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RESEARCH ARTICLE

ECOPHYSIOLOGICAL STUDIES OF THREE DESERT PLANTS GROWING IN TWO DIFFERENT HABITATS, CENTRAL REGION, SAUDI ARABIA

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ABSTRACT

Physiological adjustment to enhance tolerance or avoidance of drought were studied in three desert plants growing in Al-Thomamah and Al-Derayah habitats, central region, Saudi Arabia. Studied plants *Tamarix aphylla* L., *Zygophyllum coccineum* L. and *Artemisia monosperma* Del. were collected from three stands for each habitat in March 2012. Cell sap osmotic potential, some organic (soluble sugars, total lipids content, soluble proteins, and free fatty and amino acids) and inorganic (K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and HCO_3^-) soluble concentration were determined. In addition, chlorophyll a, b, and total nitrogen content and physiochemical parameters of the soil samples support the studied three plants were also determined. Substantial osmotic adjustment (up to 2.6 MPa) was observed in Z. *coccineum* collected from Al-Thomamah habitat. *Tamarix aphylla* was dependent on soluble sugars, soluble proteins, and free amino acids, Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-} to readjust their internal osmotic pressure and to improve its water status. It preferred Mg^{2+} concentration more than the two other plant species. *Zygophyllum coccineum* accumulated inorganic more than *Tamarix aphylla* and less free amino acids. The results suggest that, the osmotic adjustment was the main water relationship adaptation to cope with drought. Accumulation of soluble sugars, soluble proteins, free fatty and amino acids (especially proline) and inorganic elements at higher concentration often assist in turgor maintenance and helped to enhance drought tolerance.

INTRODUCTION

High temperature, high irradiance, scarce water, erratic rainfall and sand storms are climatic features of the arid environment of the central region of Saudi Arabia (Fisher and Mamery, 1998). Geomophologically, the region reveals land forms including sand plain, hills and high mountains (Ghazanfar, 1998). The wet season is a short three months period (January – March) and the long hot season extends over nine months. Most plants in the desert ecosystem are primarily depending on the availability of water. In these ecosystems, the scarce erratic rainfall is generally combined with temperatures, high evaporation and sand storms. Most of these plants are exposed to water stress due to extreme soil water deficits in arid and semi arid regions. The survival of land plants in such areas relies on the availability of water and their adaptation under stress (Kramer, 1984; Sayed *et al*., 2013). Physiological adaptation to arid environments in many desert plants amides at improving water use efficiency (Borland *et al*., 2000; Drennan, 2009; Masrahi *et al*., 2011). The adaptation in desert plants is due to their ability to maintain their turgidity and water uptake. The most important mechanism to maintain the plant water potential more negative than the external medium to insure the water uptake. So, the plants have the ability to accumulate the inorganic solutes in high quantities inside their tissues (Kan *et al*., 2000; Gadallah *et al*., 2001; Mile *et al*., 2002; Kamel, 2007). The desert plants also tend to accumulate the most compatible solutes in cytoplasm to balance the osmotic pressure inside the cells, especially by increasing their content of organic solutes (Mile *et al*., 2002). Ecophysiological studies have been powerful in elucidating plant function and identifying traits that are adaptive in specific environmental conditions (Ackerly *et al*., 2000). Therefore, in the present study we focus on some ecophysiological aspects of three of the most common dominant wild plants, *Tamarix aphylla* L., *Zygophyllum coccineum* L. and *Artemisia monosperma* Del. and corresponding sediments samples were collected from two different habitats from central region of Saudi Arabia to understand the possibility of osmatic adjustment as well as the physiological adaptional traits adopted by these plants to resist drought in the desert environment. Accordingly, cell osmotic potential, some organic solutes (soluble sugars, total lipids content, soluble proteins, and free fatty and amino acids) and inorganic (K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and HCO_3^-) were estimated to study their role in adjustment. In addition, chlorophyll a, b, total nitrogen content and physiochemical parameters of the soil samples supported the studied three plants from two different habitats (Al-Thomamah and Al-Derayah) were also determined.

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MATERIALS AND METHODS

Study area

The study area includes two different habitats Al-Thomamah and Al-Derayah in the central region of Saudi Arabia. Al-Thomamah lies at latitude 25º 11$^{/}$ 8$^{//}$ N and longitude 46º 38$^{/}$ 2$^{//}$ E, at an average altitude of 575 m.b.s.l. This area locate to northeast of Riyadh City, about 80 km away from Erqh Mountain and covered an area about 290 km^2 (Fig. 1). The second habitat Al-Derayah lies at latitude 24º 53$^{/}$ 52$^{//}$ N and longitude 46º 17$^{/}$ 54$^{//}$ E, at an average altitude of 568 m.a.s.l. It is locating to the northwest direction of Riyadh City, about 25 km away and covered an area about 180 km^2 (Fig. 1).

Plant and soil samples collection

Tamarix aphylla L., *Zygophyllum coccineum* L. and *Artemisia monosperma* Del. and the surrounding soil were collected from three stands (20 x 20 m) in each habitat in March 2012. The species included in the present research were selected according to coverage and abundance. In each stand three plant species and corresponding soil samples were collected for each habitat and then they were mixed up to form a composite plants and soil samples. Three plants species were prepared for each species at each habitat. Sediment samples were collected using a stainless steel collector at about 10 to 50 cm depth.

