

Thermostability of chlorophylls in some native species of xerophytes

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Abstract: This study was carried out on eight wild species inhabited the tributaries of wadi Al Noman, at Holey Mecca in the western Kingdom of Saudi Arabia. The plant samples were collected at different locations, where laboratory analyses were included: the water content, chlorophyll content and its stability (CSI), Mg ions, water soluble sugars and soluble proteins. The results showed that, the chlorophyll a content was higher than the chlorophyll b in the studied species. The maximum value of chlorophylls existed in *C. colocyathus* and *R. viscaria*, whereas *C. russeliana* had low content of chlorophyll a and chlorophyll b. The chlorophyll a/b ratio was balanced by the chlorophyll stability to heat. The CSI of chlorophyll a was compensated by CSI of chlorophyll b and vice versa. The maximum values of total chlorophyll stability (a + b) was found in annuals *C. colocyathus* and *D. innoxia*, whereas *C. russeliana* had low CSI. The different chlorophyll parameters were mainly affected by the interaction between wadi and species, and the species factor played the subsidiary role on the chlorophyll content and chlorophyll a/b ratio in most floristic groups, except in case of chlorophyll a of dominant species the wadi factor was subsidiary. There was no significant effect of single factor on CSI of different groups. The correlation of Mg ions, soluble sugars and soluble proteins with total chlorophyll content and CSI were discussed.

Key Words: Chlorophyll, thermostability, wild species, water content, Mg ions, soluble proteins, soluble sugars.

I. Introduction

Many wild or cultivated species inhabiting hot desert wadis under climate and edaphic variations should be subjected to changes in their photosynthetic potentials and biochemical activities. The amount of solar radiation absorbed by a leaf is largely a function of the foliar concentrations of photosynthetic pigments, and therefore low concentrations of chlorophyll can directly limit photosynthetic potential and hence primary production (Curran *et al.*, 1990; Filella *et al.*, 1995). Hence, the relative concentrations of pigments are known to change with abiotic factors such as light and so quantifying these proportions can provide important information about relationships between plants and their environment (Richardson *et al.*, 2002).

A significant correlation between both Chl. content and CSI with water content, soluble proteins and Mg²⁺, was found, with the sign of the correlation dependent on the importance of the constituents to Chl. content and CSI in the studied species (Farghali, 1998; Akinci *et al.*, 2010). Therefore, the change in Chl. a/b ratio accompanied by low Chlorophyll contents in several halo-xerophytes can be compensated by an increase in Chl. stability against the prevailing stress conditions.

This investigation aimed at determines and evaluate the photosynthetic pigments (chlorophyll a chlorophyll b content and stability to heat) and its relationships with Mg ion and main water soluble metabolites of investigated species. Statistical treatments of the data are carried to elucidate the effect of single factors (wadi and species) and their interaction on different parameters measured of plants.

II. Materials and Methods

This investigation was carried out on wild plants inhabiting 4 tributaries of wadi Al Noman at Holey Mecca in the western region of Kingdom of Saudi Arabia. Wadi Al Noman is located in the Western part of Saudi Arabia, between El Hada mountains in the East to the Red Sea coast in the West and extended between 21°06' to 21°32'N and 39°32' to 40°20'E. 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 during the period extending from January to April under the mild climatic condition.

Plant analyses:

Samples of 8 species inhabiting 4 tributaries of wadi Al Noman were chosen and collected from its 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. The investigated species were identified according to Täckholm,

1974; Migahid 1978; Collenette, 1985 and Boulos (1995, 1999, 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 100% of studied sites namely: *Cleome droserifolia*, *Abutilon pannosum*, *Tephrosia desertorum* and *Citrullus colocyanthis*.
- 2- Co-dominant species (No. 5-8) were inhabited 75% of sites were included: *Heliotropium arbainense*, *Rumex vesicarius*, *Datura innoxia* and *Caralluma russeliana*.

