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Effects of Salinity and Drought on Morphological and Chemical traits of *Aloe vera* plant

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ABSTRACT: Drought and salt stress which limit the plants growth are becoming a serious problem in the world. *Aloe vera* is one of the most valuable medicine plants in world. It requires limited irrigation depending on the capacity of the soil to retain humidity. Since *Aloe* is a CAM species it could naturally be adapted to conditions of dryness and high temperatures. In this research the conjugation effect of salinity treatments and irrigation levels on *Aloe* plant was studied. In this experiment used various levels of salinity including the control, 4, 8, and 12 (ds/m), also the irrigation treatments were FC, 40%, 60%, and 80% depletion of available water during two year studies. Results revealed that the salinity stress and water deficit affected the plant height, number of leaves, leaf length, leaf thickness, aerial fresh yield, leaf fresh weight and gel weight. Salinity affected most of growing traits in comparison to control treatment; however increasing salt concentrations did not lead to a significant difference in vegetative indices between 4 and 8 ds/m applications. Leaf fresh weight and gel weight per leaf did not show any significant differences in 12 ds/m with 8 ds/m treatment. The 60% depletion of available water was appropriated for providing the adequate height, leaves number and leaf diameter. Also 40% water depletion suggested for using water and high obtaining the leaf weight, yield and leaf gel. Therefore *Aloe* is very resistant to severe saline and drought conditions. Chemical results of the plant indicated that the increase of salinity and drought declined the total chlorophyll, but enhanced the solution carbohydrate, proline and total soluble solid. Increasing carbohydrate concentration and proline content without decreasing yield showed that this plant was resistance to high salinity and drought.

Keywords: *Aloe vera*, Drought, Salinity, Yield, Gel weight, Solution carbohydrate, Proline

INTRODUCTION

Aloe vera L. is a tropical or sub-tropical plant with turgid lace-shaped green leaves with jagged edges and sharp points (Grindlay *et al.* 1986, Ni *et al.* 2004). This is a perennial liliaceous plant with succulent green leaves joined at the stem in a whorled pattern. It is highly appreciated due to high economic value among all the aloe species, and is used in pharmaceuticals, folk medicine, healthcare, cosmetic products and food products (Reynolds and Dweck, 1999) (Eshun & He, 2008). The plant contains two separate juice materials, yellow latex (exudate), extracted from the vascular bundles at the junction between the rind and the fillets, and a transparent mucilaginous gel, extruded from the inner pulp (Grindlay *et al,* 1986) (Choi *et al,* 2001) (Yagi *et al,* 2003). The major and active constituents of aloe latex are hydroxyanthracene derivatives (15-40%) such as the anthraquinone glycosides aloin A and B (Saccu, Bogoni, & Procida, 2001) (Moghaddasi & Verma, 2011, Grace 2011). This plant is resistant to unfavorable conditions and poor and dry soil.

Damages of water deficiency, salinity and temperature to plants in the world are wider compared to other tensions. Of course, the salinity and drought have attracted more attention (Tubabicer *et al.* 2004). According to a survey, more than 800 million hectares of land throughout the world are salt affected (Anonymous, 2008). Salt stress is a limiting factor of plant growth and yield, and becoming a serious problem in the world. Estimates show that about one-thirds of irrigation sections are either saline or alkaline (Epsteine, 1980). Better understanding of the mechanisms that enable plants to adapt to salt stress and maintain growth would help in the selection of stress tolerant cultivars for exploiting tidal flats. The deleterious effects of salinity on plant growth are associated with low osmotic potential of soil solution, nutritional imbalance, specific ion effect, or a combination of these factors (Ashraf & Harris. 2004). The impact of salt stress has been correlated with some morphological and physiological traits like reduction in fresh and dry weight (Chartzoulakis & Klapaki, 2000) (Ashraf & Harris, 2004) (Munns, 2005) (Zan *et al*, 2007). Researches indicated that in Aloe vera, sever salinity effected on morphological indices. Therefore 0.1% salinity has resulted in an increase in growth parameters while 0.4% salinity reduced growth parameters (Mustafa,1995). The drought stress has been reported as one of the most important factors in yield reduction of the plants. Deficiency and fast reduction of water resources have been the key issue in many parts of the world; especially the dry and semi dry areas of the world (Sepaskhah & Akbari, 2005). Hence, drought is one of the main reasons for the declining production of bedding plants (Walterland *et al,* 2010). Plants have evolved many morphological and physiological strategies to cope with drought stress which adversely affects plant growth, productivity and their attractiveness. One of the first responses to the stress is a reduction in plant growth (Weng & Yang, 2004). Wang *et al.* (2003) reported that water stress led to a series of molecular biochemical and physiological changes, including loss of Chlorophyll in the plants. Zulini *et al.* (2007) reported that Chlorophyll content decreased with further increasing rate of drought stress. Plants can partly protect themselves against mild water stress by accumulating osmolytes. Proline is one of the most common compatible osmolytes in drought stressed plants. Proline metabolism in plants, however, has mainly been calculated in response to osmotic stress (Verbruggen & Hermans, 2008). Proline accumulation may also be part of the stress signal influencing adaptive responses (Maggio *et al*, 2002). The aim of this study was to investigation the effect of salinity and drought stress on some traits related to growth, yield and some compounds of *A. vera* L. plant.