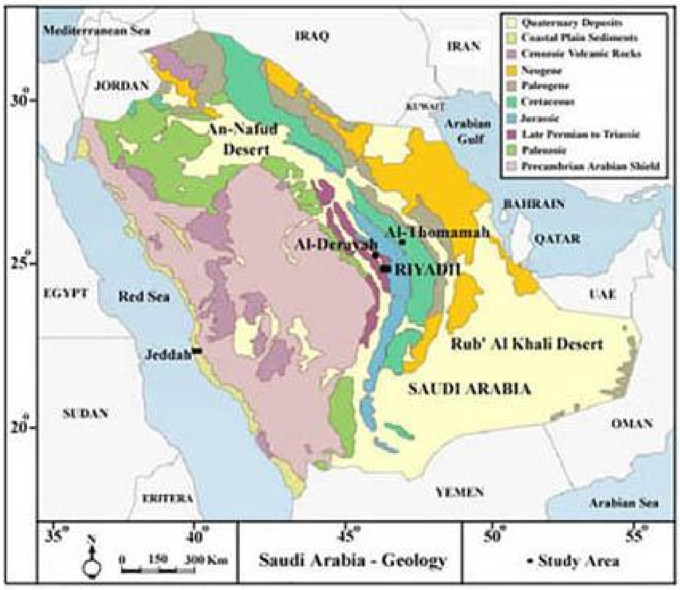

Fig. 1. Location map of the study area

Samples preparation and measurements

Plants shoots samples were dried in an aerated oven at 70 ºC to constant mass and the water content was calculated on fresh weight (FW) for plant materials. Soil samples were dried in an aerated oven at 105 ºC to constant mass and the water content was calculated on dry weight (DW) for the soil samples. Different fractions of the soil samples were separated by dry sieving methods (Jackson, 1962; Ryan *et al*., 1996). Water extracts (1:5 ratios with air dry soil) were prepared to meet the requirement for different determination. The air dry plants samples was ground and powered to pass a 60 mesh screen and kept in desiccators. Exactly from the plants samples powered 0.5 gm was taken and extracted in 25 ml distilled water by heating at 9 ºC in water bath for two hours and centrifuged at 2000 r.p.m. for 15 minutes.

The osmotic potential of shoot extracts was measured by using CL- Osmometer. Chlorophyll a and b contents were measured spectrophotometrically (Wellbum, 1994). Soluble sugars contents were determined according to Buysse and Merckx (1993). Total nitrogen content was measured as the method of Peach and Tracey (1956). In the plant extracts soluble lipids content was determined according to the procedures described by Brain and Turner (1975). Fatty acids were measured by Gas Liquid Chromatography, Perkin Elmer Precisely, Clarus 500 (Morrison and Smith, 1964). Protein content and free amino acids were determined according to the procedures by Lowry *et al*. (1951) as well as Lee and Takahashi (1966) respectively. Sodium and potassium were analyzed by flame photometer technique. In this respect flame photometer M7D was used. Calcium and magnesium were determined volumetrically by versene titration method (Jackson, 1962). Chloride content was determined by $AgNO_3$ titration method as described by Johnson and Ulrich (1959). Sulfate contents were determined by a turbidemetric technique as $BaSO_4$ using barium chloride and acidic sodium chloride solution according to Bardsley and Lancaster (1965). pH was measured by using Mettler Toledo MP220 and electric conductivity by using Electric Conductivity Meter (Fresenius *et al*., 1988). Total soluble salts were determined according to the procedures described by Jackson (1962). Bicarbonate was measured by titration method (Richards, 1954). The significant differences between three plant species in response to collection site differences were determined by variance analysis (Ostl, 1963).

RESULTS

Soil analyses

Physicochemical characters of the soil samples collected from two habitats were represented in table 1. The soil texture was sand, clay and silty loam in all stands from two habitats. The pH values fluctuated in the basic range. Generally non significant differences in the soil pH due to the location changes were noticed. The lowest pH value was recorded under *Z. coccineum* and the highest value under *A. monosperma* at Al-Thomamah habitat. Electric conductivity and total soluble salts values ranged between 522 µS cm^{-1} and 0.15% at Al-Thomamah habitat under *Z. coccineum* and 2789 µS cm^{-1} and 0.35% at Al-Derayah habitat under *A. monosperma* respectively. The percentages of soil water content ranged from 1.42% under *Z. coccineum* at Al-Thomamah habitat to 3.51% under *A. monosperma* at Al-Derayah habitat. The lowest value of organic matter was 0.07% under *A. monosperma* at Al-Derayah habitat, while the highest value was 0.22% under *T. aphylla* at Al-Thomamah habitat. Total nitrogen content varied from 2.86% under *Z. coccineum* at Al-thomamah habitat to 4.58% under *A. monosperma* at Al-Derayah habitat. Major elements content in the soil samples were illustrated in Table 1. According their concentrations, the minerals elements were arranged as general in the following order: $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+} > Cl^{-} > SO_4^{2-} > HCO_3^{-}$.

Table 1. Physiochemical parameters of soil samples from Al-Thomamah and Al-Derayah habitats (Ions contents were measured as mg g^{-1} DW). Data are means of three replicates ± ES

