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Ions Relationships between Plant and Soil under Hot Desert Conditions

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ABSTRACT

This study was carried out on eight wild species inhabited the tributaries of Wadi Noman, in the western region of Saudi Arabia. The results were indicated that, the correlations between soil texture and water soluble ions of soil extract were positive in case of clay and silt soils and negative in case of sandy soil, while the correlation with gravel was variable. A correlation between the water content of plant, fine soil and gravel was negative, while a positive correlation was existed with sandy soil. Generally, the investigated species accumulated more potassium followed by sodium. Meanwhile, calcium and magnesium were moderately accumulated in plants; the accumulation of chlorides and sulphates was minor. The high K^+/Na^+ ratio was observed in both *Heliotropium. arbainense* and low ratio in *Caralluma russeliana* (succulent species). Apparently, there were significant correlations between ions of the soil and analogous ions in plant. Also, the interaction between Wadi and species had a major role on the elemental constituents of plants, while single factors alternate the secondary role.

Keywords: Wild species, soil texture, water soluble ions, interaction, correlation, desert Wadis

INTRODUCTION

The ability of naturally occurring desert plants to grow in their habitats indicates that much information's are needed about the adaptation of plants to the stressful environment of hot desert. There can be dramatic shifts in vegetation across changes in soil texture in drier climates sandy soils can be associated with more extensive vegetation cover and an apparently more mesophytic species composition which can result from a greater availability of water in these soils (Sperry and Hacke, 2002). Maestre *et al*., (2003) suggested that, higher seedling establishment and survival associated with fine-textured soil may be favored by elevated soil water storage capacity relative to coarse textured one.

The solubility, concentration in the soil solution, ionic form, mobility and thus availability of soil nutrients often depends largely upon the soil pH. In this situation, the decrease in pH recorded below the canopy would favor the solubility and availability of salts, including carbonates, sulphates, and phosphates, promoting cation exchange, and also causing an increase in soil EC (Mengel and Kirkby, 1982; Muñoz-Vallés *et al*., 2011). Commonly, the soil heterogeneity is a basic element for competitive and/or facilitative interactions between plants, mainly in stressed environments such as semi-arid habitats (Fowler, 1986), and consequently may determine distribution patterns of plants and communities (Rubio and Escudero, 2000). In this regard, the responses of these plants through the osmotic pool to the adverse conditions indicating the adaptation to the climatic and edaphic gradients.

Accordingly, the aim of the present investigation was 1- to elucidate the correlations between the ions of soil and xerophytic species, 2- comparative study between species to understand the adaptation mechanisms to overcome stress conditions of hot desert through accumulation of inorganic solutes. Statistical treatments of data were carried to evaluate the effect of single factors (Wadi and species) and their interaction on the plant and soil parameters.

MATERIAL AND METHODS

This investigation was carried out on wild plants inhabiting four tributaries of Wadi Noman at Holey Mecca in the western region of Kingdom of Saudi Arabia (Map 1). The soil and plant samples were collected from a number of sites (stands) which represent its distribution at different edaphic habitats in the investigated Wadis. This work was carried out during the period extending from January to April, 2012 under the mild climatic condition.

Collection of soil samples

Soil samples were collected in the rooting zones of the investigated plants from different locations (20 sites) at Wadi Noman tributaries, as follows: 5 sites from W. Kharar; 5 sites from W. El-Shara; 6 sites from W. Magaresh and 4 sites from W. El-Kor. For each site, three replicates of soil samples (chosen at random) and sampled from soil at depth 0-50 cm, then transferred in plastic container to laboratory.

Preparation of soil extracts

The granulometric analysis of the different profiles was determined by the sieve method (Jackson, 1967). In the soil extracts (1 soil: 5 water), the chemical analyses including electrical conductivity (E.C.), total dissolved salts (TDS) and pH, were determined according to Tan (1998). Determination of water soluble bicarbonates was according to Rhoades (1982).In the soil extract the Fe^{+2} was determined by using Atomic Absorption Spectrophotometer according to Stewart (1974).

Collection of plant samples

Samples of 8 species inhabiting 4 tributaries of Wadi Noman were chosen and collected from their habitats as the following: 5 species from Wadi Kharar, 6 species from Wadi El-Shara, 8 species from Wadi Magaresh and 8 species from Wadi El-Kor (Table1). The investigated species were identified according to Migahid (1978); Collenette (1999) and Boulos (1999,

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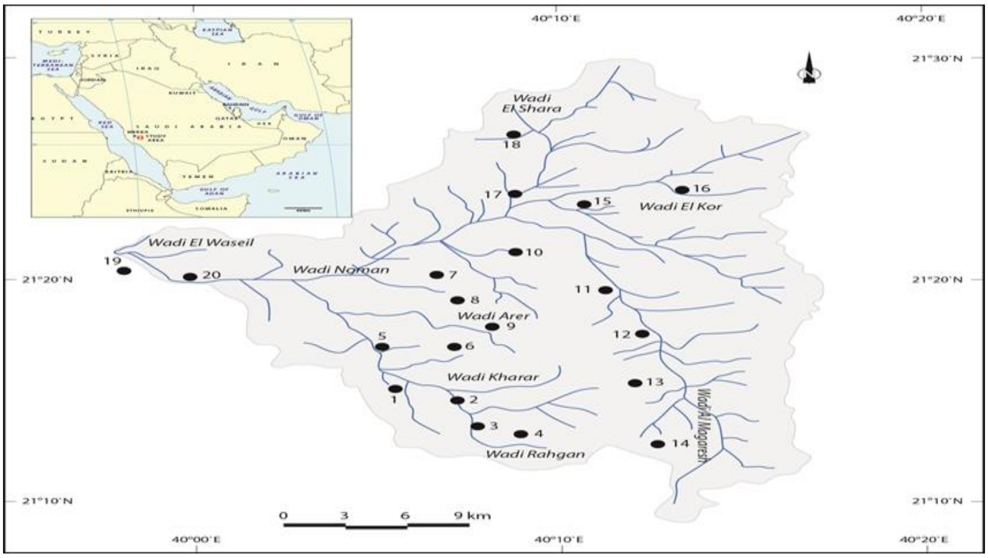
2000, 2002, 2005). These species including 5 perennials and 3 annuals (which belong to 8 families) were categorized into two groups as follows:

1- Dominant species (No. 1-4) were occupied four wadis namely: *Cleome droserifolia*, *Abutilon pannosum*, *Tephrosia desertorum* and *Citrullus colocyanthis*.

2- Co-dominant species (No. 5-8) were inhabited three wadis were included: *Heliotropium arbainense, Rumex vesicarius, Datura innoxia* and *Caralluma russeliana*. The plant samples were immediately transferred to plastic containers from their natural habitats to the laboratory. Samples of leaves were washed with cold distilled water and thoroughly dried on filter paper. For each species three samples were chosen at random.

