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The Effect of Drought Stress on Soluble Carbohydrates (Sugars) in Two Species of *Haloxylon persicum* and *Haloxylon aphyllum*

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Abstract: Soluble carbohydrates (sugars) are considered as important metabolites in plants under drought stress. In order to study the trend of changes of this osmolyte when encountering with dryness, the seeds of two species of *Haloxylon persicum* and *Haloxylon aphyllum* were planted in vase and their grown twigs underwent drought stress after a one year care and a one month compatibility with the greenhouse environment. The study of changes of this osmoiyte in branchlet and roots of the twigs of these two types of haloxylon was planned within the format of a completely randomize design with two treatments of species and fifteen tension treatments (lack of irrigation of twigs). The Two Species of *Haloxylon persicum* and *Haloxylon aphyllum* and the levels 0 (control), 2, 4… and 28 days of lack of irrigation were determined as treatments of experiment. The analysis of data in two sides analysis variance was conducted and the averages were compared by using Duncan's test. The study of data of branchlet and root showed that with the possibility of 99%, the effect of drought stress on the increase of the rate of soluble sugar of branchlet and root of both types of haloxylon was meaningful. In addition, between these two species at the same level of reliability, there was a difference. The study of the effect of drought stress on changes of the quantities of total soluble sugars showed that the changes of this factor are of more similarity with changes of soluble sugar of root and they almost obey the same model. The increase of rate of branchlet soluble sugars, root and total soluble sugars were in proportion with the intensity of tension.

Key words: Soluble carbohydrates (sugars), drought stress, resistance to dryness

INTRODUCTION

Soluble carbohydrates (sugars) are among compatible metabolites and osmolytes (Bray, 1997) which are increased by increasing drought stress and Reduction of the Soil Water Content (RSWC) (HU *et al*., 2009; Luo *et al*., 2009; Ohashi *et al*., 2009; Qi *et al*., 2009; Yang *et al*., 2009; Yuan *et al*., 2009; Li-Xin *et al*., 2009; Cong *et al*., 2007; Garcia-Sanchez *et al*., 2007; Nakayama *et al*., 2007; Xiang *et al*., 2007; Hoekstra *et al*., 1994) and protect plant against water shortage and damages resulting from drought stress on cells membrane (Ji *et al*., 2009; Crowe *et al*., 1999). The increase and accumulation of soluble sugars maintain the turgidity in leafs under tension and they prevent from dehydration of proteins and cell membranes (Sawhney and Singh, 2002; Crowe *et al*., 1990). It seems that concurrent with the induction of drought stress or reduction of soil water content and accumulation of soluble carbohydrates, the protective enzymes of plants under tension is increased (Li *et al*., 2010) and in proportion with the intensity of tension, their contents are added (Ren, 2009; Yang *et al*., 2002).

The accumulation of soluble sugars in plants under drought stress is a result of a series of metabolism interaction which has impact on formation or their transfer in the leaf (Campos *et al*., 1999). The result and physiologic response of the increase and accumulation of soluble surges in the leaf of plants influenced by drought stress is the reductions of rate of photosynthesis (Goldschmidt and Huber, 1992) and in a word, photosynthesis management is done through affecting its efficiency (Xu *et al*., 2007; Wu and Xia, 2006).

Considerable changes in accumulation and condensation of soluble sugars in response to drought stress are observed both at intra-and inter-species levels and even among the figures of species possibly subject to drought (dryness) (Ashraf and Harris, 2004). High thickness of carbohydrate, beside a role which it has in reducing water potential prevents from the oxidative destruction and helps in keeping the structure of proteins and membrane under average dehydration during drought (dryness) period. Also carbohydrates act as a signal giver molecular for genes giving response to sugar. It causes different physiological responses such as defensive responses and expansion of cells as a result of turgescence (Erdei *et al*., 2002).