The plant samples were immediately transferred to plastic containers from their natural environments 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 (as%):

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 as following equation:

$$\% \text{ of water content} = \frac{\text{Fresh weight of plant} - \text{dry weight of plant}}{\text{Fresh weight of plant}} \times 100$$

Determination of chlorophylls:

At the same time, chlorophyll *a* and chlorophyll *b* were extracted using 85% acetone and determined according to Lichtenthaler (1987). To determine the chlorophyll stability index (CSI) a sample of fresh healthy leaf was placed in 20 ml distilled water and heated in a water-bath at 56±1°C for 30 min, and the CSI calculated according to Murty and Majumder (1962) as the ratio of Chlorophyll content in heated leaf (56±1°C) to that in fresh leaf, expressed as a percentage.

Analyses of plant extracts:

A known weight of fresh leaf sample was rapidly blended with 10 cm³ of ice cold distilled water and the supernatant was kept in deep freeze until analysis.

Determination of water soluble metabolites and Mg :

- 1-Soluble sugars were determined according to Dubois *et al.*, (1956)
- 2- Total soluble proteins were determined according to Lowry *et al.*, (1951).
- 3- Magnesium was determined by using Atomic Absorption Spectrophotometer according to Stewart (1974).

Statistical analyses

The effects of single factors (wadi and species) and their interaction (wadi x species) on the contents of chlorophylls and water soluble metabolites 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 (Ostle, 1963 and Ploxinki, 1969) as applied by EL-Sharkawi and Springuel (1977). A simple linear correlation coefficient (*r*.) between ion content in soils with their analogues in plants, correlation of total chlorophyll and chl. stability with Mg⁺² ions and total chl. with soluble. sugars, and soluble proteins was tested according to Ostle (1963).

III. Results

1- Water content (as %) :

The water content as a percentage of the fresh weight was variable among various species at investigated wadis (Figure 1). 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. While mean, a minimum 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 1) 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 ($\eta^2 = 0.539$, and 0.537 of dominant, and co-dominant species, respectively) and the species factor had a subsidiary effect on the water contents in species .