Determination of water content

Water content in plant leaves was determined as a percentage of fresh weight. For each species, three samples were chosen at random, then oven-dried at 70°C for 24 hrs and reweighed to calculate their water content.



Map (1): study area of Wadi Noman and its tributaries**.**

Table (1): List of investigated plant species and their distribution at studied wadis

No.	Wadis Species		Wadi Kharar	Wadi El-Shara	Wadi Magaresh	Wadi El-Kor
1	**CAPPARACEAE** *Cleome droserifolia* (Forssk.) Delile	Per.	+	+	+	+
2	**MALVACEAE** *Abutilon pannosum*(G. Forst.) Schltdl	Per.	+	+	+	+
3	**LEGUMINOSAE** *Tephrosia desertorum* L.	Per.	+	+	+	+
4	**CUCURBITACEAE** *Citrullus colocynthis* (L.) Schrad	An	+	+	+	+
5	**BORAGINACEAE** *Heliotropium arbainense*Fresen	Per.	+	-	+	+
6	**POLYGONACEAE** *Rumex vesicarius* L.	An	+	-	+	+
7	**SOLANACEAE** *Datura innoxia* Mill.	An	-	+	+	+
8	**ASCLEPIADACEAE** *Caralluma russeliana* (Courb. Ex Brongn.) Cufod	Suc	-	+	+	+

(+) specis present in the wadi, (-) species absent in the wadi

Chemical analyses of cations and anions

Calcium and magnesium were determined by using Atomic Absorption Spectrophotometer according to Stewart (1974). Sodium and potassium were determined by the flame emission technique which is a rapid and sensitive method. The flame photometer method (Williams and Twine, 1960) using Carl Zeiss flame photometer, was applied. Chlorides were measured by $AgNO_3$ titration method as described by Jackson (1967). Sulphates were determined by a turbidemetric method as $BaSO_4$ precipitation by barium chloride and acid sodium chloride requests using a spectrophotometric technique (Black *et al*., 1965).

Statistical evaluation of experimental data

The effects of single factors (Wadi and species) and their interaction on the contents of ions in different species were evaluated statistically by the analysis of variance (F test). The relative role of each single factor and their interaction in the total response were determined by using the coefficient of determination (η_2) to indicate the degree of control of the factor on the parameter tested. A simple linear correlation coefficient (r.) between ion content in soils with their analogues in plants, and plants water content with soil texture was carried out (Ostle, 1963 and Ploxinki, 1969)

RESULTS

I-Soil analyses

1- Soil texture

At different Wadis studied, the soil texture were estimated (as percentage) at 0-50 cm soil depth (Fig. 1). The percentage of soil particles were varied in texture among soils of investigated Wadis. It was found that, a high % of the gravel (36.62%) was represented at Wadi Kharar. Whereas, the low gravel percentage was existed at W. Magaresh, which was characterized by the presence of relatively high % of fine sand (34.58%). In general, the sandy soils (fine and coarse sand) were represented by a high % among soil texture at different studied Wadis, where the low % was observed at W. El-Kor.

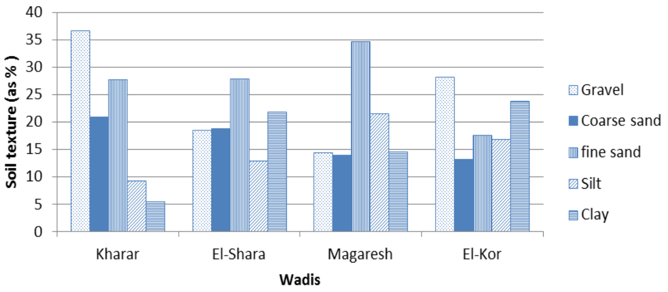


Figure (1): The average percentages of soil texture at different studied Wadis.

The clay soil reached to a high % (23.78 and 21.74%) at W. El-Kor and W. El-Shara, respectively, whereas the low percentage (5.44%) of the clay soil was found at W. Kharar. Apparently, the silt soil represented by 21.39% at W. Magaresh and 9.19% at W. Kharar.

2-Water soluble ions

a- Cations

The contents of different cations in the soil extract at different investigated Wadis were shown in Figure (2).

Calcium (Ca^{+2}): Ca^{+2} was the most abundant ion among tested cations in the soil extract. It is found that, the calcium was accumulated in both W. Magaresh and W. El-Kor soils (96.9 and 91.71 mg.kg^{-1} dry soil, respectively). Whereas the calcium content was low in both W. Kharar and W. El-Shara (42.85 and 45.75mg.kg^{-1} dry soil, respectively).

Magnesium (Mg^{+2}): The water soluble Mg^{+2} exhibited a high value (14.66 mg.kg^{-1} dry soil) in the soil at W. Magaresh. In W. Kharar and W. El-Shara, the Mg^{+2} content was equal the same (2.99 mg.kg^{-1} dry soil), which was pointed to the low value among the soils at the studied Wadis. The intermediate concentration of Mg^{+2} was attained at the W. Kharar soil.

Potassium (K^{+}): Potassium content was variable among the soils at investigated Wadis. Apparently, a highest K^{+} content (6.15 mg.kg-1 dry soil) was produced by soil at Wadi Magaresh. While, the lowest K^{+} content (2.89 mg.kg^{-1} dry soil) was found at W. El-Shara soil. At both W. Kharar and W. El-Kor, K^{+} ranged between 4.92 to 3.29 mg.kg^{-1} dry soils, respectively.

Sodium (Na^{+}): Generally, sodium ions were abundant (Fig. 2) in the soils at different investigated wadis, which were higher than that of K^{+} ions. The highest value of Na^{+} (46.71 mg.kg^{-1} dry soil) was observed at W. El-Kor soil. Whereas, the soil at W. Kharar showed a minimum Na^{+} content (17.02 mg.kg^{-1} dry soil), the same was true in case of W. El-Shara soil. While, the Na^{+} amount exhibited a moderate value (25.75 mg.kg^{-1} dry soil) at W. Magaresh soil, this means that sodium content was varied from Wadi to another, ultimately a variation of the grown vegetation.

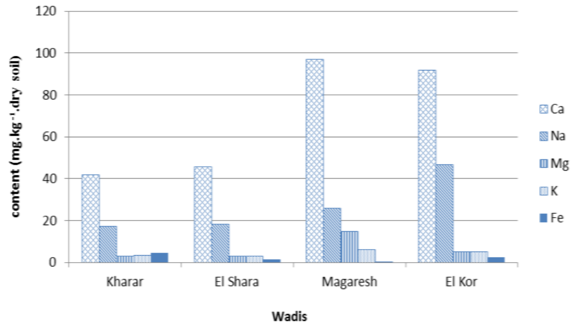


Figure (2): Average contents (mg.kg^{-1}.dry soil) of cations K^{+}, Na^{+}, Ca^{+2}, Mg^{+2} and Fe^{+2} in the soil extract at different investigated Wadis.