MATERIALS AND METHODS

A. Culture conditions

The experiment was conducted in a greenhouse in the Isfahan Agriculture Research Center, Isfahan, Iran (Latitude 32o36/ N, longitude 51o58/ E, and 1570 m elevation) in 2012 until 2014. Aloe sprouts cultured in pots with 40 cm length and 32 cm diameter. Sprouts at planting time were in the four-leaf stage. In this research were used 128 similar pots. This trial was conducted in split plot design with three replications which each replication containing one pots. The experiments were performed with controlled environmental conditions; the average temperature was 25 ?C and the relative humidity was 50%. Soil chemical appearances shown in table 1.

Table 1: Chemical analyses of soil.

pH	EC	Cl	Na	OC	So_4	Ca+Mg	Hco_3	S.Anions	S.Cations
-	**ds/m**	**meq/l**	**meq/l**	**%**	**meq/l**	**meq/l**	**meq/l**	**meq/l**	**meq/l**
7.6	12/9	84	68	2.05	38	62	8	92	130

OC= organic carbon

B. Treatments

The experiment was continued for 18 months, including a pre-experimental period of adaptation of the plants, salinity and irrigation treatments. Salinity treatment was along to irrigation treatment in through of trial. Soil texture was determined using hydrometer. Field capacity (0/3 MP) and permanent wilting point (15 MP) were determined by the pressure plate method (Manifold, UK). Soil moisture was measured at several stages with TDR and the irrigation treatments were base of depletion of available water (DAW) included field capacity (T1), 40 % depletion of available water (T2), 60 % depletion of available water (T3) and 80 % depletion of available water (T4). Soil physical analyses, irrigation treatments and condition of soil moisture indicated in Table 2. Salinity treatments were including of control (S1), 4 ds/m (S2), 8 ds/m (S3) and 12 ds/m (S4) which made by Nacl ordinary. Electric conductivity of fresh water in green house was 0.36 ds/m.

Table 2: Irrigation treatments, soil moister conditions and physical analyses of soil.

Irrigation treatments					Water volume/Soil volume			Physical analyses of soil				
DAW (%)	0	40	60	80	AM[2]	PWP	FC	Soil texture	Sandy %	Silt %	Clay %	Gravel volume %
VMP[1] (%)	35	26.9	24.4	9.21	12.6	22	35	loam-clay	19	41	40	30

1-Volumetric moisture percent (VMP). 2-Available moisture (AM).

C. Morphological observations

Drought and salinity effects studied on the Plant height, number of leaf, leaf length, leaf width, leaf thickness, aerial fresh yield, leaf fresh weight, gel weight and gel percent. The height of the plant from the pot to the tip of the longest leaf was measured by a ruler and recorded. The width and diameter of the leaf was measured by a digital caliper in one third of each leaf. The weight of whole of leaves after the out of the pot and separate the roots, was measured with a digital scale for aerial fresh yield. Leaves were taken to the laboratory and after weighing each leaf; the gel fillets were removed and weighed. The gel percent was calculated from the following formula.

Gel % = gel weight/ leaf fresh weight ×100

D. Chemical observations

The measurement of total chlorophyll (Chl) was done on the basis of Arnon (1949) method. The solution carbohydrate evaluated by Phenol-Sulfuric Acid method (DuBois *et al*, 1956).

The proline content (Pro) was determined by the method given by Bates *et al.* (1973). Total soluble solid content (TSS) determined by extracting and mixing one drop of juice from each sample into a refractometer (JENWAY - 6405 UV/V).

E. Statistical analysis

Data was analyzed on base of split plot design by statistix8 software and mean comparison was done on base of LSD test at 5% probability level. The EXCEL software was used for recording data and drawing diagrams.