The accumulation of soluble sugars as a result of application of drought stress has a positive correlation with the increase of relative contents of leaf water (Parida *et al*., 2007; Irigoyen *et al*., 1992; Wu and Xia, 2006) and plays a main role in adjusting the osmosis of plant (Hessini *et al*., 2009; Luo *et al*., 2009; Zhou and Yu, 2009; Parida *et al*., 2007; Xu *et al*., 2007; Sanchez *et al*., 2004). It seems that the mild tensions of drought are also able to increase soluble sugars and consequently activation of osmotic adjustment of plant (Zhou and Yu, 2009). Also concurrent with intensification, they increase the content of soluble sugar too (Parida *et al*., 2007). Therefore the aim of this research was to study the effect of drought stress on soluble carbohydrates (sugars) in two species of *Haloxylon persicum* and *Haloxylon aphyllum*.

MATERIALS AND METHODS

In order to study the impact of drought stress on content of soluble carbohydrates of branchlet and root of two species haloxylon (*Haloxylon persicum* and *Haloxylon aphyllum*), their seeds were planted in plastic vases. They were taken into care for one year. The plastic vases were selected with five liters capacity in order to make a better and greater growth of the roots of twigs. Their soil consisted of wind sand, soil and leaf clay in 2, 1 and 1 proportions. The aim of inclusion of leaf soil in the mentioned combination was to supply nutrition necessary for twigs during the period of experiment. At this condition, in order to prevent from unwanted accumulation of water, some holes were made in their bottom. After one year, twigs were transferred to the central greenhouse and in order to make them compatible with greenhouse condition, the treatments of dryness application was made one month after the transfer of twigs to greenhouse. For this purpose, a sufficient number of good and healthy twigs were selected for performing experiment. Half of them were considered for the application of drought treatments and the rest were considered for control that was watered every two days once.

In this research for each of the two types of haloxylon, 2 to 28 days of drought stress (prevention from irrigation of twigs) was applied regularly and in two days distance. So, totally 15 drought stress treatments (control, 2, 4, 6, 8, 10... 24, 26 and 28 days of lack of irrigation) and 2 treatments of species as test treatments were determined. In each experiment (measuring the content of soluble carbohydrate), branchlet and root of 5 twigs were cut (repetition of measuring in each tension treatment). For measuring soluble sugars, the methods of Irigoyen *et al*. (1992) and also Palonen (1999) were used. The obtained data were reviewed within the format of a Randomized Complete Design. Analysis of data was made by using two-side variance analysis; and comparison of averages was made by using Duncan's test. The rate of each data in the tables of comparing averages was the result of at least five measuring.

RESULTS

The analysis of the variance of changes of soluble carbohydrates (sugars) in the branchlet of both types of haloxylon (Table 1) showed that in addition to the tension which was effective on changes of the rate of soluble carbohydrates with 99% possibility in both species, the change of species also had impact on quantitative difference of this osmolyte with the same percent of possibility. The above-mentioned model, in relation with the changes of soluble sugars of root was also prevailing in both species of haloxylon (Table 2).

The study and comparison of averages of effect of drought stress on changes of branchlets soluble carbohydrates of both types of haloxylon (Table 3) showed that it is possible to classify the mentioned effects in two categories of treatment A (0 to 10 days of lack of irrigation) and B (12 to 28 days of lack of irrigation), such that the difference between the two categories (in both species of haloxylon) became meaningful at the statistical level of 1%. The difference between treatments in the category A and in the category B (with the exception of treatment of 18 days of lack of irrigation which was different with the treatment prior to that with the 95% possibility) was meaningful with 95% and 99% possibility respectively. The difference between tension treatments and control treatment in both types of haloxylon started from a 2 days lack of irrigation at the possibility level of 95% and continued from the treatment of 12 days lack of irrigation onwards at the level of 1% meaningfulness. The intensity of effect of drought stress on changes of soluble carbohydrates rate of branchlet in both types of haloxylon was different. It was such that the least effect was related to category A and the greatest rate belongs to category B. The study of the impact of type of

Table 1: Analysis of variance of soluble sugars changes in the branchlet of *Haloxylon persicum* and *Haloxylon aphyllum*

SOV	DF	SS	MS	F
Species (A)	2-1 = 1	1826.315	1826.315	9.438
Stress (B)	15-1 = 14	31489.69	2249.264	11.642
Interaction (AB)	1×14 = 14	9321.472	665.819	3.441
Sum	29	42637.48	1470.258	-
Error	120	23219.58	193.496	-
Total	149	65857.06	-	-