Na^{+}/K^{+} ratio: The calculated Na^{+}/K^{+} ratio ranging between 4.1 at W. Magaresh soil to 13.15 at Wadi El-Kor soil. This ratio was 5.17 and 6.21 at W. Kharar and W. El-Shara soils, which pointed to the degree of salinization at different soil Wadis. Accordingly, the W. El-Kor soil is more salinized, due to the excess of Na ions than that in the soils at the rest Wadis.

Iron (Fe^{+2}): The content of iron as a micronutrient ranging between 0.54 mg.kg^{-1} dry soil at W. Magaresh, which exhibited a low value to 4.47 mg.kg^{-1} at W. Kharar, which showed a maximum content of iron. Meanwhile, the iron content was 2.6 mg.kg^{-1} dry soil at W. El-Kor, the iron level was tended to 1.39 mg.kg^{-1} dry soil at W. El-Shara.

b- Anions

The average contents of different anions in the Wadi soils were shown in figure (3).

Chlorides (Cl^-): The chlorides in the soil extracts were variables among soils at studied Wadis. Maximum contentsof chlorides (47.16 $mg.kg^{-1}$ dry soil) were existed at Wadi Kharar soil. Likewise the soil at W. Magaresh exhibited a high level of Cl^- (42.53 $mg.kg^{-1}$ dry soil). Meanwhile, the minimum value of chlorides was observed at W. El-Shara soil (12.75 $mg.kg^{-1}$ dry soil), the soil at Wadi El-Kor exhibited a moderate content of the chloride ion (31 $mg.kg^{-1}$ dry soil).

Sulphates (SO_4^{-2}): The dissolved SO_4^{-2} in soil extract was produced a high values than that of chlorides. It was reached to the highest value (125.17 $mg.kg^{-1}$ dry soil) at W. Magaresh soil followed by SO_4^{-2} content at W. El-Kor soil. The SO_4^{-2} content was decreased at soils of both W. Kharar and W. El-Shara (38.8 and 32 $mg.kg^{-1}$ dry soil, respectively).

Bicarbonates (HCO_3^-): Clearly, the bicarbonate contents at W. El-Kor were relatively higher among the studied wadis. At W. El-Kor the bicarbonate content tended to 185 $mg.kg^{-1}$ dry soil. Whereas, at the rest Wadis the bicarbonate contents were 110.3 $mg.kg^{-1}$ dry soil at W. Magaresh and 126.2 $mg.kg^{-1}$ dry soil at W. Kharar. It was quite clear that the soluble bicarbonates were abundant among the tested anions, which reflected the chemical nature of soils at Wadi Noman tributaries.

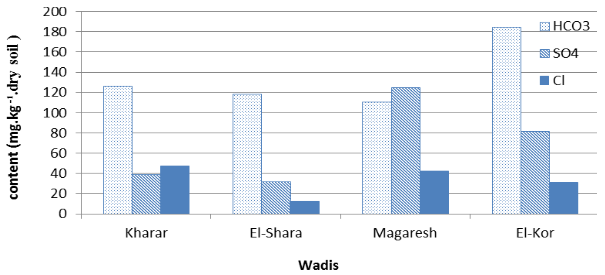


Figure (3): Average contents ($mg.kg^{-1}$.dry soil) of anions Cl^-, SO_4^{-2} and HCO_3^- in soil extract at different investigated Wadis

Total dissolved salts (T.D.S.) & Electric conductivity (E.C.)

Obviously, W. Magaresh showed the highest value (516.92 $mg.kg^{-1}$ dry soil) of T.D.S. followed by soils at W. El-Kor; which exerted 450.73 $mg.kg^{-1}$ dry soil. The T.D.S., at rest Wadis was ranged between 259.54 to 228.94 $mg.kg^{-1}$ dry soil. Therefore, T.D.S. at W. El-Kor more salinized due to the presence of a high amount of Na^+, however the salinity in the rest Wadi soils may be had a neutralized salts. It was found that, the maximum E.C. values (793.9 and 825.8 $\mu S.cm^{-1}$) were existed at W. Magaresh and W. El-Kor soils. Otherwise, E.C. was low in the rest Wadis which exerted 389.8 and 352.7 $\mu S.cm^{-1}$ of soil extracted at W. El-Shara and W. Kharar, respectively. This was in agreement with the presence of T.D.S. in the Wadis soils.

c- Soil pH

At the Wadis under experimentation, the soils exhibited a slightly alkaline, where its values ranged between 7.15 at W. Magaresh to 7.53 at W. El-Kor. This indicated that, the soils of Wadi Noman tributaries were slightly alkaline soils amended by neutralized salts.

Correlation between ions and soil texture

Apparently, the cations and anions were significantly affected by the soil texture at different studied Wadis (Table 2). It was found that gravel positively correlated with Ca^{+2}, Mg^{+2} and K^+ particularly at W. kharar and W. Al-Magaresh soils, as well as, with Fe^{+2} at W. Al-Magaresh. Whereas, Fe^{+2} at W. Kharar was negatively correlated with the gravel, the same correlations existed between gravel and both of Ca^{+2} and SO_4^{-2} at W. El-Kor, as well as, with Ca^{+2} at W. El-Shara. Likewise, all significant correlated values between experimented ions and sandy (coarse and fine) soils were negative. Exceptionally, the correlations of SO_4^{-2}, Cl^- (at W.El-Kor and W. Al-Magaresh) with fine soils (silt and clay) and Fe^{+2} (at W. Kharar) with coarse sand and fine sand respectively were positive. In case of silt and clay soils, the major correlations with different ions were positive at various sites, except at W. Al-Magaresh there was a negative correlation between silty soil and $K^{+.}$ This may be depends on the cation exchange capacity of both soils. Also, the elemental constituents of those soils increased with the percentage increasing of both soil types. This mention to the independent correlation between soil texture and ion content (e.g. gravel with Na^+, HCO_3^- and Cl^-, coarse sand with K^+, Fe^{+2} and Cl^-, fine sand with K^+ and HCO_3^-, silt with Na^+, Fe^{+2} and HCO_3^- and clay with Fe^{+2} and Cl^- at different sites studied).

II- Plant analyses

Water content (%)

The water content as a percentage of the fresh weight was variable among various species at investigated Wadis (Fig. 4). Obviously, the mean % of water content of plants inhabited W. El-Kor was the lowest (74.70%) among species inhabited the rest Wadi (its water content ranged between 78.72 to 80.45%). Among species, the mean % of water content tended to a maximum (89.80 %) in both *R. vesicarius* (annual) and *C. russeliana* as a succulent plants. Meanwhile, a minimum of value (66.00%) was observed in *A. pannosum*, particularly at W. El-Kor. This may be a reflection of soil water conservation at Wadis inhabited by studied species.