RESULTS

Salinity and irrigation treatments affected the most morphological and chemical traits in *Aloe vera.* The effects of different levels of salinity on the plant height, number of leaves, leaf length, leaf thickness, aerial fresh yield, leaf fresh weight and gel weight of per leaf exception to leaf width and gel percentage were statistically significant (P<0.01), (Table 3). Based on the results, the increased salinity up to 12 ds/m intensively reduced the plant height, number of leaves and leaf thickness. In the control salinity treatment the plant height (52.13cm), leaves number (16 No) and leaf diameter (1.31 cm) were observed. However, there hadn't significant differences between 4 and 8 (ds/m) levels on plant height and leaves number traits.

Table 3. Analysis of variance for morphological traits in *Aloe vera.*

		Mean Square								
S.O.V	**DF**	**Plant height (cm)**	**Number of leaves**	**Leaf length (cm)**	**Leaf width (cm)**	**Leaf thickness (cm)**	**Arial fresh yield (kg)**	**Leaf fresh weight (g)**	**Gel weight per leaf (gr)**	**Gel (%)**
Rep (R)	2	4.304	1.6458	1.206	3.04771	0.05896	0.13247	2530.8	204.6	192.940
Salinity (S)	3	373.727**	27.0208**	122.266**	1.36770 ns	0.29278 **	2.57762**	26287.1**	11394.5**	91.401ns
Error R*S	6	18.091	2.2292	9.158	1.08041	0.03007	0.13522	640.2	256.3	24.435
Irrigation (DAW)	3	109.681**	9.4097**	30.097ns	1.39694 ns	0.67389 **	1.39146**	16792.1**	7624.4**	136.965**
S×DAW	9	32.529 **	8.1505**	24.419ns	1.38026 ns	0.06704 ns	0.73406**	5709.1**	2248.2**	25.719ns
Error R×S×DAW	24	8.286	1.6944	12.526	0.73284	0.04479	0.07699	752.1	342.2	19.874
CV (R×S×DAW) %		6.35	8.99	8.52	14.28	18.27	20.38	16.86	20.42	8.15

*, **, ns shows significant in 5%, 1%, and insignificant, respectively.

There was no significant different in the leaf length at plants treated with fresh water and 4ds/m treatment (Table 4). The maximum aerial fresh yield and leaf fresh weight was obtained in the control treatment than other saline treatments. The aerial fresh yield declined from 1.97 kg in S1 to 0.87 kg in S4. Although severe salinity (12 ds/m) reduced this factor about 50% in comparison to the control treatment, there were no significant difference between 8 and 12 ds/m levels (Table 5). The maximum gel weight of per leaf was observed at the control treatment (no saline) (129.80 gr), while the least amount was obtained in the severe salt (12 ds/m) treatment (61.94 gr). However, significant differences were not observed between S3 and S4 treatments (Table 5). Based on Table 6, the effect of salinity on total chlorophyll, solution carbohydrate, proline and total soluble solid was statistically significant (P<0.01).

Table 4. Mean comparison of Plant height, Number of leaf, Leaf length, Leaf width, Leaf thickness traits under the different levels of salinity and irrigation treatments.

Treatment	Plant height (cm)	Number of leaves	Leaf length (cm)	Leaf width (cm)	Leaf thickness (cm)
Salinity					
control	52.13^{a}	16.33^{a}	44.12^{a}	6.26^{a}	1.31^{a}
4 ds/m	56.80^{b}	14.58^{b}	44.35^{a}	5.89^{a}	1.14^{b}
8 ds/m	43.50^{b}	14.33^{b}	39.54^{b}	6.26^{a}	1.22^{ab}
12 ds/m	38.87^{c}	12.66^{c}	38.08^{b}	5.56^{a}	0.95^{c}
Irrigation					
FC	48.12^{a}	15.58^{a}	42.01^{a}	6.05^{ab}	1.39^{a}
40%	46.76^{ab}	14.41^{b}	43.05^{ab}	6.34^{a}	1.25^{ab}
60%	45.28^{b}	14.50^{ab}	41.73^{ab}	6.06^{ab}	1.15^{b}
80%	41.14^{c}	13.41^{b}	39.30^{b}	5.52^{b}	0.83^{c}

The mean for each experimental factor in each characteristic which has at least one letter in common are not statistically significant based on LSD test at 5% level.

Table 5: Mean comparison of Aerial fresh yield, Leaf fresh weight, Gel weight per leaf, Gel percent traits under the different levels of salinity and irrigation treatments.