	Al – Thomamah habitat Plant species			Al – Derayah habitat Plant species		
Parameters	*Tamarix aphylla*	*Zygophyllum coccineum*	*Artemisia monosperma*	*Tamarix aphylla*	*Zygophyllum coccineum*	*Artemisia monosperma*
Gravel (%)	1.12	4.62	10.11	4.50	11.17	5.64
Coarse sand (%)	3.26	11.50	34.64	15.28	26.06	12.94
Fine sand (%)	83.40	71.76	44.96	75.04	48.93	73.10
Silt (%)	4.35	7.20	3.68	4.33	6.40	6.20
Clay (%)	7.87	4.92	6.61	0.85	7.44	2.12
PH	7.22±0.06	7.10±0.05	8.71±1.7	7.71±0.02	7.61±0.04	8.57±0.09
EC (µs cm^{-1})	804±26	522±36	676±22	2122±19	2111±16	2789±14
TSS (%)	0.19±0.06	0.15±0.05	0.18±0.05	0.38±0.08	0.3±0.05	0.35±0.5
WC (%)	1.73±0.7	1.42±0.19	1.72±0.14	2.91±0.06	2.93±0.14	3.51±0.19
OM (%)	0.22±0.12	0.18±0.06	0.09±0.02	0.18±0.06	0.21±0.07	0.07±0.02
TN (%)	3.07±0.33	2.86±0.25	4.19±0.27	3.72±0.18	2.67±0.24	4.58±0.20
K^+	47±0.42	23±0.37	13±0.48	95±0.22	74±0.14	20±0.28
Na^+	193±0.30	471±0.42	197±0.43	157±0.93	135±0.92	131±0.54
Ca^{2+}	420±0.38	470±0.34	497±0.35	548±0.61	631±0.66	463±0.40
Mg^{2+}	308±0.32	310±0.28	273±0.33	136±0.53	389±0.85	415±1.00
Cl^-	3.0±0.50	2.56±0.59	0.72±0.29	8.83±0.50	9.0±0.50	2.0±0.5
SO_4^{2-}	2.0±0.27	1.21±0.15	1.38±0.25	3.62±0.12	2.41±0.17	3.65±0.30
HCO_3^-	1.91±0.09	2.66±0.45	2.70±0.09	1.77±0.10	2.68±0.12	2.11±0.09

Explanations: EC – electric conductivity, TSS – total soluble salts, WC – water contents, OM – organic matter, TN – total nitrogen.

Table 2. F – values of Physiochemical parameters of soil samples from Al-Thomamah and Al-Derayah habitats

Soil parameters	PH	EC	TSS	WC	OM	TN	K^+	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-
	2.01^{ns}	4.06^{ns}	4.34^{ns}	23.12**	19.02*	3.05^{ns}	2.03^{ns}	17.04*	18.13*	41.22**	29.45**	16.32*	5.04^{ns}

Explanations: * - significant at 5% confidence level, ** - significant at 1% confidence level, ^{ns} – non significant.

Generally, Na^+ contents were higher than those of K^+. The maximum value of Na^+ (471 mg g^{-1} DW) was recorded under Z. *coccineum* at Al-Thomamah habitat, but the minimum value (131 mg g^{-1} DW) was detected under *A. monosperma* at Al-Derayah habitat. K^+ contents ranged from 13 mg g^{-1} DW under *A. monosperma* at Al-Thomamah habitat to 95 mg g^{-1} DW under *T. aphylla* at Al-Derayah habitat. Calcium contents were higher than those of magnesium and were fluctuated according to the collection stands differences for each habitat. Ca^{2+} content ranged from 420 mg g^{-1} DW under *T. aphylla* at Al-Thomamah habitat to 631 mg g^{-1} DW under Z. *coccineum* at Al-Derayah habitat. The highest Mg^{2+} content (415 mg g^{-1} DW) was recorded under *A. monosperma*, while the lowest value (136 mg g^{-1} DW) was detected under *T. aphylla* at Al-Derayah habitat. The lowest Cl^- content was recorded (0.72 mg g^{-1} DW) under *A. monosperma* at Al-Thomamah habitat and the highest value (9.0 mg g^{-1} DW) under Z. *coccineum* at Al-Derayah habitat. Sulfate content ranged from 1.21 mg g^{-1} Dw under Z. *coccineum* at Al-Thomamah habitat to 3.65 mg g^{-1} DW under *A. monosperma* at Al-Derayah habitat. Bicarbonate varied from 1.77 mg g^{-1} DW under *T. aphylla* at Al-Derayah habitat to 2.70 mg g^{-1} DW under *A. monosperma* at Al-thomamah habitat. The effects of collection habitats differences on the elements contents as indicated by F-value (Table 2) were statistically significant for Mg^{2+}, Cl^- and soil water content at 1% confidence level. Na^+, Ca^{2+}, SO_4^{2-} and organic matter were statistically significant at 5% confidence level.

Plant analyses

Chlorophyll a and b contents were higher in *A. monosperma* and *T. aphylla* than in the Z. *coccineum* in two habitats. Chlorophyll a content was varied from 1.35 mg g^{-1} FW of leaves in Z. *coccineum* at Al-Derayah habitat to 1.65 mg g^{-1} FW of leaves in *A. monosperma* at Al-Thomamah habitat (Table 3). Chlorophyll b ranged from 0.67 mg g^{-1} FW in Z. *coccineum* at Al-Derayah habitat to 0.93 mg g^{-1} FW in *A. monosperma* at Al-Thomamah habitat. Shoot water content (Table 3) showed slight variation with collection habitat difference *T. aphylla*, Z. *coccineum* and *A. monosperma*. In general *A. monosperma* growing at Al-Derayah had higher content than those collected from Al-Thomamah habitat. The studied plants show a clear response in their osmotic potential to their arid environment (Table 3). The highest shoot osmotic potential reached about 2.9 MPa in Z. *coccineum* at Al-Derayah habitat, while the lowest value was recorded in Z. *coccineum* (2.6 MPa) at Al-Thomamah habitat. The nitrogen content varied from 26.25% in *T. aphylla* to 38.13% in *A. monosperma* at Al-Derayah habitat (Table 3). In *T. aphylla*, soluble sugar content attain the highest value (8.90 mg g^{-1} DW) at Al-Derayah habitat, but the lowest value (5.97 mg g^{-1} DW) was recorded in Z. *coccineum* at Al-Thomamah habitat (Table 3). Total lipids content (Table 3) showed great variation with collection from two different habitats in three studied plants species. Total lipids varied from 1.70 mg g^{-1} DW in Z. *coccineum* at Al-Thomamah habitat to 4.20 mg g^{-1} DW in *A. monosperma* at Al-Derayah habitat. Soluble protein contents (Table 3) ranged between 8.92 mg g^{-1} DW in *A. monosperma* at Al-Thomamah habitat and 12.25 mg g^{-1} DW in *T. aphylla* at Al-Derayah habitat. Free fatty acids showed great variation with collection from two different habitats in *T. aphylla*, Z. *coccineum* and *A. monosperma* (Table 4). The lowest percentage of fatty acids (stearic fatty acid) 1.83% was recorded in Z. *coccineum*, but the highest percentage (olic fatty acid) 36.50% in *A. monosperma* at Al-Derayah habitat. The free fatty acids were recorded in three studied plants species at the two different habitats are palmitic, stearic and olic fatty acids. Linolic fatty acid was recorded only in *A. monosperma* at two habitats (Table 4).

