in *Limonium* 'Emily'. These results were in agreement with Jaimez *et al*. (2000) and Bissuel-Belaygue *et al*. (2002) who found that water shortage significantly affected the number of aborted flowers, bulb size, inflorescence length, and number of floral buds per plant. Drought stress and its interaction with water salinity stress increased the damaging effects of drought stress. The first response of virtually all plants to acute water deficit is the closure of their stomata to prevent the transpirational water loss (MansWeld and Atkinson, 1990). Stomatal closure in response to a water deficit stress primarily will result in decline of photosynthesis rate (Mahajan and Tuteja, 2005). Decrease in photosynthesis rate and reduction of photosynthates transport to the inflorescences will consequently reduce the formation and production of the flowers and will result in significant decrease in reproductive variables.

Vegetative Variables

Chlorophyll content of leaves of both cultivars decreased with increasing the salinity and drought stresses levels compared with the control. However, at S1W0, S2W0 and S1W4 in both cultivars, and at S4W4 in 'Mahallati' cultivar, there was an insignificant increase in chlorophyll content of leaves compared with the control (Tables 2 and 3). In comparing the cultivar means, 'Mahallati' declined chlorophyll content more than 'Dezfuli' but this decrease was not significant (Table 4). These observations 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). Results of this experiment indicated that the effects of increase in irrigation water salinity and interval on dry weights of roots and shoots were statistically significant (Tables 2 and 3). Data showed significant decrease in dry weight of roots and shoot at salinity means of S1, S2 and S3, and at irrigation interval means of W2 and W3 compared with the control. Furthermore, this decrease in dry weight of roots in 'Dezfuli' cultivar and in dry weight of shoots in 'Mahallati' cultivar was more pronounced but not significant (Table 5). Results indicated that growth of roots system was more than shoots. Results of the present study are in agreement with several other reports: water salinity and drought stresses had significant effects on the vegetative variables, the same as Moftah and Al-Humaid (2006) reports on decrease in shoot dry weight of tuberose under drought stress and results of Navarro *et al.* (2007) who reported a significant decrease in total plant biomass of *Arbutus unedo* L. under water salinity stress, and results of Navarro *et al.* (2005), Fornes *et al*. (2007), Shillo *et al.* (2002). Also, Egert and Tevini (2002) and Bass *et al*. (1995) reported significant reduction in dry matter and chlorophyll content of plants treated with saline water or drought stress. Likewise, Mamnouie *et al.* (2006) reported that drought stress reduced the chlorophyll content of *Hordeum vulgare* L. Amount of salinity of soil after long irrigation interval with saline water can increase and induce oxidative osmotic stress, this decrease of chlorophyll content of *H. vulgare* might be the result of adaptation of plants to drought condition. Oxidative stress in both drought and water salinity stresses might be the cause of decrease in chlorophyll content of leaves (Seel *et al*., 1992). Moisture stress could inhibit the biosynthesis of chlorophyll precursor, which in turn would reduce the chlorophyll content (Prakash and Ramachandran, 2000).

Proline, RWC, and CMI

Content of proline in leaves increased in both cultivars at higher stress levels. This increase was significant in most of the treatments (Tables 2 and 3). The means of salinity level at S2 and S3, and the means of irrigation interval at W2 and W3, showed a significant increase (Table 6). Increase in proline content of leaves in 'Dezfuli' cultivar was more than 'Mahallati' cultivar, but this difference was not significant (Table 6). To prevent water loss from the cells and protect the cellular proteins, plants accumulate many metabolites that are also known as "compatible solutes." These solutes do not inhibit the normal metabolic reactions. Frequently observed metabolites with an osmolyte function are sugars, mainly fructose and sucrose, sugar alcohols, and complex sugars like trehalose and fructans. In addition, charged metabolites like glycine betaine, proline, and ectoine are also accumulated. The accumulation of these osmolytes, facilitate the osmotic adjustment. Water moves from high water potential to low water potential side and accumulation of these osmolytes lowers the water potential inside the cell and prevents the intracellular water loss (Mahajan and Tuteja, 2005).