Treatment	Aerial fresh yield (kg)	Leaf fresh weight (g)	Gel weight per leaf (gr)	Gel (%)
Salinity				
control	1.97^{a}	223.51^{a}	129.80^{a}	57.01^{a}
4 ds/m	1.41^{b}	174.91^{b}	99.98^{a}	56.29^{a}
8 ds/m	1.18^{bc}	130.88^{c}	70.54^{b}	54.71^{ab}
12 ds/m	0.87^{c}	121.32^{c}	61.94^{b}	50.83^{b}
Irrigation				
FC	1.56^{a}	187.80^{a}	104.85^{a}	54.48^{b}
40%	1.69^{a}	198.18^{a}	116.87^{a}	59.37^{a}
60%	1.25^{b}	147.53^{b}	79.94^{b}	53.64^{b}
80%	0.93^{c}	117.11^{c}	60.61^{c}	51.34^{b}

The mean for each experimental factor in each characteristic which has at least one letter in common are not statistically significant based on LSD test at 5% level.

Table 6: Analysis of variance for chemical traits in *Aloe vera*.

		Mean Squares			
S.O.V	DF	Total chlorophyll (mg/g)	Solution carbohydrate (mg/g)	Proline (µg/g)	TSS (%)
Rep (R)	2	0.00698	4.8624	0.00247	0.00812
Salinity (S)	3	0.13690**	18.7542**	3.26313**	0.87389**
Error R×S	6	0.00085	0.1581	0.08415	0.01035
Irrigation (DAW)	3	0.03851**	23.4019**	1.46491**	1.18778**
S×DAW	9	0.00238^{ns}	0.5086*	0.06094^{ns}	0.05537**
Error R×S×DAW	24	0.00161	0.2057	0.03207	0.01118
CV (R×S×DAW) %		10.51	6.34	8.55	9.00

*, **, ns shows significant in 5%, 1%, and insignificant, respectively

The maximum and the minimum chlorophyll content were indicated to the control salinity (0.494 mg/g) and 12 ds/m (0.249 mg/g) treatments, respectively (Table 7). The effects of salinity showed that the increasing saline enhanced the solution carbohydrate. Solution carbohydrate ranged from the control treatment (5.85 mg /g) to salinity of 12 ds/m (8.66 mg/g).

The mean comparison showed that the maximum proline content was belonged to 12 ds/m treatment (2.65 µg/g) and the least amount was related to control treatment (1.43 µg/g). The highest level of TSS was evaluated up to 1.43% at the severe salinity and the least level was 0.87 % at the control salinity treatment (Table 7).

Table 7. Mean comparison of Total chlorophyll, Solution carbohydrate, Proline and TSS traits under the different levels of salinity and irrigation treatments.

Treatment	Total chlorophyll (mg/g)	Solution carbohydrate (mg/g)	Proline (µg/g)	TSS (%)
Salinity				
control	0.4942[a]	5.8589[d]	1.4340[d]	0.875[d]
4 ds/m	0.4358[b]	6.4522[c]	1.9720[c]	1.041[c]
8 ds/m	0.3460[c]	7.6456[b]	2.3227[b]	1.300[b]
12 ds/m	0.2499[d]	8.6630[a]	2.6535[a]	1.483[a]
Irrigation				
FC	0.3822[b]	5.1684[c]	1.7924[c]	0.7667[c]
40%	0.4349[a]	7.1909[b]	2.0267[b]	1.2167[b]
60%	0.4059[ab]	8.1477[a]	1.9649[b]	1.1833[b]
80%	0.3029[c]	8.1127[a]	2.5981[a]	1.5333[a]

The mean for each experimental factor in each characteristic which has at least one letter in common are not statistically significant based on LSD test at 5% level.

The irrigation treatments showed statistically significant on the plant height, number of leaves, leaf thickness, aerial fresh yield, leaf fresh weight, gel weight and gel percent of per leaf exception to the length and width of leaf (Table 3). At 80% depletion of available water, plant height (41.14 cm) significantly declined in comparison to other different water depletion levels (Table 4). Drought declined the number of leaves. The most difference in the leaves number was observed between the field capacity (15.58 numb) and 80 % depletion available water (13.41 No). *Aloe vera* leaves diameter reduced with less irrigation as the most diameter in control treatment (1.39 cm) and the least thickness in the 80 % DAW (0.83 cm) were observed (Table 4). Severe water stress at 80 % decreased aerial fresh yield (0.93 kg), leaf fresh weight (117.11 gr) and gel weight of each leaf (60.61 gr). However there was no significant different between the field capacity and 40% level. But 60 % DAW could intensively reduce these indices. The most gel percent of each leaf was measured at the rate of 59.37 % in the treatment of 40 % DAW but there was no significant different between other irrigation treatments (Table 5).