Table 3. Variations in chlorophyll a , b, shoot water contents, osmotic potential, total nitrogen, soluble sugars, total lipid and soluble protein contents of *Tamarix aphylla*, *Zygophyllum coccineum* and *Artemisia monosperma* plant species in two different habitats. Data are means of three replicates ± SE.

Parameters	Plant species	Al – Thomamah habitat	Al – Derayah habitat
Chlorophyll a content (Chl a mg g^{-1} FW of leaves)	*Tamarix aphylla*	1.63 ± 0.56	1.57 ± 0.63
	Zygophyllum coccineum	1.40 ± 0.06	1.35 ± 0.36
	Artemisia monosperma	1.65 ± 0.8	1.43 ± 0.56
Chlorophyll b content (chl b mg g^{-1} FW of leaves)	*Tamarix aphylla*	0.91 ± 0.25	0.89 ± 0.34
	Zygophyllum coccineum	0.72 ± 0.02	0.67 ± 0.07
	Artemisia monosperma	0.93 ± 0.05	0.75 ± 0.27
Shoot water content (WC %)	*Tamarix aphylla*	80.67 ± 0.96	73.00 ± 1.28
	Zygophyllum coccineum	71.61 ± 1.23	78.45 ± 1.00
	Artemisia monosperma	73.61 ± 1.27	82.00 ± 1.00
Osmotic potential (OS, MPa)	*Tamarix aphylla*	2.8 ± 1.56	2.8 ± 1.49
	Zygophyllum coccineum	2.6 ± 1.06	2.9 ± 1.41
	Artemisia monosperma	2.7 ± 1.22	2.7 ± 1.46
Total nitrogen content (TN %)	*Tamarix aphylla*	32.40 ± 0.48	26.25 ± 0.45
	Zygophyllum coccineum	30.45 ± 0.49	30.24 ± 0.63
	Artemisia monosperma	35.83 ± 0.60	38.13 ± 0.61
Soluble sugars content (SS, mg g^{-1} DW)	*Tamarix aphylla*	7.70 ± 0.62	8.90 ± 0.60
	Zygophyllum coccineum	5.97 ± 0.24	6.60 ± 0.20
	Artemisia monosperma	6.90 ± 0.53	7.83 ± 0.35
Total lipid content (TL, mg g^{-1} DW)	*Tamarix aphylla*	2.50 ± 0.78	2.83 ± 0.61
	Zygophyllum coccineum	1.70 ± 0.44	1.83 ± 0.51
	Artemisia monosperma	4.13 ± 0.71	4.20 ± 0.66
Soluble protein content (SP, mg g^{-1} DW)	*Tamarix aphylla*	10.53 ± 0.51	12.25 ± 0.68
	Zygophyllum coccineum	9.58 ± 0.35	11.38 ± 1.22
	Artemisia monosperma	8.92 ± 0.62	9.64 ± 1.52

Table 4. Variations percent in free fatty acids of *Tamarix aphylla*, *Zygophyllum coccineum* and *Artemisia monosperma* plant species in two different habitats

	Al – Thomamah habitat			Al – Derayah habitat		
Plant species	Number of C.atom	%	Name of fatty acid	Number of C.atom	%	Name of fatty acid
Tamarix aphylla	16:0	22.8	Palmitic	16:0	30.20	Palmitic
	18:0	17.44	Olic	18:0	14.71	Stearic
	18:1	29.06	Stearic	18:1	10.64	Olic
Zygophyllum coccineum	16:0	4.78	Palmitic	16:0	30.50	Palmitic
	18:0	1.2	Stearic	18:0	1.83	Stearic
	18:1	2.6	Olic	18:1	2.83	Olic
Artemisia monosperma	16:0	33.70	Palmitic	16:0	19.96	Palmitic
	18:0	14.56	Stearic	18:0	13.90	Stearic
	18:1	17.20	Olic	18:1	36.50	Olic
	18:3	1.99	Linolic	18:3	2.05	Linolic

Table 5. Variations percent in free amino acids of *Tamarix aphylla*, *Zygophyllum coccineum* and *Artemisia monosperma* plant species in two different habitats