Table 2: Analysis of variance of soluble sugars changes in the root of *Haloxylon persicum* and *Haloxylon aphyllum*

SOV	DF	SS	MS	F
Species (A)	2-1 = 1	1592.149	1592.149	10.665
Stress (B)	15-1 = 14	27299.82	1949.987	13.063
Interaction (AB)	1×14 = 14	7652.397	546.599	3.662
Sum	29	36544.37	1260.15	-
Error	120	17913.42	149.278	-
Total	149	54457.79	-	-

Table 3: The impact of the rate of drought stress on average changes of Soluble Sugars (milligram pr gram wet weight) of branchlet of *Haloxylon persicum* and *Haloxylon aphyllum*

Stress intensity (days of no-irrigation)	*Haloxylon aphyllum*	*Haloxylon persicum*
0	2.118±0.2900[0, 1]	1.809±0.3200[0, 1]
2	2.950±0.3300[1, 2]	2.149±0.3110[1, 2]
4	4.042±0.2900[2, 3]	3.391±0.3090[2, 3]
6	4.911±0.3600[3, 4]	4.292±0.3170[3, 4]
8	6.081±0.2700[4, 5]	5.300±0.3130[4, 5]
10	7.494±0.3400[5, 6]	6.614±0.3260[5, 6]
12	9.243±0.2900[7, 8]	8.202±0.3190[7, 8]
14	11.021±0.2500[9, 10]	9.939±0.3230[9, 10]
16	12.899±0.2100[11, 12]	11.744±0.3300[11, 12, 24]
18	13.750±0.3400[12, 13]	12.592±0.3280[12, 13, 24]
20	15.600±0.2300[14, 15]	14.428±0.3170[14, 15, 25]
22	18.141±0.3100[16, 17]	16.542±0.3400[16, 17, 26]
24	20.315±0.3600[18, 19]	18.423±0.3370[27, 28]
26	23.018±0.2600[20, 21]	20.846±0.3250[29, 30]
28	27.148±0.3500[22, 23]	23.709±0.3320[31, 32]

species in changes of the content of soluble carbohydrates of branchlet showed the difference between two species began from a 16 days treatment of lack of irrigation at the level of 95% possibility level and continued from the treatment of 24 days of lack of irrigation at the level of 99% reliability (Table 3 and Fig. 1).

The impact of drought stress on the increase average changes of roots? soluble carbohydrates in both species of *Haloxylon persicum* and *Haloxylon aphyllum*, despite similarity with the model of branchlet with a little difference (as compared with the changes of soluble carbohydrates of branchlet) was at the level of tension treatment and treatments of species (Table 4). It is such that the effect of tension on changes of soluble sugars in both species of haloxylon can be placed in two categories of treatment A (0 to 8 days lack of irrigation) and B (10 to 28 days of lack of irrigation). The difference between these two categories of treatment was meaningful with the possibility of 99%. The difference between treatments in category A with a 95% trust and in the category B with 99% trust became meaningful.

The difference between treatments of tension and control (standard) treatment in both species of haloxylon started from the treatment of 2 days of lack of irrigation at the level of 5% error and continued from the treatment of 10 days of lack of irrigation on wards at the 99% reliability level. The intensity of the effect of drought stress on changes of the rate of roots' soluble sugar of both types of haloxylon in both categories was different from each other. It was such that the minimum effect was related to category A and its maximum was related to category B. The study of the effect of the type of species in changes

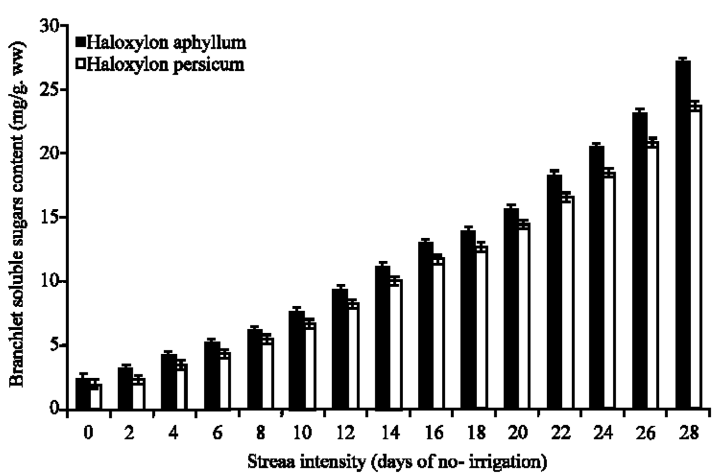

Fig. 1: The impact of the rate of drought stress on average changes of Soluble Sugars (milligram pr gram wet weight) of branchlet of *Haloxylon persicum* and *Haloxylon aphyllum*