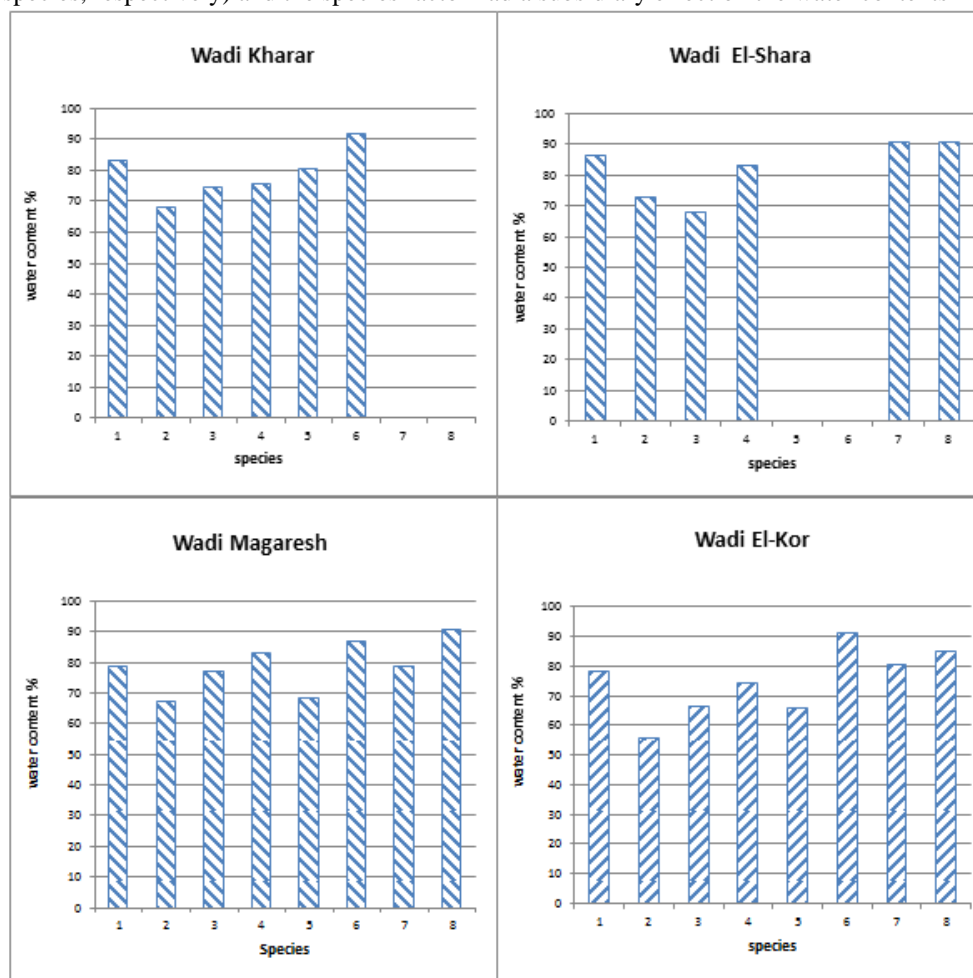


Figure (1): Average values of water content in different species inhabiting wadi Kharar, wadi El- Shara, wadi Magaresh and wadi El-Kor:(1) *C. droserifolia*; (2) *A. pannosum*; (3) *T. desertorum*; (4) *C. colocynthis*;(5) *H. arbainense*; (6) *R. vesicarius*; (7) *D. innoxia*; (8) *C. russeliana*.

2- Chlorophyll content, a/b ratio and stability index :

a- Chlorophyll content (fractions & total) :

plants (Figures 2-4). It is found that, chlorophyll *a* and *b* tended to a maximum (e.g. 2.74 and 2.28 mg.g⁻¹ fresh weight in *A. pannosum*) in species inhabited W. El-Kor. At the same wadi, the minimum value (0.063 and 0.028 mg.g⁻¹ fresh weight) was detected in the succulent species *C. russeliana* at different wadis studied. It seems that, the average chlorophyll *a* content in dominant species was 2.36-1.89 mg.g⁻¹ fresh weight and in co-dominant species was 2.15-0.197 mg.g⁻¹ fresh weight. While mean, chlorophyll *b* content was ranged between 1.57 to 0.87 mg.g⁻¹ fresh weight in dominant species, 1.23 to 0.09 fresh weight and in co-dominant species. The summation of chlorophyll *a* and *b* content (Figure 9) indicated that, *A. pannosum* had a high value (5.02 mg.g⁻¹ fresh weight) at W. El-Kor, whereas *C. russeliana* had a low chlorophyll contents not only in W. El-Kor, but also at W. Magaresh and W. El-Shara . In general, the average values of the total chlorophyll were high (4.52 to 2.76 mg.g⁻¹ fresh weight) in dominant species compared to that values in co-dominant (3.38-0.29 mg.g⁻¹ fresh weight). Obviously, the total chlorophyll or its fractions (Chl. *a* or chl. *b*) of each species were differed among wadis investigated.

Statistically, the chlorophyll *a*, chlorophyll *b* and total chlorophyll contents were significantly affected by wadi, species and their interaction factors with few exceptions (Table,1). It was found that, (wadi x species) interaction had a dominant role (Judged by η^2) on the chlorophyll content of species in different floristic groups. Meanwhile, the wadi factor had a secondary role on the chlorophyll *a* and total chlorophyll of the dominant species, the species factor had a secondary effect on chlorophyll *b*. Likewise, the species factor had a subsidiary role on chlorophyll *a*, chlorophyll *b* and total chlorophyll of co-dominant species.

b- Chlorophyll a/b ratio :

It was noticed that, the chlorophyll a/b ratio had a values ranging between 3.23 and 1.48, where the majority of the ratios in tested species above 2.0 (Figure 5). Meanwhile, the mean value of species at wadi El-Kor was the lowest (1.92), the highest mean value (2.33) was showed in species at W. El-Shara. In general, the mean ratios among species, regardless of its wadis were differed and ranged between 2.74 in *H. arbainense* to 1.62 in *T. desetorum*. It seems that, the highest chlorophyll content a & b corresponding to the lowest chlorophyll a/b ratio and vice versa. This may be due to chlorophyll balanced in wild species as adaptive features in plants responded to high light intensities prevailing in the wadis under investigation. F values (Table 1) indicated that, the wadi, species and their interaction factors had a highly significant effect on the chlorophyll a/b ratio, except wadi factor in co-dominant species. The determination coefficient (η^2) indicated that, the interaction (wadi x species) had a dominant role on the chlorophyll ratio of dominant and co-dominant species (0.575 and 0.629 respectively) and the role of species factor was subsidiary.

c-Chlorophyll stability index (CSI) :

The thermostability of both chlorophyll a and chlorophyll b of plants studied were shown in Figure (6-8). At wadi Kharar and wadi Magaresh, *H. arbainense* and *D. innoxia* (also *T. desetorum*) held the highest CSI percentage of chlorophyll a (91.09 and 91.96 %, respectively). The same was true for CSI of chlorophyll b in case of *H. arbainense*. The lowest CSI of chlorophyll b (41.1%) was noticed in *C. russeliana* at W. El-Shara.