	Al – Thomamah habitat			Al – Derayah habitat		
Amino acid	*Tamarix aphylla*	*Zygophyllum coccineum*	*Artemisia monosperma*	*Tamarix aphylla*	*Zygophyllum coccineum*	*Artemisia monosperma*
Asp	5.76	1.18	3.43	1.55	4.68	3.41
Thr	0.94	1.99	1.80	8.30	0.86	27.38
Ser	0.39	2.96	4.28	0.74	5.06	--
Glu	1.42	--	--	--	--	--
Pro	55.27	32.80	40.53	73.91	20.59	40.82
Gly	0.31	2.99	10.27	4.15	2.12	--
Ala	2.42	--	--	--	--	4.23
Val	1.25	6.40	5.50	1.95	10.97	3.99
Iie	--	--	2.06	--	1.69	1.02
Leu	--	--	4.09	--	0.94	1.01
Tyr	3.34	20.72	11.23	4.65	13.23	8.15
Phe	0.73	--	2.85	0.99	1.67	2.49
His	--	7.45	3.46	--	10.52	1.94
Lys	0.64	13.10	3.95	1.03	8.74	1.74
Arg	32.11	5.84	6.53	2.72	18.93	3.82

Fifteen free amino acids were recorded in three studied plants species at the two habitats with highly great variation between them (Table 5). Free amino acids ranged between 0.31% (Gly. amino acid) in *T. aphylla* at Al_thomamah habitat and 73.91% (Pro. amino acid) in *T. aphylla* at Al-Derayah. Also, Glu. amino acid (1.42%) was recorded only in *T. aphylla* at Al-Thomamah habitat. The proline amino acid recorded the highest value in the three studied plants of the two different habitats (Table 5). The major elements contents in the three studied plants were displayed in table 6. Potassium concentration ranged between 320 mg g^{-1} DW in *T. aphylla* at Al-Thomamah habitat and 617 mg g^{-1} DW in *A. monosperma* at Al-Derayah habitat (Table 6). Sodium content fluctuated from 433 mg g^{-1} in *T. aphylla* to 677 mg g^{-1} DW in Z. *coccineum* at Al-Derayah habitat. The range of calcium varied from 325 mg g^{-1} DW in *A. monosperma* at Al-Derayah habitat to 691 mg g^{-1} in *T. aphylla* at Al-Thomamah habitat. Magnesium concentration varied from 199 mg g^{-1} DW in *A. monosperma* at Al-Thomamah habitat to 566 mg g^{-1} in Z. *coccineum* at Al-Derayah habitat (Table 6). The minimum value of chloride (620 mg g^{-1} DW) was recorded in *T. aphylla* at Al-Thomamah habitat, while the maximum value (698 mg g^{-1} DW) in *A. monosperma* at Al-Derayah habitat (Table 6).

The minimum and maximum values of sulfate were recorded in *T. aphylla* and Z. *coccineum* (701 and 795 mg g^{-1} DW) at Al-Thomamah habitat respectively. Accordingly the main values of Cl^- and SO_4^{2-} of the three studied plants from two habitats can be arranged as the followind order: *A. monosperma* > Z. *coccineum* > *T. aphylla*. Although all major elements contents in the soil samples were small, the studied three plants species showed high content of all major elements, especially HCO_3^- is the highest one (Table 6). The range of HCO_3^- showed slight variation with a minimum value of 785 and a maximum value of 880 mg g^{-1} DW in *T. aphylla* and in Z. *coccineum* at Al-Thomamah and Al-Derayah habitats respectively (Table 6). The effects of collection from two different habitats changes on the contents of chlorophyll and water content were statistically significant at 1% confidence level for the three studied plants species (Table 7). Mostly non significant differences in soluble proteins were noticed between plants collected from two habitats as indicated by the analysis of variance in Z. *coccineum* and *A. monosperma*. Mostly no significant difference of Na^+, Mg^{2+} and Cl^- contents were noticed in Z. *coccineum* and *A. monosperma* plants species collected from two different habitats. On the contrary, contents of Ca^{2+}, Mg^{2+} and Cl^- were significantly affected by collection from two different habitats in *T. aphylla* (Table 7).

Table 6. Variations in elements contents (mg g^{-1} DW) of *Tamarix aphylla*, *Zygophyllum coccineum* and *Artemisia monosperma* plants pecies in two different habitats. Data are means of three replicates ± SE

Parameters	Plant species	Al – Thomamah habitat	Al – Derayah habitat
Potassium (K^+)	*Tamarix aphylla*	320.83±0.56	543.21±0.38
	Zygophyllum coccineum	586.50±0.42	641.69±0.22
	Artemisia monosperma	325.41±0.40	617.38±0.31
Sodium (Na^+)	*Tamarix aphylla*	518.81±0.47	433.18±0.41
	Zygophyllum coccineum	662.79±0.39	677.91±0.40
	Artemisia monosperma	476.91±0.38	597.36±0.19
Calcium (Ca^{2+})	*Tamarix aphylla*	691.23±0.29	625.39±0.24
	Zygophyllum coccineum	676.54±0.27	5121.75±0.31
	Artemisia monosperma	382.92±0.44	325.50±0.44
Magnesium (Mg^{2+})	*Tamarix aphylla*	350.30±0.35	377.31±0.40
	Zygophyllum coccineum	527.85±0.30	566.87±0.29
	Artemisia monosperma	199.95±0.33	128.38±0.31
Chloride (Cl^-)	*Tamarix aphylla*	620.21±0.15	630.54±0.22
	Zygophyllum coccineum	639.75±0.43	654.87±0.53
	Artemisia monosperma	651.22±0.54	698.32±0.13
Sulfate (SO_4^{2-})	*Tamarix aphylla*	701.76±0.23	735.14±0.23
	Zygophyllum coccineum	795.45±0.13	770.13±0.56
	Artemisia monosperma	780.12±0.44	756.65±0.45
Bicarbonate (HCO_3^-)	*Tamarix aphylla*	785.03±0.08	786.23±0.36
	Zygophyllum coccineum	810.31±0.67	880.65±0.34
	Artemisia monosperma	807.13±0.38	813.15±0.22