In general, the percentages of water content were recorded a minimum values (55.77-68.06%) in *A. pannosum* at W. El -Kor, W. Magaresh and W. Kharar; whereas in *T. desertorum* the same was true at W. El Shara. Conversely, a maximum value of water content (91.40 %) were observed in *R.vesicarius* at both W. El-Kor and

W. Kharar, in *C. russeliana* at both W. Magaresh and W. El-Shara, as well as, in *D. innoxia* at W. El-Shara.

F values (Table 3) showed a highly significant effect of the species and the interaction (Wadi x species) factors on the water content in species of different groups, whereas the Wadi factor had no significant effect. Therefore, the interaction (Wadi x species) had a dominant role (η^2=0.539, and 0.537 of dominant, and co-dominant species, respectively) and the sp. factor had a subsidiary effect on the water contents in species.

Table (2): Correlation coefficient (r.) values between Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}, Fe^{+2}, SO_4^{-2}, HCO_3^{-} and Cl^{-} in soil with soil texture at different studied Wadis.

Ion	Wadis	Gravel	Coarse sand	fine Sand	Silt	clay	D.F
Ca^{+2}	1	0.9300*	0.004	-0.848	-0.483	0.985**	Wadi =3
	2	-0.8780	-0.930*	-0.598	0.575	0.890*	
	3	0.43300	-0.878*	-0.850	0.667	0.950*	
	4	-0.973**	-0.992**	-0.973**	0.948*	0.998**	
Mg^{+2}	1	0.930*	0.186	-0.887*	-0.516	0.930*	
	2	-0.45800	-0.574	-0.520	0.046	0.670	
	3	0.937*	-0.548	-0.963**	-0.044	0.896*	
	4	-0.966**	-0.997**	-0.984**	0.950*	1.00**	
K^{+}	1	0.748	-0.692	-0.724	0.846	0.570	
	2	-0.841	-0.841	-0.474	0.880*	0.700	
	3	0.993**	0.738	-0.540	-0.878*	-0.370	
	4	-0.563	-0.262	-0.170	0.575	0.360	
Na^{+}	1	0.457	-0.878*	-0.333	0.280	0.855	
	2	-0.613	-0.830	-0.956*	0.366	0.966**	
	3	0.486	0.150	-0.634	-0.204	0.484	
	4	-0.098	0.230	0.328	0.074	-0.128	
Fe^{+2}	1	-0.980**	0.398	0.990**	-0.400	-0.863	
	2	0.588	0.583	0.234	-0.260	-0.534	
	3	0.964**	0.678	-0.517	-0.775	-0.390	
	4	0.271	0.571	0.644	-0.246	-0.484	
SO_4^{-2}	1	-0.534	-0.344	0.474	0.690	0.038	
	2	-0.694	-0.763	-0.606	0.726	0.710	
	3	0.770	0.862	-0.740	-0.701	-0.131	
	4	-0.998**	-0.961**	-0.927*	0.977**	0.984**	
HCO_3^{-}	1	0.662	-0.546	-0.755	-0.190	0.973**	
	2	-0.841	-0.968**	-0.798	0.575	0.988**	
	3	-0.256	-0.613	-0.860	0.560	0.916*	
	4	-0.360	-0.037	0.066	0.336	0.140	
Cl^{-}	1	-0.826	-0.216	0.883*	0.110	-0.396	
	2	0.097	-0.205	-0.853	-0.256	0.521	
	3	-0.164	-0.490	-0.276	0.878*	0.522	
	4	-0.288	0.041	0.142	0.272	0.063	

(1): Wadi Kharar (2): Wadi El-Shara (3): Wadi Magaresh (4): Wadi El-Kor
*Significant at P < 0.05 level,
**Significant at P < 0.01 level

Table (3): ANOVA test showed the effect of Wadis, species and their interaction on the water content of dominant and co-dominant species

Content	Group of species / Source of variance	Dominate sp.		Co dominate sp.	
		F	η2	F	η2
Water content	Wadi	2.748	0.090	2.572	0.106
	species	27.076**	0.371	20.606**	0.358
	Wadi x species	34.848**	0.539	191.025**	0.537

*Significant at P < 0.05 level,
**Significant at P < 0.01 level

Correlation between water content of plants and soil texture

The soil texture exhibited different behaviors with the water contents of plants (Table 4). In the gravel soil, the water content of plants had a negative correlation in *C. colocynthis* and *C. russeliana.* Whereas, in co-dominant a highly significant correlation between sandy soils (coarse and fine) and water content was positive with few exceptions

In case of silt and clay soils, apparently there were no significant correlations between water contents of dominant and co-dominant species with fine soil particles due to independent relation between the water content of those species and the soil texture.

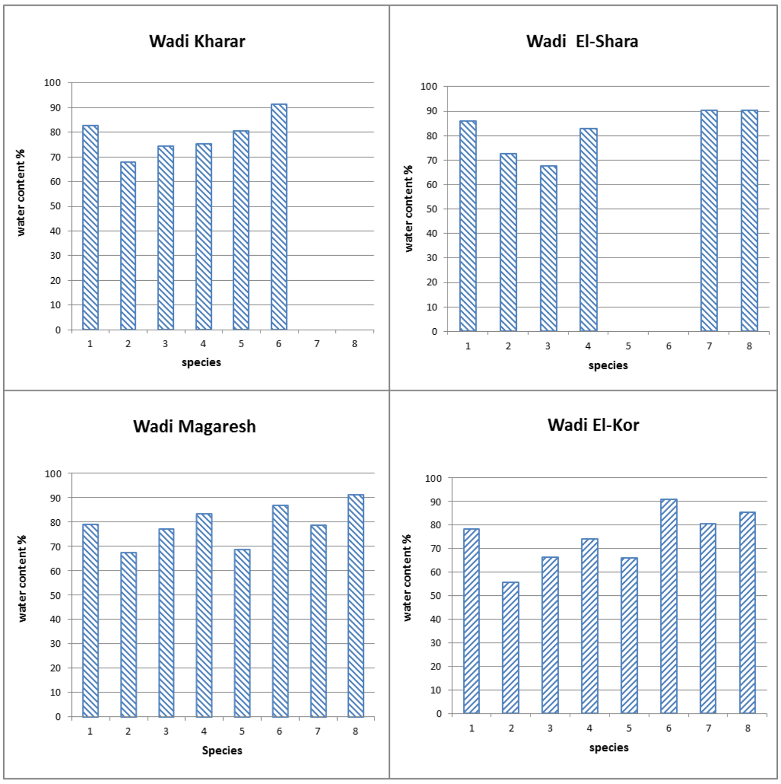


Figure (4): Average values of water content in different species inhabiting Wadi Kharar, Wadi El-Shara, Wadi Magaresh and Wadi El-Kor:(1) *C. droserifolia*; (2) *A.pannosum*; (3) *T. desertorum*; (4) *C. colocynthis*;(5) *H. arbainense*; (6) *R.vesicarius*; (7) *D. innoxia;* (8) *C. russeliana*

Table (4): Correlation coefficient (r.) values between water content of different studied species and different soil texture.