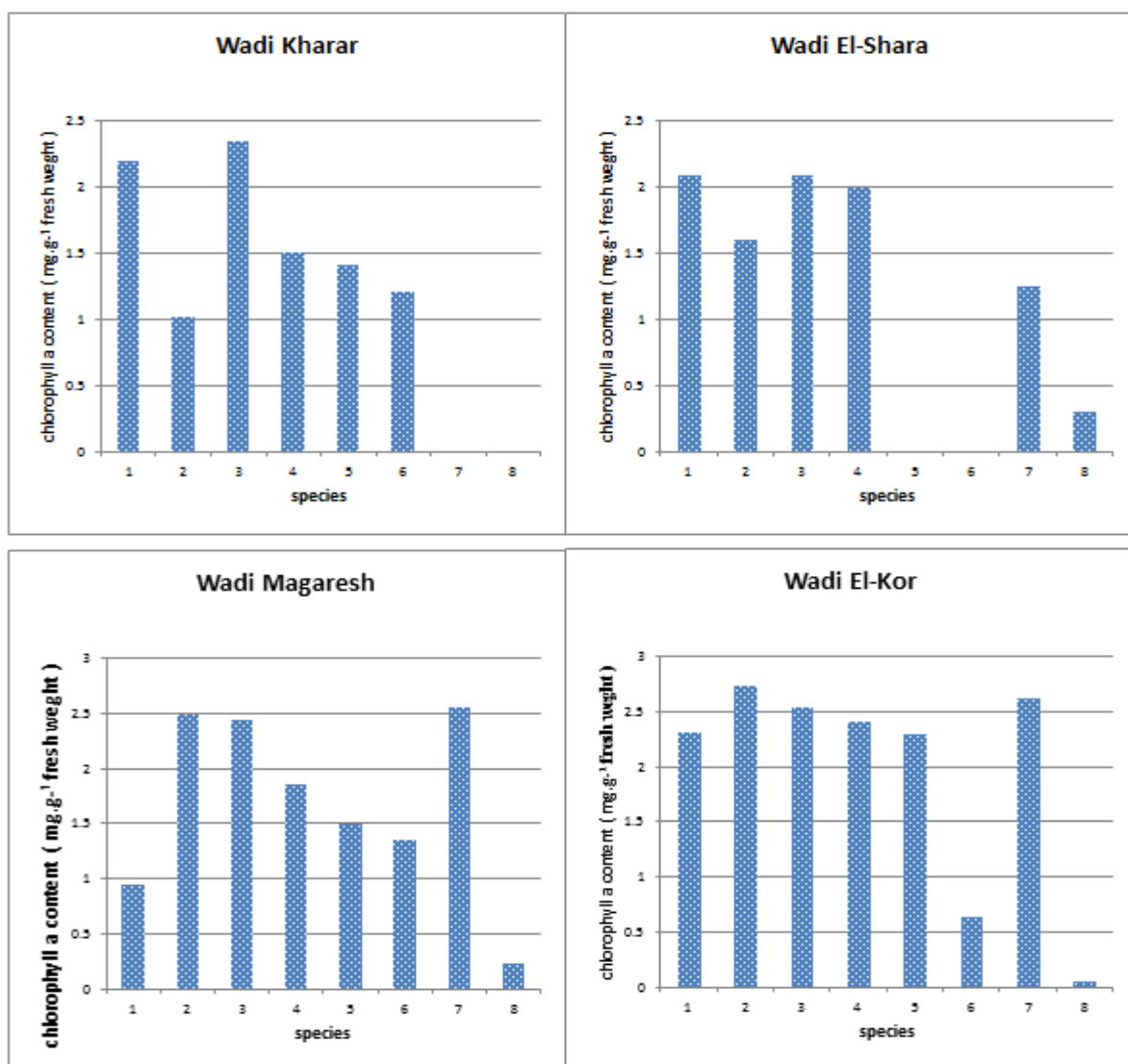


Figure (2): Average values of chlorophyll (a) in different species inhabiting wadi Kharar ,wadi El-Shara, wadi Magaresh and wadi El-Kor: (1) *C. droserifolia*; (2) *A.pannosum*; (3) *T. desetorum*; (4) *C. colocynthis*;(5) *H. arbainense*; (6) *R.vesicarius*; (7) *D. innoxia*; (8) *C. russeliana*.

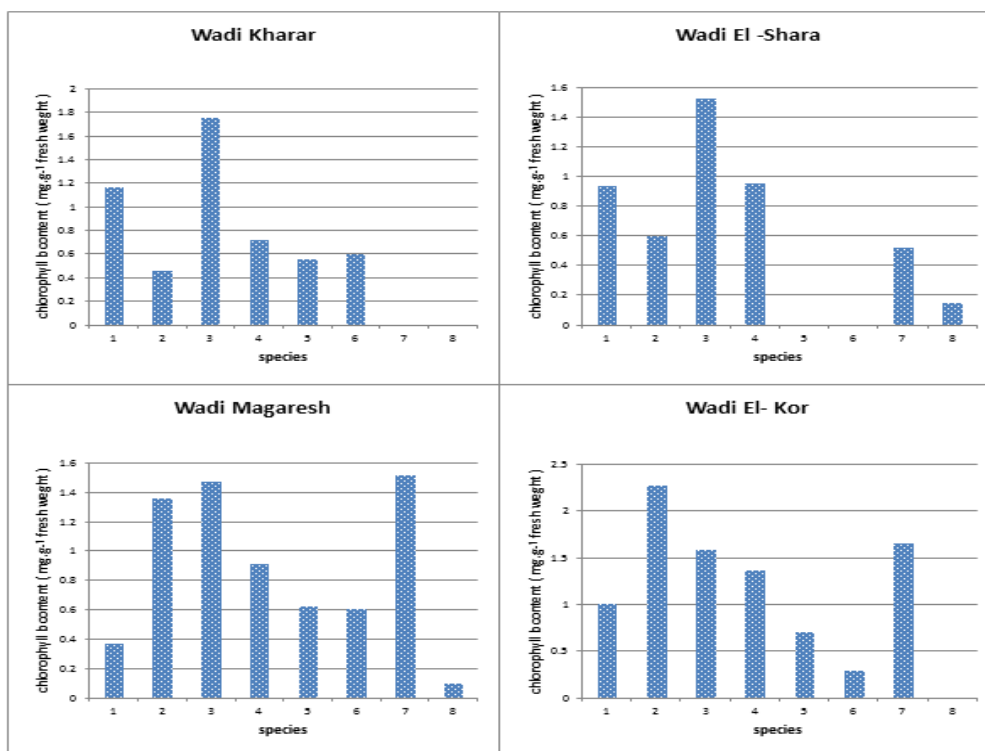


Figure (3): Average values of chlorophyll (b) in different species inhabiting wadi Kharar , wadi El-Shara, wadi Magaresh and wadi El-Kor (1) *Cleome droserifolia*; (2) *Abutilon pannosum*; (3) *Tephrosia desertorum*; (4) *Citrullus colocynthis*; (5) *Heliotropium arbainense*; (6) *Rumex vesicarius*; (7) *Datura innoxia*; (8) *Caralluma russeliana*.