Table 7. F - values for chlorophyll (chl a, chl b), shoot water content (WC), Osmotic potential (OP), Total nitrogen content (TN), soluble sugars content (SS), Total lipid content (TL), Soluble protein content (SP) and K^+, Na^+ Ca^{2+} Mg^{2+} Cl^- SO_4^2 HCO_3^- in *Tamarix aphylla*, *Zygophyllum coccineum* and *Artemisia monosperma* plant pecies in two different habitats

Parameters	*Tamarix aphylla*	*Zygophyllum coccineum*	*Artemisia monosperma*
Chlorophyll (chl a)	128.92**	17.22*	89.41**
Chlorophyll (chl b)	76.23**	148.52**	13.78*
water content (WC)	147.73**	76.18**	451.54**
Osmotic potential (OP)	13.22*	12.65*	11.42*
nitrogen content (TN)	22.13**	21.98**	23.42**
Soluble sugars (SS)	28.19**	5.24^{ns}	26.48**
lipid content (TL)	16.24*	15.54*	14.62*
Soluble protein (SP)	25.48**	4.32^{ns}	5.83^{ns}
Potassium (K^+)	21.18**	13.12*	64.52**
Sodium (Na^+)	8.54^{ns}	3.83^{ns}	255.22**
Calcium (Ca^{2+})	23.65**	4.38^{ns}	274.82**
Magnesium (Mg^{2+})	24.76**	6.35^{ns}	7.43^{ns}
Chloride (Cl^-)	181.75**	9.54^{ns}	7.22^{ns}
Sulfate (SO_4^{2-})	2.89^{ns}	74.82**	2.28^{ns}
Bicarbonate (HCO_3^-)	3.24^{ns}	82.65**	4.62^{ns}

Explanations: * - significant at 5% confidence level, ** - significant at 1% confidence level, ^{ns} – non significant.

The minimum value of chloride (620 mg g^{-1} DW) was recorded in *T. aphylla* at Al-Thomamah habitat, while the maximum value (698 mg g^{-1} DW) in *A. monosperma* at Al-Derayah habitat (Table 6). The minimum and maximum values of sulfate were recorded in *T. aphylla* and Z. *coccineum* (701 and 795 mg g^{-1} DW) at Al-Thomamah habitat respectively. Accordingly the main values of Cl^- and SO_4^{2-} of the three studied plants from two habitats can be arranged as the followind order: *A. monosperma* > Z. *coccineum* > *T. aphylla*. Although all major elements contents in the soil samples were small, the studied three plants species showed high content of all major elements, especially HCO_3^- is the highest one (Table 6). The range of HCO_3^- showed slight variation with a minimum value of 785 and a maximum value of 880 mg g^{-1} DW in *T. aphylla* and in Z. *coccineum* at Al-Thomamah and Al-Derayah habitats respectively (Table 6). The effects of collection from two different habitats changes on the contents of chlorophyll and water content were statistically significant at 1% confidence level for the three studied plants species (Table 7). Mostly non significant differences in soluble proteins were noticed between plants collected from two habitats as indicated by the analysis of variance in Z. *coccineum* and *A. monosperma*. Mostly no significant difference of Na^+, Mg^{2+} and Cl^- contents were noticed in Z. *coccineum* and *A. monosperma* plants species collected from two different habitats. On the contrary, contents of Ca^{2+}, Mg^{2+} and Cl^- were significantly affected by collection from two different habitats in *T. aphylla* (Table 7).

DISCUSSION

To subdue the external stresses as salinity or water deficiency, the plants tend to readjust their internal osmotic pressure (Kamel, 2007). Osmotic adjustment is considered as one of the most important adaptations of plants to drought, because it allows to maintain absorption, cell turgor and metabolic activity during periods of drought stress, and also enables quick resumption of growth when water becomes available again (Fahmy and Swaf, 1992; Scholz *et al*., 2012). The adaptation of the three investigated plants to the arid environment in term of osmotic adjustment was documented in the research. Substantial osmotic adjustment (up to 2.9 MPa) was observed in *T. aphylla* (Table 3). To overcome the soil water deficiency, the plants tend to reduce their internal osmotic potentials through accumulation of osmotically active metabolites (soluble sugars), inorganic solutes (K^+, Ca^{2+}, Mg^{2+} and Cl^-) and improved water retention properties through the accumulation of soluble proteins (Tables 3 and 6). The amount of bound water depends on the availability of organic solutes (Boscalu *et al*., 2009). Organic solutes, especially soluble sugars played most important role in drought adaptation in xerophytes (Paleg *et al*., 1984). In the three studied desert plants species SO_4^{2-} and HCO_3^- ions were accumulated in high concentration compared with Na^+ ions. *Zygophyllum coccineum* was dependent mainly on inorganic solutes in their osmotic adjustment. Therefore, its contents of K^+, Ca^{2+} and Mg^{2+} ions were higher than in the other two studied plants species. *Tamarix aphylla* was dependent upon Ca^{2+} as cationic osmotical while, *Artemisia monosperma* dependent on Cl^- anionic osmotical.