The results of variance analysis (Table 6) showed that the effects of irrigation treatments on total chlorophyll content, solution carbohydrate, proline and total soluble solids were significant ($P<0.01$). The chlorophyll range varied from 0.434 mg/g in the 40% treatment to 0.302 mg/g in 80 % (Table 7).

The results indicated that the lowest and highest solution carbohydrate content was observed in the treatment of field capacity (5/16 mg/g) and 60 % treatment (8.14 mg/g), respectively. There was no significant difference between 60 and 80 % treatments (Table 7). The Proline content varied from FC treatment (1.79 µg/g) to 80 % depletion available water (2.59 µg/g). There was no significant difference between 40 and 60 % treatments for proline content (Table 7). The highest total soluble solid was observed in 80 % treatment (1.5 %) and the lowest in the treatment of field capacity (0.7 %). There was no significant difference between the 40 and 60 % treatments (Table 7).

The interaction effect of salinity and drought on the plant height, leaves number, aerial fresh yield, leaf fresh weight and gel weight of each leaf was statistically significant ($P<0.01$) while there was no significant difference in the length, width, thickness and gel percent of each leaf (table 3). The interaction effect showed the highest plant was in the field capacity treatment with control saline treatment (58/66 cm). The minimum plant height was evaluated in the 40 and 80 % depletion of available water with severe salinity (12 ds/m) where reduced 35 percent. However we can carefully see that salinity of 12 ds/m had an excessive effect on the height. As the plant height was decreasing at the all of the irrigation treatments with severe salinity in S4 (Fig. 1).

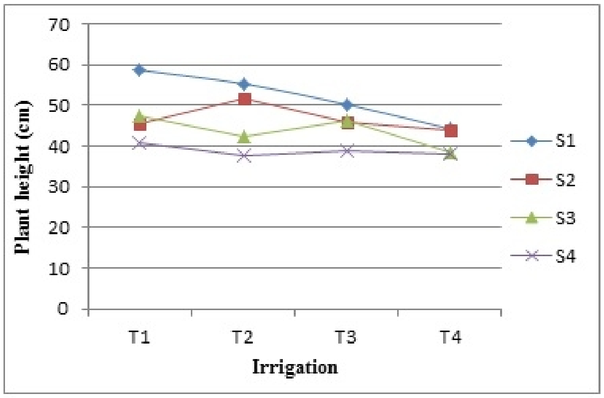

Fig. 1. Interaction effects of salt and irrigation on plant height in *Aloe vera*.

The maximum number of leaves was obtained in control salinity with field capacity treatment (20 No) that had significant differences with other treatments. There after the number of leaves were observed in the condition without salt with 40% DAW treatment and salinity 8 ds/m with FC treatment (16.33 numb). The minimum number of leaves per plant (11.66 No) was shown at salinity 12 ds/m and FC treatment (Fig. 2).

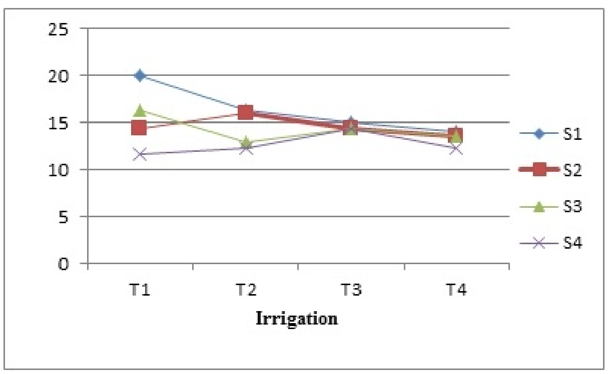

Fig. 2. Interaction effects of salt and irrigation on leaves number in *Aloe vera*.

According to Fig. 3, the most aerial fresh yield was measured in FC and 40% depletion of available water with no salt level (2/66 kg); however, it decreased with increasing of drought in S1. In addition in the treatment of 4 ds/m saline, the aerial fresh yield improved at 40% DAW while more droughts led to sharp drop in yield. The least aerial fresh yield (0.64 kg) was observed at 40% depletion of available water with severe salinity (12 ds/m) which was about 75 percent lower than the highest yield. Aerial fresh yield decreased by reducing amount of water in the treatment of 80% in all salt treatments (Fig. 3).