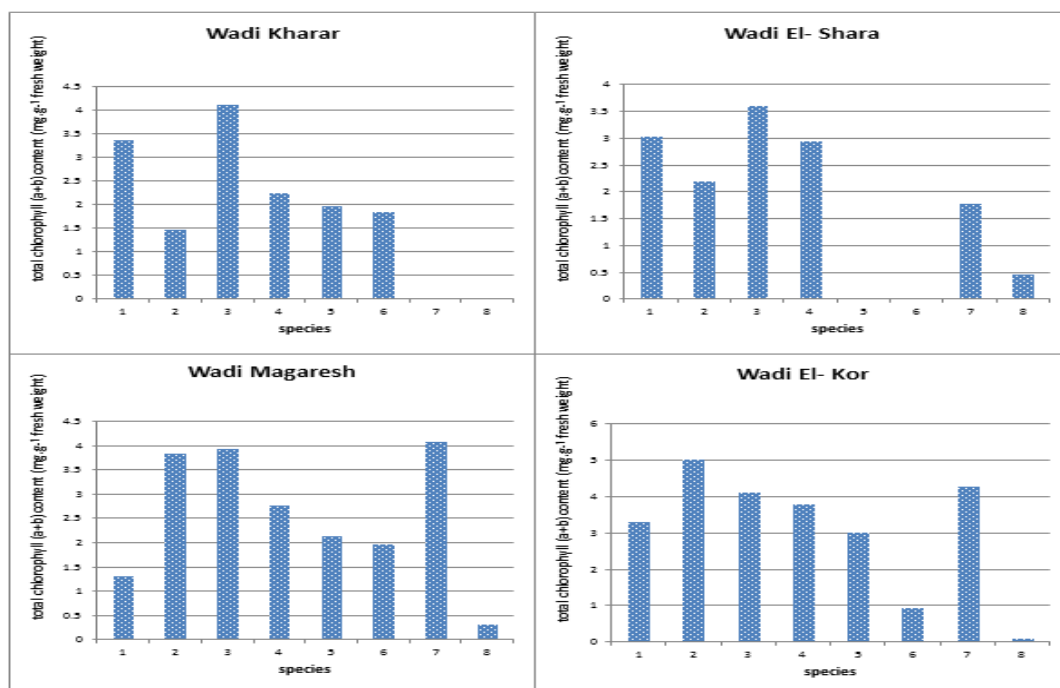


Figure (4): Average values of chlorophyll (a+b) in different species inhabiting wadi Kharar , wadi El-Shara, wadi Magaresh and wadi El -Kor (1) *Cleome droserifolia*; (2) *Abutilon pannosum*; (3) *Tephrosia desertorum*; (4) *Citrullus colocynthis*; (5) *Heliotropium arbainense*; (6) *Rumex vesicarius*; (7) *Datura innoxia*; (8) *Caralluma russeliana*.

Statistically (Table 1), the interaction between wadi & species had a highly significant effect on the CSI of chlorophyll a, chlorophyll b and total CSI in both dominant and co-dominant species, which had the

predominant role ($\eta^2 = 0.815- 0.660$). Also, the species factor had a significant effect on the CSI of chlorophyll *a* of co-dominant species, which was played a secondary role ($\eta^2 = 0.266$).

Table (1): ANOVA test showed the effect of wadis, species and their interaction on the water content, chlorophyll content, stability and chlorophyll *a/b* ratio of investigated species .

contents	Group of species Source of variance	Dominate sp.		Co dominate sp.	
		F	η^2	F	η^2
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
Chl. <i>a</i>	Wadi	4.628*	0.203	0.815	0.0413
	species	1.791	0.092	26.749**	0.416
	Wadi x species	10.502**	0.705	29.843**	0.543
Chl. <i>b</i>	Wadi	6.468**	0.200	0.813	0.042
	species	7.524**	0.222	21.303**	0.395
	Wadi x species	16.301**	0.578	40.402**	0.563
Chl. <i>a + b</i>	Wadi	6.916**	0.220	0.846	0.042
	species	5.472**	0.187	26.045**	0.410
	Wadi x species	13.483**	0.593	40.968**	0.548
Chl. <i>a/b</i>	Wadi	4.328*	0.156	0.268	0.023
	species	9.559**	0.270	6.320**	0.348
	Wadi x species	11.321**	0.575	4.500**	0.629
CSI <i>a</i>	Wadi	0.907	0.082	1.032	0.074
	species	1.151	0.103	4.987*	0.266
	Wadi x species	2.928*	0.815	8.222**	0.660
CSI <i>b</i>	Wadi	1.550	0.101	0.432	0.038
	species	2.116	0.133	2.773	0.199
	Wadi x species	5.604**	0.767	8.135**	0.763
CSI <i>a+b</i>	Wadi	0.779	0.063	0.378	0.034
	species	1.589	0.122	3.078	0.224
	Wadi x species	3.969**	0.814	6.255**	0.742
D.F		Wadi =3	sp=3	Wadi =2	sp=3
		wadi x sp=15		wadi x sp=11	