Organic solutes known as compatible solutes include sugars, glycerol, fatty acids, amino acids and other low molecular weight metabolites, serve a function in cells to lower balance the osmotic potential of intracellular and extracellular ions in resistance to osmotic stress (Alkhail and Moftah, 2011). The present data showed that *T. aphylla* and *A. monosperma* had higer soluble sugars content and chlorophyll content than Z. *coccineum*. The higher accumulation of soluble sugars with corresponding higher chlorophyll content means that the increase in soluble sugars was the results of higher photosynthetic activities. The higher soluble sugars concentration may be an adaptive response which involves adjustment of osmotic potential that facilitates the maintenance of favorable water balance (Pelag *et al*., 1984; Gadallah, 2001; Kamel, 2007; Chen and Jiang, 2010; Sayed *et al*., 2013). Soluble protein, total lipids and total nitrogen contents in the three studied plants species were higher than the free fatty and amino acids. Protein and lipids accumulation in leaves and roots are associated with improved drought tolerance (Premachandrea *et al*., 1992). In Z. *coccineum* plant species, the free fatty and amino acids reduced notably under drought (Tables 4 and 5). Therefore, amino acids especially proline may be the major osmotic solute in the osmotic adjustment of all species in drought environment. On the contrary, free fatty and amino acids contents were higher in *T. aphylla* and *A. monosperma* collected from Al-Thomamah and Al-Derayah habitats. Accumulation of free fatty and amino acids under such conditions can be explained by enhancement proteolysis of proteins, inhibition of fatty and amino acids incorporation in protein synthesis or both (Merewitz *et al*., 2011). Accumulation of fatty and amino acids under water stress may be actually a part of an adaptive process contributing to osmotic adjustment and has been taken as an index for determining the drought tolerant potential of many plants species (Duby, 1994; Gadallah, 1995; Ramanjulu and Sudhakar, 1997).

According to the specific mechanism of elements absorption and utilization, the ability of the study plants to absorb and accumulate ions at different extent appears well documented. Generally, the contents of SO_4^{2-} and HCO_3^- were higher than the other estimated ions in all collected habitats. K^+ largely accumulated in the shoots of the studied three plants collected from two different habitats may be to avoid Na^+ toxicity (Table 6). On the contrary, Na^+ contents were lower than Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and HCO_3^- (expect in *A. monosperma*) at two different habitats. Z. *coccineum* preferred Mg^{2+} more than *T. aphylla* and *A. monosperma*, such variation in elements accumulation at two different habitats indicate the ability of the study three plant species to regulate the uptake and accumulation of the elements from the external source according to their adjustment requirements. This means that ions are the most important in generation of osmotic potential in the studied xerophytes plants. The water status and cell turgidity are the most important features for plants especially desert plants, to ensure the biological processes. In the present research, the maintenance of relatively high water content despite the development of the low water potential appears to be a common trait in the studied plants species. Accumulation of soluble sugars and some minerals ions (Tables 3 and 6) and the strong dehydration action of sulfates content on the cell proteins often assist in turgor maintenance.

Conclusion

The present study gives a good idea about the physiological behavior of three of the most common plants in Al-Thomamah and Al-Derayah habitats, central region, Saudi Arabia. The results indicate that, to solute the external stress in the arid environment, the studied three plants species tend to re-adjust their internal osmotic pressure through accumulation of inorganic and organic solutes. The differences in the concentration of the measured elements not attributed to the composition of the soil in which the plants grow, but may depend on the interactions of the elements or the plants genotype. *A. monosperma* is the most tolerant plants to drought than the two other plants species and they are favourable to the conditions of the arid environment.

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REFERENCES

Ackerly, D.D., Dudley, S.A., Sulton, S.E., Schmitt, J., Coleman J.S. and Linder, C. R. 2000. The evolution of the plant ecophysiological traits: recent advances and future directions. *Bioscience,* 50: 979 – 995.

Alkhail, M. S. A. and Moftah, A. E. 2011. Adaptation mechanisms of some desert plants grown in central region of Saudi Arabia. *Int. Res. J. Agri. Sci. Soil Sci*., 1(11): 462 – 470.

Bardsley, C.E. and Lancaster, J.D. 1965. Sulfur. In: Methods of Soil Analysis. Partz-Black, C.A., Evans, D.D., White, J.L., Jusminger, L.E. and Clark, F.E. (Eds). Madison, Amer Soc. Agron., PP: 1102 - 1116

Borland, A.M., Maxwell, K. and Griffiths, H. 2000. Ecophysiology of plants with grassulacean acid metabolism. In: Photosynthesis: Physiology and Metabolism. Leegood, R., Sharkey, T.D. and Von Caemmerers (Eds). Kluwer Academic Publishers, Amsterdam, PP. 583 – 605.

Brain, K.P. and Turner, T.D. 1975. The practical evaluation of phytopharma centicals. Bristol: Wright Scien Technical.

Boscalu, M., Fola, O., Scridon, S., Liinares, J. and Vicente, O. 2009. Osmolyte accumulation in xerophytes as response to environment stress. UASVM Hort Bull., 66: 96 – 102.

Buysse, J. and Merckx, R. 1993. An improved colorimetric method to quantify sugar content of plant tissue. *J. Exp. Bot.,* 44: 1627 – 1629.

Chen, H. and Jiang, J. 2010. Osmotic adjustment and plant adaptation to environmental changes related to drought and salinity. *Environ. Rev.,* 18: 309 – 319.

Dernnan, P. M. 2009. Temperature influences on plant species of arid and semi-arid regions with emphasis on CAM succulents. In: Perspectives in Biophysical plant Ecophysiology, a Tribute to Park. Nobel, S. (Ed). Universidad Nacional Autónoma de Mexico, Mexico, PP: 57 – 94.

Duby, R. S. 1994. Protein synthesis by plants under stressful conditions. In: Handbook of Plant and Crop Stress. Pessarki, M. (Ed). PP. 277 – 299. New York. Marcel Decker Inc.

Fahmy, G.M. and Swaf, N.A. 1992. Aspects of leaf senescence in desert plants. 1. Ionic composition, carbohydrate and total protein of green and senescing leaves of four species in Zygophyllaceae. *J. Edu. Fac. Ain Shams Univ*., 17: 101 – 116.