Species group	Contents / Species	Water content & gravel	Water content & Coarse sand	Water content &fine sand	Water content & silt	Water content & clay	D.F
Dominant species	***C.droserifolia***	0.026	0.814	0.188	-0.694	-0.086	Wadi =2 Wadi =3
	A.pannosum	-0.316	0.671	0.764	-0.298	-0.370	
	T.desertorum	-0.102	0.123	0.818	0.224	-0.780	
	C. colocynthis	-0.893*	-0.051	0.780	0.436	0.141	
Co-dominant species	***H. arbainense***	0.671	0.997**	0.281	-0.844	-0.940	
	R.vesicarius	0.955*	0.494	-0.753	-0.841	-0.083	
	D.innoxia	-0.103	0.964*	-0.016	-0.904	0.434	
	C. russeliana	-0.988*	0.506	0.962*	0.179	-0.760	

*Significant at $P < 0.05$ level,
**Significant at $P < 0.01$ level

Cation and anionic contents in plants

a- Cations

Studied wadis, the most investigated species exhibited a large variation in the constituents of main cations (Ca^{+2}, Mg^{+2}, K^{+} and Na^{+}, Fig. 5).

Calcium

It is quite clear that, the species inhabited Wadi Magaresh, had a higher Ca^{+2} content than that in the species inhabited the rest of Wadis, whereas the lowest values were found in species at W. El-Shara. Among species, *Heliotropium arbainense* accumulated more Ca^{+2} at W. El-Kor than other species. The lowest Ca^{+2} content (0.02 $mg.g^{-1}$ fresh weight) was estimated in *D. innoxia* inhabited W. Magaresh and W. El-Shara. The same was true in case of *R. vescarius* at W. Kharar.

F values (Table 5) showed that, species factor had a significant effect on Ca^{+2} of the dominant and co-dominant species. However, (Wadi x species) interaction had the same effect on Ca^{+2} in species of different groups. This interaction played the major role on Ca^{+2} of different species (η^2 = 0.81and 0.63).The secondary role on Ca^{+2} of the dominant and co-dominant species was played by the species factor.

Magnesium

The accumulation of magnesium in studied species showed a lower trend than that of calcium. Generally, the species inhabited W. El-Kor had a tendency to accumulated more Mg^{+2} than species inhabited the remaining Wadis, particularly species inhabited W. El-Shara which had a lowest mean value of Mg^{+2} (0.183 $mg.g^{-1}$ fresh weight). However, a maximum value (0.993 $mg.g^{-1}$ fresh weight) was recorded by *Heliotropium arbainens* at W. El-Kor, while a minimum value was existed in *A. pannosum* (0.041 $mg.g^{-1}$ fresh weight) at W. Kharar. The same was true in case of *C. droserifolia* at W. El-Shara.

F and η^2 values indicated that, the (Wadi x species) interaction had a highly significant effect on Mg^{+2} content in species of all groups, which had a major role (η^2= 0.74 and 0.55 for dominant and co-dominant species, respectively). However, Wadi factor had a significant effect and played a subsidiary role on Mg^{+2} content of selective species. However, the role of species factor was minor (Table 5).

Sodium

The accumulation of Na^+ was variable among species inhabited different wadis. The species at W. Magaresh were accumulated a maximum Na^+ followed by species at W. El-Shara. The minimum accumulation of Na^+ was observed in species inhabited W. Kharar. Among species, the highest Na^+ content (1.99 $mg.g^{-1}$ fresh weight) was found in *Tephrosia desertorumat* W. El-Shara, as well as *Datura innoxia* at W. Magaresh while the lowest amount of Na^+ was given by *C. colocynthis* at W. Kharar (0.038$mg.g^{-1}$ fresh weight). In general, Na^+ content in the dominant species exerted higher values of Na than that of the co-dominant species at different Wadis, with few exceptions.

From the ANOVA (Table 5), the effect of Wadi and its interaction with species on Na^+ in the dominant and co-dominant species were significant. The values of η^2 indicated that, this interaction had a dominant role on Na+ amounts in different groups. (η^2= 0.69 – 0.59) while, the Wadi effect had a secondary role on Na^+ of dominant and co-dominant species (η^2= 0.26 and 0.31, respectively).

Potassium

Compared to Na^+, K^+ was more accumulated in species studied at various locations. At W. El-Kor, the mean value of K^+ content in species tended to a maximum (5.09 $mg.g^{-1}$ fresh weight), while a minimum value (3.48 mg.g-¹ fresh weight) was exerted by species inhabited W. El-Shara. Furthermore, *T.desertorum* inhabited W. El-Kor gained a highest accumulation of K^+ (6.28$mg.g^{-1}$ fresh weight). Whereas, the lowest level of K^+ (1.82 $mg.g^{-1}$ fresh weight) was detected in *C. russeliana* at W. El-Shara and W. Magaresh.

Statistically, wadi, species and their interaction had a highly significant effect on K^+ content in different studied groups, except species and Wadi factor in case of the dominant and co-dominant species, respectively. Therefore, the interaction between Wadi and species had a dominant role on the K^+ content of dominant and co-dominant (η^2= 0.61 and 0.57, respectively). Meanwhile, Wadi factor played the secondary role on K^+ in dominant; the species factor had the subdominant role in case co-dominant species.

K^+ /Na^+ ratio

Generally, the species investigated had a tendency to accumulate more K^+ against Na^+ toxicity (Table 6). Clearly, this ratio represented by a range between 2.28 in *C. russeliana* to 9.08 in *H. arbainense*. Among Wadis, the species inhabited W. Kharar gained a highest mean value (9.09), followed by species at W. El-Kor, while K^+/Na^+ ratio was 2.9 in species at both W. El-Shara and W. Magaresh.

b- Anions

The pattern of both chloride and sulphate were shown in Figure (6). The accumulation of Cl^- and SO_4^{-2} were varied among plants inhabited Wadis under investigation.