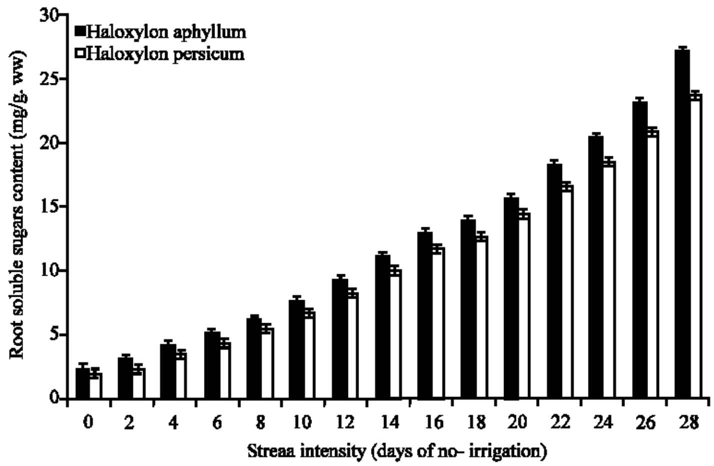

Fig. 2: The impact of the rate of drought stress on average changes of Soluble Sugars (milligram pr gram wet weight) of root of *Haloxylon persicum* and *Haloxylon aphyllum*

Table 4: The impact of the rate of drought stress on average changes of Soluble Sugars (milligram pr gram wet weight) of root of *Haloxylon persicum* and *Haloxylon aphyllum*

Haloxylon persicum	*Haloxylon aphyllum*	Stress intensity (days of no-irrigation)
0.838±0.3100^{0,1}	0.996±0.3500^{0,1}	0
1.537±0.3800^{1,2}	1.808±0.4100^{1,2}	2
2.242±0.4400^{2,3}	2.715±0.3900^{2,3}	4
3.074±0.3500^{3,4}	3.620±0.3100^{3,4}	6
3.877±0.3200^{4,5}	4.689±0.4300^{4,5}	8
4.988±0.3900^{26,27,7}	6.024±0.4100^{6,7}	10
6.291±0.3300^{28,29,8}	7.512±0.3800^{8,9}	12
7.501±0.4600^{30,31,10}	9.191±0.3600^{10,11}	14
9.011±0.3700^{32,33,12}	10.966±0.4500^{12,13}	16
9.812±0.4200^{34,35}	12.861±0.3400^{14,15}	18
11.713±0.3900^{36,37}	14.712±0.4100^{16,17}	20
13.694±0.3100^{38,39}	16.819±0.3800^{18,19}	22
15.488±0.3800^{40,41}	18.760±0.4300^{20,21}	24
17.682±0.4600^{42,43}	21.231±0.4900^{22,23}	26
20.293±0.4300^{44,45}	24.669±0.3500^{24,25}	28

*:One common figure shows the meaningfulness at the level of 5%, two common figures shows the lack of meaningfulness and uncommon figures means its meaningfulness at the level of 1%

Table 5: The impact of the rate of drought stress on average changes of Total Soluble Sugars (milligram pr gram wet weight) of *Haloxylon persicum* and *Haloxylon aphyllum*