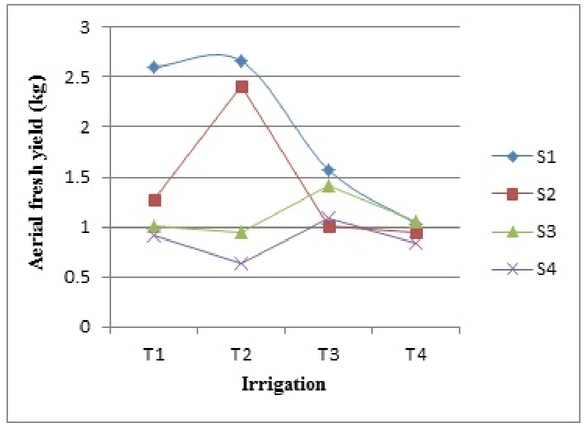

Fig. 3. Interaction effects of salt and irrigation on aerial fresh yield in *Aloe vera.*

Treatments of FC (293.71 gr) with control salinity treatment and 40% DAW with 4 ds/m treatment (263.17 gr) had heavier leaves then other treatments. The least leaf was belonged to 80% DAW with 8 ds/m (103.57 g) that caused the decreased leaf fresh weight up to 65 percent. In the 40% depletion of available water treatment the salinity of 4 ds/m couldn't decrease the leaf fresh weight, while the increase of salt concentration drastically reduced the leaf fresh weight. In all salinity treatments, irrigation reduction in 80% resulted in a decrease in leaf weight (Fig. 4).

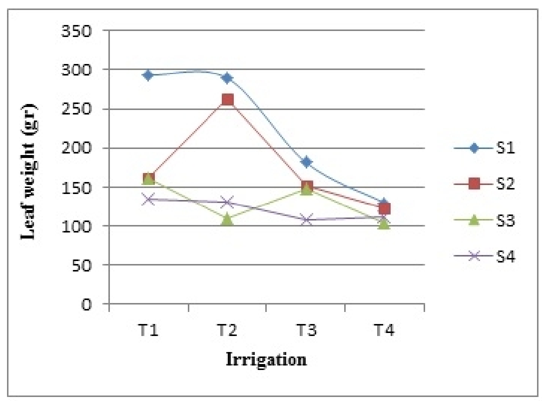

Fig. 4. Interaction effects of salt and irrigation on leaf weight in *Aloe vera*.

The highest gel weight of per leaf obtained at T1 irrigation regime (179.00 gr) with control salinity treatment. Also there was a heavy gel at 40% depletion of available water with 4 ds/m treatment (159.63 gr). The least gel weigh found in the 80% DAW with salinity equal to 8 ds/m (50.81 gr) that declined gel weight about 72% in comparison to the highest level (Fig. 5).

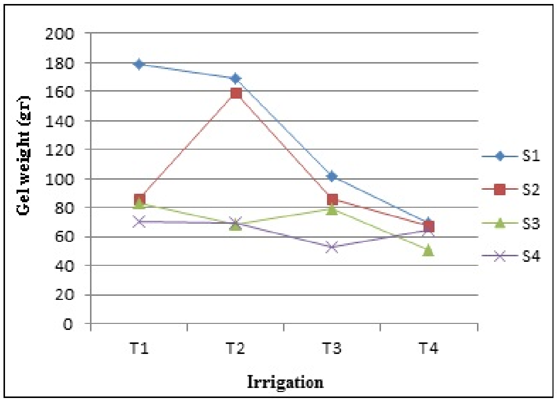

Fig. 5. Interaction effects of salt and irrigation on gel weight in *Aloe vera*.

Based on table 6, the interaction effect of salinity and irrigation treatments on TSS ($P<0.01$) and solution carbohydrate ($P<0.05$) was statistically significant. The highest level was observed in 12 ds/m and 80% depletion of available water (S4-T4) and the least level in S1-T1 and S2-T1 treatments.

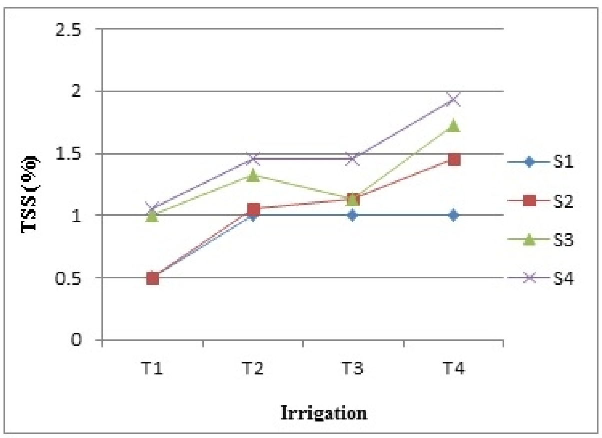

Fig. 6. Interaction effects of salt and irrigation on gel weight in *Aloe vera*.