Chloride

Generally, the high accumulation of Cl^- was observed in species at W. El-Kor. followed by species at W. Kharar and the mean values represented by 1.57 – 1.05 $mg.g^{-1}$ fresh weight. While, the species inhabited both W. El-Shara and W. Magaresh had amount of Cl^- ranging between 0.62 to 0.69 $mg.g^{-1}$ fresh weights. The highest Cl^- content was recorded in *C. procera* (3.7 $mg.g^{-1}$ fresh weight) at W. El-Shara and W. El-Kor. At W. Kharar, a similar accumulation of Cl^- existed in *C. colocynthis*, whereas the lowest value (0.25 $mg.g^{-1}$ fresh weight) was estimated in *T. macropterus*. Also, the same level of Cl^- was recorded in *S. alexandrina* at W. Magaresh.

The chloride content of the common species was significantly affected by wadi, species and their interaction (Table 5). This interaction had a significant effect on Cl^- content in both dominant and co-dominant, whereas species factor had a highly significant effect on Cl^- content in co-dominant species.

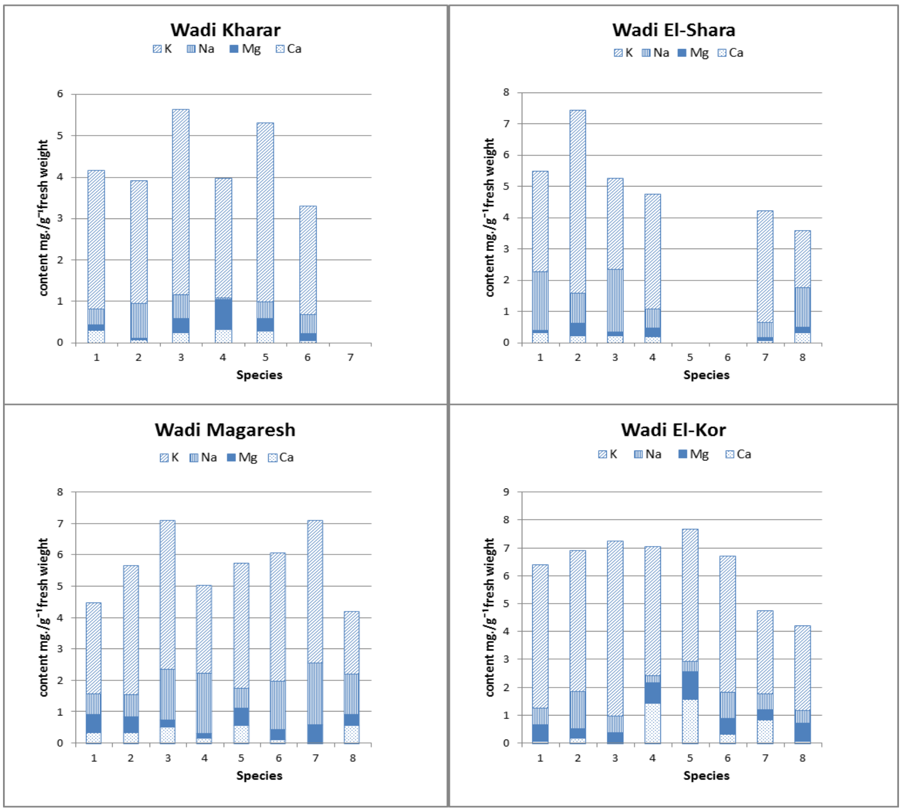


Figure (5): Average content of anions K^{+},Na^{+},Ca^{+2} and Mg^{+2} in different species inhabiting Wadi Kharar, Wadi El-Shara, Wadi Magaresh and Wadi El-Kor: (1) *C. droserifolia*; (2) *A.pannosum*; (3) *T. desertorum*; (4) *C. colocynthis*;(5) *H. arbainense*; (6) *R.vesicarius*; (7) *D. innoxia*; (8) *C. russeliana*.

Table (5): ANOVA test showed the effect of Wadis, species and their interaction on cation and anion ions in the investigated species of different floristic groups.

Ions	Floristic Group / Source of variance	Dominant species F	Dominant species η2	Co- dominant species F	Co- dominant species η2
Ca^{+2}	**Wadi**	0.840	0.052	3.099	**0.172**
	species	2.464	0.138	3.775*	**0.20**
	Wadi x species	11.277**	0.809	10.091**	**0.628**
Mg^{+2}	**Wadi**	3.592*	0.173	5.358*	**0.335**
	species	1.619	0.087	1.391	**0.116**
	Wadi x species	11.425**	0.740	2.656*	**0.550**
Na^{+}	**Wadi**	6.452**	0.258	6.125*	**0.309**
	species	1.117	0.060	1.449	**0.101**
	Wadi x species	9.011**	0.682	4.967**	**0.589**
K^{+}	**Wadi**	6.698**	0.267	1.745	**0.095**
	species	2.423	0.121	10.395**	**0.333**
	Wadi x species	5.516**	0.613	12.012**	**0.572**
Cl^{-}	**Wadi**	3.047	0.148	2.058	**0.136**
	species	3.038	0.148	7.630**	**0.349**
	Wadi x species	9.728**	0.705	3.484*	**0.515**
SO_4^{-2}	**Wadi**	5.001**	0.205	1.361	**0.067**
	species	2.425	0.113	23.938**	**0.4**
	Wadi x species	12.022**	0.683	29.015**	**0.533**
	D.F	**Wadi =3 wadi x sp=15**	**sp=3**	**Wadi =2 wadi x sp=11**	**sp=3**

*Significant at P < 0.05 level
**Significant at P < 0.01 level

Table (6): Average values of K^+/Na^+ ratio in different studied species .

Species / Ratio	*C.droserifolia*	*A.pannosum*	*T.desertorum*	*C. colocynthis*	*H. arbainense*	*R.vesicarius*	*D.innoxia*	*C. russeliana*
K^+/Na^+	4.17	4.65	3.86	5.02	9.08	3.94	3.67	2.28