*Haloxylon persicum**	*Haloxylon aphyllum**	Stress intensity (days of no-irrigation)
2.647±0.5260^{0,1}	3.114±0.4190^{0,1}	0
3.956±0.4180^{1,2}	4.758±0.6310^{1,2}	2
5.633±0.6290^{2,3}	6.757±0.5240^{2,3}	4
7.366±0.5190^{3,4}	8.531±0.4440^{3,4}	6
9.177±0.5320^{4,5}	10.770±0.4390^{4,5}	8
11.602±0.7410^{6,7,26}	13.518±0.5150^{6,7}	10
14.493±0.6260^{8,9,27}	16.755±0.4320^{8,9}	12
17.440±0.4350^{10,11,28}	20.212±0.6430^{10,11}	14
20.755±0.5380^{12,13,29}	23.865±0.4210^{12,13}	16
22.404±0.4160^{14,15,30}	26.611±0.5350^{14,15}	18
26.141±0.6090^{31,32}	30.312±0.4290^{16,17}	20
30.236±0.7120^{33,34}	34.960±0.5490^{18,19}	22
33.911±0.6430^{35,36}	39.075±0.5330^{20,21}	24
38.528±0.7310^{37,38}	44.249±0.4270^{22,23}	26
44.002±0.5220^{39,40}	51.817±0.6420^{24,25}	28

*:One common figure shows the meaningfulness at the level of 5%, two common figures shows the lack of meaningfulness and uncommon figures means its meaningfulness at the level of 1%

of the content of root's soluble carbohydrate indicates a meaningful difference between these two species at the level of 1%. This difference starts from a treatment of 10 days of lack of irrigation with a 95% reliability and continued from the treatment of 18 days of lack of irrigation onwards at the reliability level of 99% (Table 4 and Fig. 2).

The study of the impact of drought stress on changes of total soluble carbohydrates (branchlet + root) by using the scale of averages in both species of haloxylon (Table 5) confirms the similarity of this effect with the effect of the drought stress on changes of roots soluble sugars. It is such that the effect of tension on changes of total soluble carbohydrates can be classified in two categories of treatment A (0 to 8 days of lack of irrigation) and B (10 to 28 days of lack of irrigation) which the difference between these two categories is meaningful at the level of 1%. The difference between treatments in category A with 95% reliability and in category B with 99% reliability became meaningful. Difference between treatments of tension and control treatment started from the treatment of 2 days of lack of irrigation at possibility level of 95% and continued from treatment of 10 days of lack of irrigation on wards at the level of 99% meaningfulness. The intensity of the effect of drought stress on changes of the rate of total soluble sugars in both species of *Haloxylon persicum* and *Haloxylon aphyllum* in both categories was different. It was such that the least effect was related to the category A and the greatest effect was related to category B. The study of the

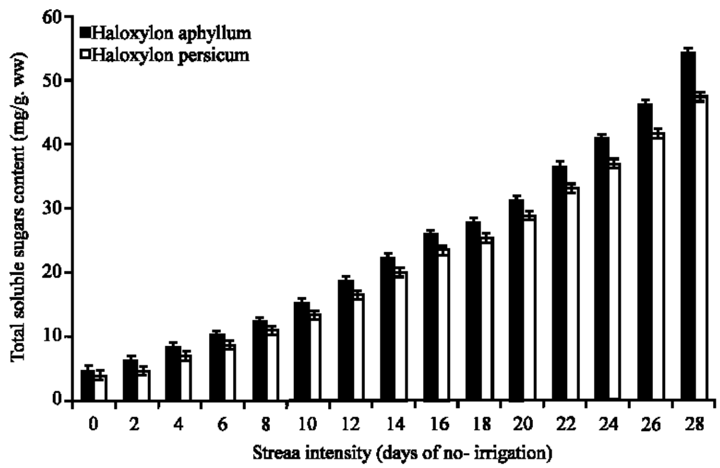

Fig. 3: The impact of the rate of drought stress on average changes of Total Soluble Sugars (milligram pr gram wet weight) of *Haloxylon persicum* and *Haloxylon aphyllum*

effect of species on changes of total soluble carbohydrates contents indicated a meaningful difference between two species of *Haloxylon persicum* and *Haloxylon aphyllum*. It was such that this difference started from the treatment of 10 days of lack of irrigation at the reliability level of 95% and continued from treatment of 20 days of lack of irrigation at the possibility level of 99% (Table 5 and Fig. 3).