Tuberose such as other plants creates physiological mechanisms of stress tolerance with production of proline. This compatible solute found in high concentrations to protect cytoplasmic structures when plants are exposed to stresses. Increase in proline content under both stress conditions was the same as the results of Jampeetong and Brix (2009) who reported increase in proline content and decrease in chlorophyll content of *Salvinia natans* L. under salinity stress condition.

Table 5. Means of salinity, irrigation interval and cultivars effects based on chlorophyll content of leaves (mg g^{-1}), and dry weight of roots and shoots of tuberose (*Polianthes tuberosa* L.).[a]

	The means of salinity level				The means of irrigation interval				The means of cultivar	
	0.7 (S0)	1.9 (S1)	3.1 (S2)	4.3 (S3)	2 (W0)	4 (W1)	6 (W2)	8 (W3)	"Mahallati"	"Dezfuli"
Chlorophyll content of leaves (mg g^{-1})	04.66 A	04.47 A	04.26 AB	03.45 B	05.10 A	04.30 AB	04.06 BC	03.37 C	07.99 A	09.44 A
Dry weight of roots (g)	08.40 A	06.13 B	05.29 BC	04.53 C	08.70 A	06.17 A	04.88 B	04.70 B	06.21 A	05.94 A
Dry weight of shoots (g)	04.46 A	03.30 B	02.38 C	01.47 D	03.76 A	03.06 B	02.69 BC	02.10 C	02.38 A	03.42 A

[a] Means in the same column followed by the same letter(s) are not significantly different using LSD test (5%).

Table 6. Means of salinity, irrigation interval, and cultivars effects based on proline (mg g^{-1}) of leaves, relative water content (RWC) of leaves, cell membrane injury (CMI) of leaves, Na content (µg g^{-1}) dry matter of shoots, Cl content (%) dry matter of shoots, Na content (µg g^{-1}) dry matter of roots, and Cl content (%) dry matter of roots of tuberose (*Polianthes tuberosa* L.).

	The means of salinity level				The means of irrigation interval				The means of cultivar	
	0.7 (S0)	1.9 (S1)	3.1 (S2)	4.3 (S3)	2 (W0)	4 (W1)	6 (W2)	8 (W3)	"Mahallati"	"Dezfuli"
Proline of leaves (mg g^{-1})	04.81 B	09.47 B	15.90 A	24.23 A	07.84 B	11.29 B	15.43 A	19.85 A	13.26 A	13.95 A
Relative water content of leaves (RWC)	77.94 A	70.29 B	65.63 C	60.09 D	84.91 A	73.96 B	62.35 C	52.72 D	70.82 A	66.14 A
Cell membrane injury of leaves (CMI)	30.80 C	39.08 B	41.79 B	46.76 A	49.19 A	39.28 B	37.44 B	32.53 C	44.58 A	34.63 A
Na content (µg g^{-1}) dry matter of shoots	236.7 C	300.7 BC	363.4 B	470.6 A	407.3 A	366.5 AB	307.2 BC	290.4 C	356.1 A	329.5 A
Cl content (%) dry matter of shoots	01.69 D	03.18 C	03.68 B	04.17 A	02.91 B	03.33 A	03.23 A	03.25 A	03.52 A	02.84 A
Na content (µg g^{-1}) dry matter of roots	443.7 C	531.3 B	659.3 A	648.9 A	588.8 A	597.7 A	583.6 AB	583.6 AB	550.0 A	591.5 A
Cl content (%) dry matter of roots	01.03 B	01.52 A	01.58 A	01.26 AB	01.40 A	01.44 A	01.26 A	01.28 A	01.24 A	01.45 A

[a] Means in the same column followed by the same letter(s) are not significantly different using LSD test (5%).