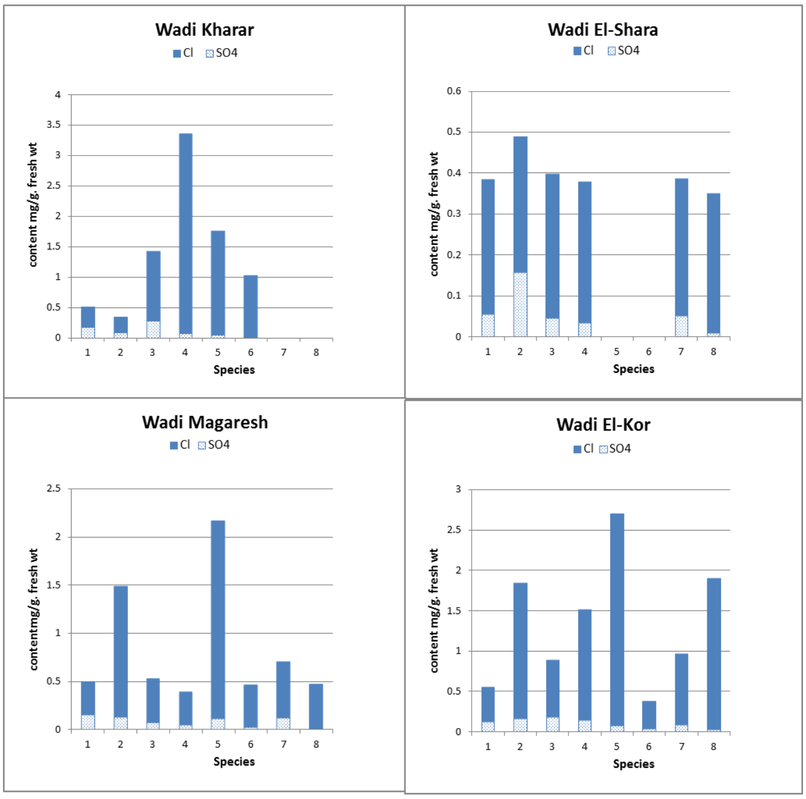


Figure (6): Average content of anions Cl^- & SO_4^{-2} in different species inhabiting Wadi Kharar, Wadi El-Shara, Wadi Magaresh and Wadi El-Kor: (1) *C. droserifolia*; (2) *A.pannosum*; (3) *T. desertorum*; (4) *C. colocynthis*;(5) *H. arbainense*; (6) *R.vesicarius*; (7) *D. innoxia*; (8) *C. russeliana*.

Table (7): Correlation coefficient (r) values between ion concentrations in plants and ion concentrations in the soil at different studied species.

Floristic group	Contents / species	Ca^{+2}&soil Ca^{+2}	Mg^{+2}&soil Mg^{+2}	Na^+&soil Na^+	K^+&soil K^+	Cl^-&soil Cl^-	SO_4^{-2}&soil SO_4^{-2}	D.F
Dominant species	*C.droserifolia*	-0.390	0.670	-0.337	0.108	0.044	0.334	Wadi =3
	A.pannosum	0.633	0.668	0.804	-0.132	0.160	0.025	
	T.desertorum	0.216	-0.094	-0.447	0.615	0.680	-0.315	
	C. colocynthis	0.448	-0.643	-0.075	-0.057	0.597	0.016	
	H. arbainense	0.611	0.021	0.524	-0.366	-0.995**	0.973*	
Co-dominant species	*R.vesicarius*	0.530	0.021	0.198	0.695	0.813	0.194	Wadi =2
	D.innoxia	0.387	0.926	-0.196	0.496	0.568	0.996**	
	C. russeliana	0.122	0.040	-0.971*	0.266	0.193	0.040	

The relative role of the interaction (Wadi x species) was dominant (ɳ²= 0.71and 0.52) while species factor had a subdominant role on the Cl^- content of the investigated plant groups.

Sulphate

The species were grown at studied Wadis exhibited a less accumulation of SO_4^{-2}than Cl^- (Fig. 6). Accumulation of SO_4^{-2}, as in case of Cl^-, was found in species inhabited W. El-Kor and W. Kharar of SO_4^{-2}, whereas the low values were observed at W. El-Shara and W. Magaresh. Among species the highest SO_4^{-2} content (0.314 $mg.g^{-1}$ fresh weight) was accumulated by *H. pterocarpum* at W. El-Kor. The same was found in *T. desertorum* at W. Kharar. A low value of SO_4^{-2}(0.007 $mg.g^{-1}$ fresh weight) was recorded in the succulent *C. russeliana* growing at various Wadis, likewise in the annual *R. vesicarius* at W. Kharar .

F and ɳ² values (Table 5) indicated that, the Wadi, species and their interaction had a significant effect on SO_4^{-2} in species of different plant groups. Exceptionally, species and Wadi as single factors had no effect on SO_4^{-2} content in the dominant and co-dominant species, respectively. The interaction had a dominant role on SO_4^{-2} content of species. While, Wadi factor in case of dominant species and species factor in case of both co-dominant and common species had a secondary role on SO_4^{-2} content.

Correlation between elemental contents in plants and analogous in soil

According to data shown in table (7), the correlation coefficient (r.) between ions in the plants and ions of the soils under the effect of Wadi factor showed that: the correlations between ions in the dominant species with analogous ions in the soil were non-significant. While, in the co-dominant species, there was a significant negative correlation between Cl^- ions in case of *H. arbainense*, and Na^+ ions in case of *C. russeliana* and analogous ions in the soil. However, a significant positive correlation between SO_4^{-2} ions existed in case of *H. arbianense* and *D. innoxia* with that in the soil.

DISSCUSION

A basic soil property is texture which influences infiltration and moisture retention and thus the availability of water and nutrients to the plants (Sperry and Hacke, 2002). In the present work, the soil texture at different tributaries of Wadi Noman was varied. Meanwhile, the gravel is represented by a high percentage with a low clay soil at W. Kharar, this value of gravel were decreased in the rest soil Wadis with an increasing of fine particles(fine sand, silt and clay fractions). This was reflected on the elemental constituents of each soil depending on the cation exchange capacity and ionic conservation. Therefore, at Wadi Magaresh the soil had a high amount of Ca^{+2}, Mg^{+2}, SO_4^{-2} and K^+, where the soil contained a relative high % of clay and silt fractions. The same was true in case at Wadi El Kor, but Na^+ was more accumulated in this soil. In general, K^+ is accumulated in response to low soil moisture, while Na^+ is accumulated under saline conditions (Glenn *et al*., 1996). This high concentration of Na^+ in soils as being probably due to deficiency of other nutrients (Silberbrsh and Ben-Asher, 2001),or may be as a result of interaction with other environmental factors such as drought, which exaggerates the problems of Na^+ toxicity.

In this respect, the Na^+/K^+ ratio was higher in soils at W. El-Kor than that of the rest Wadis, whereas a lowest value was found at W. Magaresh soil. However, the availability of macro-nutrients in soil of W. Magaresh more increased than that at W. El-Kor. Ultimately, the total soluble salts exerted a high content in soil at W. Magaresh followed by W. El-Kor soil. Whereas, a low amount of total soluble salts was found in the soils of W. El-Shara and W. Kharar. This was reflected on the electrical conductivity (E.C.) at different studied locations. Likewise, at W. El-Kor the pH was variable, where the soil showed a maximum value among soils mostly due to the high levels of Na^+ and bicarbonate ions. Accordingly, the availability of Fe^{+2} was affected by the soil pH, where the soil had a high soluble iron at W. Kharar and vice vera at the rest Wadis. This means that, the utilizationand uptake of growth limiting nutrients such as Fe^{+2} can be inhibited (Tester and Davenport, 2003; Youssef, 2009).