DISCUSSION

The study of the average of the content of soluble sugars in two treatments of control and 28 days of lack of irrigation indicate the increase of this osmolyte up to 12.8 times (in branchlets of *Haloxylon aphyllum*) and 13.1 times (in branchlets of *Haloxylon persicum*) at the highest intensity of dryness tension as compared with zero tension. The study of control treatments and 28 days of lack of irrigation of root of these two species also confirms the increase of 24.8 times (in roots of *Haloxylon aphyllum*) and 24.3 times (in roots of *Haloxylon persicum*) of soluble sugars at maximum of the intensity of drought stress as compared with zero tension (Table 6). Though the rate of soluble carbohydrates of branchlet in both species of haloxylon when ideal condition is in place (control or lack of any kind of water tension) in comparison with soluble sugars of root had about 2.1 times increase; however, this increase had a milder slope when inducing drought stress. It was such that at the highest intensity of tension, the rate of soluble carbohydrates of both species branchlets were increased by about 1.1 times of the rate of soluble sugars of root (Table 6).

Table 6: Comparing the Soluble Sugars of branchlet and root of two types of *Haloxylon persicum* and *Haloxylon aphyllum* in drought tensions of zero (standard/check) and 28 days of lack of irrigation

Average of soluble sugars of *Haloxylon aphyllum* (mg g^{-1} wet weight)				Average of soluble sugars of *Haloxylon aphyllum* (mg g^{-1} wet weight)			
Root		Branchlet		Root		Branchlet	
28 Days	Control	28 Days	Control	28 Days	Control	28 Days	Control
420.293	0.838	323.709	1.809	224.669	0.996	2.118	127.148

[1]-12.8 times the control value [2]-24.8 times the control value, [3]-13 times the control value, [4]-24.2 times the control value

Studies conducted on plants of peas (Ford, 1984), tomato (Handa *et al*., 1983), Pigeonpea (Keller and Ludlow, 1993), different varieties of wheat (Kameli and Losel, 1993), different geo types of winter wheat (Kameli and Losel, 1993) and corn (Permachandra *et al*., 1993) showed the rate of soluble sugars in plant increased as a result of drought stress. This shows the compatibility of plant with the external environment which as a result of water shortage, the plant balances its osmotic potential proportion with the external environment by increasing its soluble sugars at the level of cells. By reducing activities in roots and reducing the metabolism of carbohydrates as a result of intensive tension, the plant reduces the transfer of sugars in rinsing vessels (Westgate and Peterson, 1993).

Anyway, it seemed that at the time of existence of ideal wet conditions, the rate of soluble sugar of branchlet of both types of *Haloxylon persicum* and *Haloxylon aphyllum* is more than 2 time of the rate of soluble carbohydrates of their roots. But in harmony with the increase of dryness and in proportion with their intensity and in the maximum rate of water tension, about 50% of this ratio reduced and diminished by about 1.1 times. This indicates the importance of allocation and strategy of the root of these two types of haloxylon in confronting with intensive drought. On the other hand, the increase of almost 25 times of soluble sugars of root (in the treatment of 28 days of lack of irrigation) in both species of haloxylon proportion with their corresponding control content and their comparison with the increase of almost 13 times of soluble sugars of branchlet (in treatment of 28 days of lack of irrigation), in both species as compared with their corresponding control indicate a more organized role of root in confronting with intensive and almost long term drought.

The results of this research showed the rate of soluble carbohydrates increased under the influence of water tension (Tables 3, 4 and 5). The increase (proportion with the tension intensity) of the rate of protecting enzymes (Li *et al*., 2010; Ren, 2009; Yang *et al*., 2009), analyzing compound carbohydrates into simple carbohydrates and reduction of transfer of sucrose to the outside of leaf are among the factors for the increase and accumulation of soluble carbohydrates in identified drought conditions (Pereira and Chaves, 1993) and play an important role adjusting the Osmosis (Watanabe *et al*., 2000; Morgan, 1984). The rate of increase of total soluble carbohydrates in the conditions of drought stress in both species of *Haloxylon persicum* and *Haloxylon aphyllum* proportion with the intensity of tension was changing. It had a very important role in reducing the Osmotic potential and increase of water absorption. A lower rate of soluble sugars in control treatments of roots and branchlets of both species of haloxylon as compared with the high quantities of these sugars in the highest treatment of tension (28 days of lack of irrigation) confirms this idea that prevention from damages resulting from intensive drought tension has a positive correlation with the increase of quantities of soluble sugars (Table 6).

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