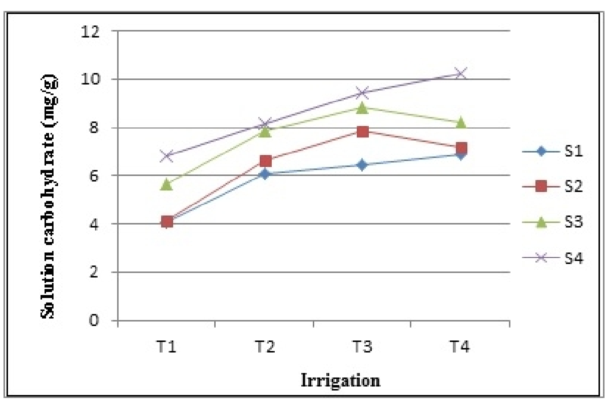

Fig.7. Interaction effects of salt and irrigation on solution carbohydrate in *Aloe vera*

The total soluble solid was not changing in the control salinity treatment by the increased drought but it was growing in another treatment by the decline in irrigation. The TSS in the 8 ds/m was highly reduced by 60% DAW (Fig. 6).

Increasing salinity, the solution carbohydrate enhanced. The highest level of solution carbohydrate was indicated at the treatment of 12 ds/m with 80% DAW and the lowest amount in the control salinity with FC treatment (Fig. 7).

DISCUSSION

Although *Aloe vera* is a plant adapted to arid environments, but water deficiency and salinity had effects on the morphology and physiology traits of the plant. So this study had investigated the changes in growth indices such as the plant height, number of leaves, leaf length, leaf thickness, leaf weight and weight of the gel produced in the leaves and chemical changes such as chlorophyll, solution carbohydrate, proline and TSS. The increased salt concentration reduced the vegetative growth, yield, gel content and chlorophyll of aloe plant. The highest decrease was observed in the S4 treatment (12 ds/m). the plant height up to 25%, leaf number up to 22%, leaf length up to 14%, leaf thickness up to 27% , aerial fresh yield up to 55%, leaf weight up to 45%, gel weight at per leaf up to 52% (from 129 gr to 61 gr) declined in comparison to the control salt treatment. It is worth to say the lowest salt concentration changed the leaf fresh weight and the gel content sensible which started to decrease. Probably this exhibited the effect of salt on the water aggregation reeducation in the leaves.

Pasternak et al. (1986) and Fuentes et al. (1988) reported similar results and revealed that leaves and sprouts reduced with increasing salinity in different Aloe spp. Mustafa (1995) argued that in Aloe vera, severe salinity had resulted in reducing in growth parameters. By increasing salinity stress, the plant response changed negatively. Results indicated that aloe plants are not able to tolerate long time salinity stress while in short time they show some positive responses (Moghbeli *et al.*, 2012).

Chlorophyll content decreased by about 51 % in severe salinity. Probably too much salt was involved in preventing the formation or destruction of chlorophyll. According to Ueda et al. (2003) the chlorophyll content in the leaves can be an indicative of stressful conditions, such as water or salt stress. On the other hand, increasing salt concentration improved the amount of total soluble solid, proline and solution carbohydrate, as the lowest levels were measured in the treatment without salt.

Salt increasing up to 12 ds/m enhanced 48 % solution carbohydrate, 85% proline and 70 % TSS compared to the control salinity treatment (no salt). Perhaps the increase of solution carbohydrate and proline concentration raised the plant resistance to high salinity. In fact, salinity affects plant metabolism by disturbing physiological and biochemical processes of plants due to ionic and osmotic imbalances which results in the reduction of plant growth and productivity (Munns, 2005). The deleterious effects of salinity on plant growth are associated with low osmotic potential of soil solution, nutritional imbalance, specific ion effect, or a combination of these factors (Ashraf and Harris, 2004). Sucrose is the predominant transport and storage sugar at maturity. Results for accumulation of sucrose under salt stress revealed that sucrose played a role in lowering osmotic potential. The accumulation of soluble sugars in plants has been widely reported as a response to salinity (Murakeozy *et al*, 2003). Water stress makes plants respond in morphological, physiological and biochemical processes. The effects of irrigation treatments expressed the most difference in the plant height, leaf number, leaf diameter, aerial fresh yield and gel weight between control and 80% DAW treatments. The Severe drought stress intensively reduced the plant vegetative traits including the plant height up to 14%, leaves number to 14%, leaf thickness to 40%, aerial fresh yield to 40%, leaf weight to 38% and gel weight to 42% in comparison to the field capacity. Also Yin et al. (2005) reported that the prolonged low-water period caused the most branches of plants to fall. Gupta *et al.* (1995) reported that drought stress in plants causes their growth rate to fall and the reduction of the amount of leaves and branches of the plant takes place by water loss. Also the results of Rahmani *et al.* (2008) showed that the reduction of water in the *Calendula officinalis* plant led to a reduction in the plant size and canopy.