Plants synthesize proline from glutamine in their leaves. Some crop species, for instance wheat, are marked by low level of these compounds and correspondingly the accumulation and mobilization of proline is found to increase tolerance towards water deficit stress. The over-expression of *P5CS* (pyrroline-5-carboxylate synthase) gene from *Vigna aconitifolia* (Jacq.) Marechal. in tobacco led to increase in the level of proline and, consequently, improved the growth under drought stress (Mahajan and Tuteja, 2005). Relative water content RWC of leaves decreased in all water salinity and drought stress treatments (Tables 2 and 3). Decrease in means of RWC in high salinity and long irrigation intervals was significant. This decrease in 'Dezfuli' cultivar was more than 'Mahallati' cultivar (Table 6). Results indicated that average effect of irrigation interval on the cell membrane injury CMI of leaves decreased with longer irrigation interval, but, compared to the control, average effect of salinity levels on the CMI increased with the increase in the concentration of salts in both cultivars, during the two years of experiment (Tables 2 and 3). Anyia and Herzog (2004) reported that the significant correlations between stomatal conductance for CO_2 and *RWC* in their study was a confirmation of the role of stomatal regulation in maintaining tissue water content in cowpea [*Vigna unguiculata* (L.) Walp.] under drought stress.

Content of Na, and Cl in Roots and Shoots

Results of this experiment indicated that in both cultivars of tuberose Na and Cl content in both the root and shoot systems increased at higher levels of stress compared with the control treatment (Tables 1 and 2). Shoots Na and Cl content in 'Mahallati' cultivar was more than 'Dezfuli' cultivar, while Na and Cl content of roots in 'Dezfuli' cultivar was more than 'Mahallati' cultivar (Table 6). Our results was the same as the results of Jampeetong and Brix (2009) and Bass *et al.* (1995) who reported increase in Na and Cl content of shoot and root systems of *Salvina natans* L., *Dianthus caryophyllus* L. and *Gerbera jamesonii* L. under water salinity stress. High NaCl concentration in the growing medium of plants generate primary and secondary effects that negatively affect plant growth and development. Primary effects are ionic toxicity and osmotic stress. Ionic toxicity occurs because high concentrations of Na^+ and Cl^- in the cytoplasm of cells disturb several biochemical and physiological processes, and osmotic stress is induced by the lowering of the water potential causing turgor reduction and cellular water loss. Secondary effects of NaCl stress include inhibition of K^+ uptake, membrane dysfunction, and generation of reactive oxygen species in the cells (Agarwal and Pandey, 2004; Upadhyay and Panda, 2005; Jampeetong and Brix, 2009). In *Capsicum*, excess Cl was shown to be related to inhibition of photosynthesis under saline condition (Bethke and Drew, 1992). Based on the present study, it can be concluded that tuberose is sensitive to water and salinity stresses. In both cultivars of tuberose, vegetative and reproductive parameters were unfavorably affected by stresses applied. However, 'Mahallati' cultivar was more sensitive to stress. Based on the present results, it is impossible to conclude what exactly caused the decrease of growth and flowering parameters in both cultivars. Both physiological and biochemical processes can be affected by salinity and drought stress and their interaction. Further investigations are needed to clarify in depth the mechanism of tuberose sensitivity to environmental stresses at both molecular and ultrastructural levels.

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رشد و گلدهی دو رقم گل مریم (*Polianthes tuberosa* L.) در شرایط کم آبیاری با آب شور

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چکیده

گل مریم (*Polianthes tuberosa* L.) یکی از مهمترین گیاهان سوخوار زینتی در نواحی گرمسیری و نیمه گرمسیری است. موضوع پژوهش حاضر بررسی برهمکنش اثرهای شوری و دورهای آبیاری روی رشد و گلدهی دو رقم تجاری مهم ("محلاتی" و "دزفولی") از گل مریم (*Polianthes tuberosa* L.) بود. تیمارهای آبیاری شامل 4 دوره آبیاری 2، 4، 6 و 8 روز و تیمارهای شوری آب آبیاری شامل سطوح شوری 0/7 (شاهد)، 1/9، 3/1 و 4/3 دسی زیمنس بر متر بود. این پژوهش در غالب طرح به طور کامل تصادفی با آزمایش های فاکتوریال انجام شد. نتیجه گیری شد که گل مریم به تنش های شوری و خشکی حساس است. رقم "محلاتی" نسبت به رقم "دزفولی" حساس تر بود.

پژوهش های بیشتر به منظور ارزیابی مکانیسم حساسیت گل مریم به تنش های محیطی بررسی شده در سطح های مولکولی و فرا ساختاری مورد نیاز می باشد.

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