Fisher, M. and Membery, D.A. 1998. Climate. In: Vegetation of the Arabian Peninsula. Ghazanfar, S. A. and Fisher, M. (Eds). Kluwer Academic Publishers, PP: 5 -38.

Fresenius, W., Quentin, K. E. and Schneider, W. 1998. Water analysis a practical guide to physco-chemical, chemical and microbiological water examination and quality assurance. Springer Verlag, Berlin, Heidelberg.

Gadallah, M.A.A.1995. Effects of water stress, abscisic acid and proline on cotton plants. *J. Arid Environ.,* 30: 315 – 325.

Gadallah, M.A.A., Sayed, S.A. and Salama, F.M. 2001. Some metabolic aspects of *Zygophyllum coccineum* (L.) growing in different habitats in Eastern Desert, Egypt. *Bull. Fac. Sci. Assuit Univ.,* 30(I-D): 33 – 42.

Ghazanfar, S.A. 1998. Vegetation of the plains. In: vegetation of the Arabian Peninsula. Ghazanfar S. A. and Fisher, M. (Eds). Kluwer Academic Publishers, PP: 175 – 190.

Jackson, M.L.1962. Soil chemical analysis. Constable and Co. Ltd. London. In drought stressed plants under laboratory condition. Plant and soil, 40: 689 – 692.

Johnson, C.M. and Ulrich, A. 1959. Analytical method for use in plant analysis. US Department of Agriculture, California University, PP: 766.

Kamel, M. 2007. Osmotic adjustment in three succulent species of Zygophyllaceae. *Afric. J. Ecol.,* 46: 96 – 104.

Kan, M.A., Ungar, I.A. and Showalter, A.H. 2000. The effect of salinity on growth, water status and ion content of leaf succulent perennial halophytes, *Suaeda fruticosa* (L.) Forssk. *Journal Arid Environment,* 45: 73 – 84.

Karmer, P. J. 1984. Problems in water relations of plants and cell. In: International Review of Cytology. *Krmer, R. J.* (Ed). PP. 254-286.

Lee, Y.P. and Takahashi, T. 1966. An improved colorimetric determination of amino acids with the use of ninhydrin. *Anal Biochem.,* 14: 71 – 77.

Lowry, C.H., Rosebrough, N.J., Farr, A.L. and Bandall, H.J. 1951. Protein measurement with the folin phenol reagent. *J. Biol. Chem.,* 193: 265-275.

Masrahi, Y.S., Al-Yemeni, M.N., Al-Turki, T.A. and Sayed, O.H. 2011. cophysiological mechanisms of succulent survival in natural conditions: photosynthetic carbon fixation in *Caralluma acutangula* (Decne. N. E. BR.) (Asclepiadaceae). *Polish Journal of Ecology,* 59(3): 437-442.

Merewitz, E.B., Gianfogna, T. and Huang, B. 2011. Protein accumulation in leaves and roots associated with improved drought tolerance in creeping bentgrass expression an ipt gene for cytokinins synthesis. *J. Exp. Bot.,* 62: 5311 – 5333.

Mile, O., Meszaros, J., Verse, S.Z. and Lakatos, G. 2002. Ecophysiological study on the salt tolerance of a Pannonia endemism (*Lepidum cressifollum*) in inland saline area. *Acta Biol. Szeg.,* 46: 249 – 250.

Morrison, W.R. and Smith, S. 1964. Preparation of fatty acid methylesters and dimethylacetate from lipids with boron fluorid – methanol. *J. Lipid Res.,* 3: 600 – 608.

Ostle, B. 1963. Statistics in Research. PP. 585. Iowa State University Press.

Paleg, L.G., Stewart, G.R. and Bradbear, J.W. 1984. Proline and glycinebetaine influence protein salvation. Plant Physiol., 75: 974 – 978.

Peach, K. and M.V. Tracey,1956. Modern methods in plant analysis. Vol. I, Berlin. Springer – Verlag. Gottingen. Heidenberg, PP: 542.

Premachandrea, G.S., Saneoka, H., Fujita K. and Otaga, S. 1992. Osmotic adjustment and stomatal response to water deficits in maize. *J. Exp. Bot.*, 43: 1451 - 1456

Ramanjulu, S. and Sudhakar, M.T. 1997. Drought tolerance is partly related to amino acid accumulation and ammonia assimilation. A comparative study in two mulberry genotype differing in drought sensitivity. *J. Plant Physiol.*, 150: 345 – 350.

Richards, L.A. 1954. Diagnosis and improvement of saline and alkali soil USDA. Agric. Handbook 60. Washigton, DC.

Ryan, P.J., Mckenzie, N.J., Loughhead, A. and Ashton, L. 1996. New methods for forest soil surveys. In: The Role of *Eucalyptus* and other fast growing species. Eldrige, K.G., Crowe, M. P. and Olds, K.M. (Eds). Csiro Publishing Collingwood, Victoria.

Sayed, S.A., Gadallah, M.A.A. and F.M. Salama, 2013. Ecophysiological studies on three desert plants growing in wadi Natash, Eastern Desert, Egypt. *Journal of Biology and Earth Sciences*, 3(1): B135 – B143.

Scholz, F.G., Bucci, S.J., Arias, N., Meinzer F.C. and Goldstein, G. 2012. Osmotic and elastic adjustment in cold desert shrubs differing in rooting depth: Coping with drought and subzero temperature. Oecologia, 170: 885 – 897.

Wellbum, A.R. 1994. The spectral determination of chlorophyll a and b, as well as total caretenoids, using various solvent with spectrophotometers of different solution. *J. Plant Physiol.*, 144: 307 – 313.

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