Chemical changes were created in plants by the water stress as with the most severe water restrictions (80% DAW) total chlorophyll content reduced up to 30% in comparison to maximum amount. The chlorophyll pigment is necessary for photosynthesis process and the most other studies have shown changes in the rate of photosynthesis related to drought stress. Chylinski *et al.* (2007) considered that the total concentration of Chl in the leaves of Impatiens walleriana significantly reduced due to stress levels. Water shortage up to 60 and 80% had similar effects on the amount of gel solution carbohydrate. In fact these treatments in comparison to control one increased the gel solution carbohydrate to 57%. This indicated that even 60% treatment increased the concentration of solution carbohydrate before application of more stress. *Aloe vera* plants must have physiological mechanisms for maintaining internal water under severe water deficiency. The qualitative and quantitative composition of the gel of the leaves surely plays a very important physiological role in the retention of water, and then in the maintenance of the water supply for cell synthesis and leaf growth (Del Viso *et al*, 2009. Delatorre *et al*, 2010). Zan et al. (2007) showed the amounts of total sugars, oligo and polyfructans in leaves of plants subjected to the water treatments; all increased with increasing water deficiency. Proline and total soluble solids were measured at the highest level in the severe stress (80%) where they increased 44 % and 100% respectively. In the case of Aloe vera, there was an additional synthesis of specific proteins made by the plant in conditions of water deficiency (Huerta *et al.*, 2008). One of the compatible solutes is proline (Pessarakli 2008). It has been reported that the proline accumulation is a response to drought (Jia *et al.* 2002). Also Yamada *et al.* (2005) reported when plants experience environmental stresses, such as drought, high salinity, and low temperatures, they activate various metabolic and defense systems to survive. Furthermore, water-stressed plants synthesize other protector molecules such as fructans which mitigate the detrimental effects induced by water deficit. These polysaccharide molecules are synthesized in plants exposed to very dry environments, increasing the cellular osmotic pressure by rapidly releasing oligofructans from the polyfructans (Van Den Ende *et al.*, 2004). The physiological roles of fructans have been reinforced by the demonstration that transgenic plants able to synthesize fructans after transgenesis became more tolerant to, drought (Kawakami *et al.*, 2008; Li *et al.*, 2007)

The interaction effects of salinity and irrigation expressed irrigation levels in the plant height, leaves number, aerial fresh yield, leaf fresh weight and weight of gel had different responses to salinity. This means that with increasing irrigation restrictions and also rising salt concentration, these factors were reduced, but the reduction in all treatments was not the same. For example in 4 ds/m salt concentration, at first increasing drought by 40 % increased the growth rate and gel weight which then decreased in the intensity dry condition. This process was different from other irrigation treatments. Aliabadi *et al*. (2009) showed plants design certain mechanisms to survive under water scarcity. Increase of drought and salt caused the soluble sugar to improve however severe drought with 4 and 8 ds/m was resulted in the solution carbohydrate drop while in the highest saline concentration (12 ds/m) the solution carbohydrate rose. The amount of total soluble solid was almost constant in the free salt treatment while in the high salinity; it improved gradually by the increased drought.

CONCLUSION

Due to the importance of the *Aloe vera* in the agriculture, medicine and industry and reduction of water resources, *Aloe vera* can be used in our schedule. Intensive drought stress (80%) reduced the growth and chlorophyll greatly but leads to the increased solution carbohydrate, proline and total soluble solid. Although the lack of plant available water results in the cell plasmolysis and loss of cell turgidity, considering the suitable condition of 60% depletion of available water it is recommended for maintaining the height, number of leaves, leaf thickness and saving water. An increase in drought up to 60 % depletion of available water had a main impact on the decline of leaf weight, aerial fresh yield and leaf gel so 40% depletion of available water suggested for getting appropriate yield and gel amount. Salinity affected many growth factors compared to the no salt treatment. But with increasing salt concentration, there was no difference in vegetative indices between 4 and 8 ds/m application. Hence the plant growth was probably resistant to this salt concentration. Even in the leaf weight and the leaf gel content there were no significant differences between 12 ds/m and less saline treatment which demonstrated the plant resistance to extra saline conditions. It is worth to mention that the partial increase of salt reduced level of chlorophyll and enhanced the solution carbohydrate, Proline and TSS slowly so the maximum accumulation of these compounds were found in the sever salinity (12ds/m). These compounds causing the osmotic pressure and increase of plant extract concentration made the plant resistant to high salinity.

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