Gravel and edaphic variables related to salinity such as electrical conductivity or ionic content, have been found to determine vegetation changes in arid and semi-arid regions (Maesture *et al*., 2003; Cañadas *et al*., 2010). In general, the most significant correlations between gravel and tested ions was positive with Ca^{+2} and K^+ and negative with Mg^{+2} and Fe^{+2} in soils at different wadis with some exceptions. Meanwhile, the sandy soil was negatively correlated with the majority of ions in the soil, both silt and clay fractions were positively correlated with different ions, as a response to high cation exchange capacity. Exceptionally, in case of K^+ with clay and sandy soil, as well as Fe^{+2} with clay and silt soils there was no significant correlation.

Under atmospheric and soil drought, the accumulation of mineral ions facilitate osmotic adjustment of plants (Farghali, 1998). Apparently, the accumulation of various ions in the studied plants was affected by the variation in mineral contents of soil. Meanwhile, plants had a tendency to accumulate Ca^{+2} and Na^+ at W. Magaresh, the high mean values of Mg^{+2}, K^+, Cl^- and SO_4^{-2} existed in plants inhabited W. El-Kor. While, a low levels of investigated ions were detected in species inhabited W. El Shara, except Na^+ ions exerted a low mean values in species at W. Kharar. This implies that, the ion accumulation in plants was depending on the ion concentration in the soil. In general, the major ionic concentration in studied species showed the following pattern: $K^+ > Na^+ > Ca^{+2} > Mg^{+2} > Cl^- > SO_4^{2}$.

Therefore, K^+ ion is not only an essential macro-element for plant growth and development, but also a primary osmoticum in maintaining low water potential for plant tissues (Wang *et al*., 2004). According to Gorham (1990), the effect of enhanced K^+/Na^+ discrimination in most pronounced at low salinity. It was found that, high K^+/Na^+ value was recorded in *H. arbainense* followed by *M. parviflora*, which refers to an avoidance mechanism against Na^+ toxicity. Whereas, in succulent species *C. russeliana* the decreased K^+/Na^+ ratio was due to accumulated higher amount of Na^+ as strategy could be related to the ionic adjustments of the plants to achieve osmotic balance. Commonly, the K^+/Na^+ ratio indicated that, the most species inhabited tributaries of W. Noman had a tendency to accumulate more K^+ than Na^+. This indicate that drought and salinity interact in influencing physiological traits such as increase in osmolyte concentration, decreased water potential, improved Na^+, K^+ and water use efficiencies in high stress tolerant species (Nunes *et al*., 2008; Aziz *et al*., 2011). Furthermore, the K^+/Na^+ ratio can be considered as a salt tolerance index in plants (Morant-Manceau *et al*., 2004). Also, K^+ is accumulated in response to low soil moisture, while Na^+ is accumulated under saline conditions (Glenn *et al*., 1996).

Nutrient deficiencies can occur in plants when high concentration of Na^+ in the soil reduce the amounts of available K^+, Mg^{+2} and Ca^{+2} (Epstein, 1972; Wang *et al.*, 2004), or when Na^+ displaces membrane-bound Ca^{+2} (Khan *et al*., 2000). Apparently, Ca^{+2} and Mg^{+2} contents in plants had lower values than that of K^+ and Na^+ at different locations. The Ca^{+2} content in species inhabited W. Magaresh was higher than the mean amounts exerted by species at the rest Wadis. While, in case of Mg^{+2} these higher values were shifted to species inhabited W. El-Kor. Regardless of Wadi, it found that, *H. arbainense* had a highest amounts of Ca^{+2} and Mg^{+2} among studied species. The succulent and annual species had a moderate level of Ca^{+2} and Mg^{+2}. Both species namely: *C. russelina* and *R. vescarius* had a tendency to minimize the uptake of SO_4^{-2} and Cl^- ions, while *H. arabianense* had a high amount of both ions. Clearly, the mean values of SO_4^{-2} and Cl^- were relatively high in species at W. El-Kor. Commonly, the investigated species had less accumulation of both anions than in halophytic species which requires an increase of osmotic in cells (Tester and Davenport, 2003). ANOVA test indicated that, the accumulation of ions in plants was mainly affected by the (Wadi x species) interaction. Whereas, the Wadi factor had a secondary role on the majority of ions, the species role was subsidiary in case of Ca^{+2} in dominant species, K^+ and SO_4^{-2} in co-dominant species.

Apparently, the relationships between soluble ions in plants and ions in the soil were variable. The non-significant correlations between ions in the dominant species and ions in the soil were found. The levels of SO_4^{-2} in *H. arbainense* and *D. innoxia* were greatly linked with SO_4^{-2} ions of soils, while, Cl^- in *H. arbainense* had a negative correlation and associated with the same ion of root media. This implies that, species were osmotically adjusted in response to toxicity and salinity of Na^+ and Cl^- ions and this strategy could be related to the ionic adjustments of plants to achieve osmotic balance (Aziz *et al*., 2011). Also, Porta *et al*. (2003) concluded that, Sulphate with chlorides is more directly responsible for the formation of saline soils and salinity stress in plants. Accordingly, salt induces osmotic stress by limiting absorption of water from soil, and ionic stress resulting from high concentrations of potentially toxic salts within plant cells (Youssef and Al-Fredan, 2008).

The osmotic adjustment in plants might be simply an indicator of a higher carbon or nutrient status. Ultimately, a genotype which had better root growth under dry or saline soil may have more available water. Therefore, solutes were important in maintaining turgid at some desired value. The obtained results pointed to that, the investigated species seem to depend on osmotic adjustment driven by accumulation of major ions. This implies that, osmotically adjusted species essentially accumulate solutes depending on the Wadi and species variations. Thus, the ionic osmotic potential in the studied species were mainly related to K^+ followed by Na^+ to tolerate the water stress and higher temperatures. It is found that, such plants could be adapted to drought stress, which might reflected their sensitivity to Na^+ toxicity by accumulation of K^+ ions. Hence, K^+ is not only an essential macro element for plant growth and development, but also a primary osmoticum in maintaining low water potential for plant tissues (Wang *et al*., 2004). Apparently, the osmotic potential (ionic) makes the plants the most drought tolerant species in the studied Wadis. This view was true in case of *A. pannosum* and *T. desertorum*. Whereby, the succulent *C. russeliana* which had the highest partial osmotic potential could be adapted to drought injury by increased soluble K^+ and Na^+ ions, and adjusted osmotically.

CONCLUSION

Accordingly, the mechanisms of osmotic adjustments of different species were mainly depending on the accumulation of K^+ and/or sharing with Na^+ ions. Furthermore, the application of any cropping projects at Wadi Noman must be taken in consideration the interactive effects of biotic and abiotic variables on the productivity and conserve diversity of species grown in arid and semi-arid regions.

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