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

Apparently, in most species the thermostability of chlorophyll *a* was higher than that of chlorophyll *b*. Among wadis, the mean CSI of chlorophyll *a* in different species was increased at W. Magaresh, while species produced a minimum CSI value at W. El-Shara and *vice versa* for CSI of chlorophyll *b*. The total thermostability of chlorophyll (CSI *a* + CSI *b*) in plants inhabited tributaries of wadi Al Noman was variable among wadis studied. Meanwhile, the highest mean value of CSI was

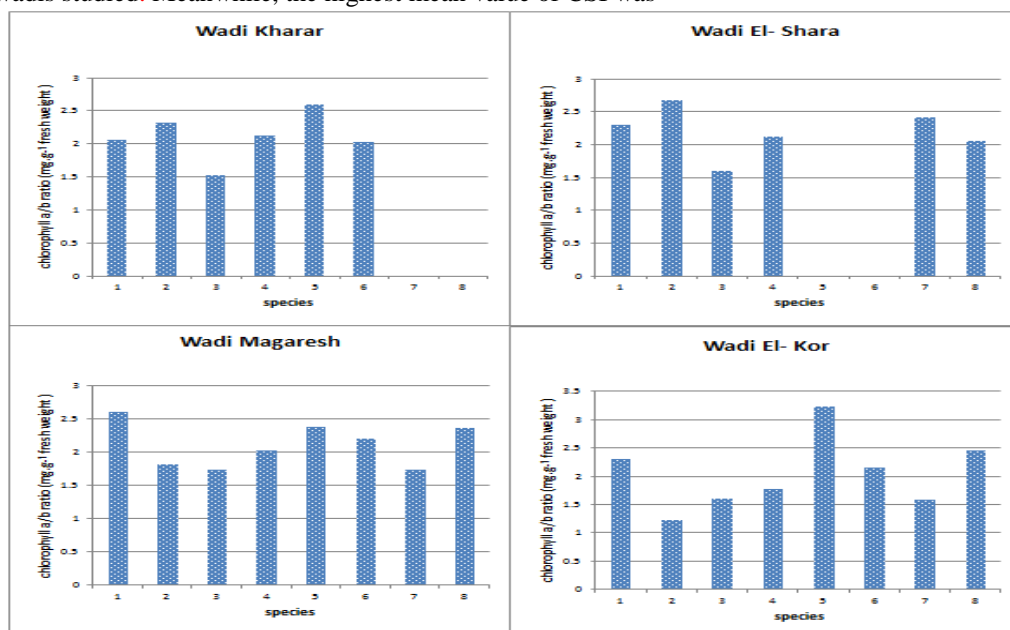


Figure (5): Average values of ratio chlorophyll (*a* / *b*) in different species inhabiting wadi Kharar, wadi El-Shara, wadi Magaresh and wadi El- Kor: (1) *Cleome droserifolia*; (2) *Abutilon pannosum*; (3) *Tephrosia desertorum*; (4) *Citrullus colocynthis*; (5) *Heliotropium arbainense*; (6) *Rumex vesicarius*;

(7) *Datura innoxia*; (8) *Caralluma russeliana*.

represented by 70.0 % in species inhabited W. El-Kor, the lowest mean value was showed in species at W. Kharar (67.0 %). Regardless of wadis, species namely: *T. desertorum*, *C. colocynthis* (dominant species), *D. innoxia* (co-dominant sp.) had a highest mean value of chlorophyll stability to heat. Whereas, the lowest mean of CSI was exerted by succulent *C. russeliana* (co-dominant species). Obviously, a maximum CSI ($a+b$) was represented by 92.71 % in *H. arbainense* at W. Kharar and the minimum value (48.9 %) was in *C. colocynthis* at W. Magaresh.

The correlations between total chlorophyll content and CSI were shown in table (2). A significant negative correlation was found between chlorophyll content and its stability to heat in *C. russeliana* (succulent). However, the chlorophyll content was positively correlated with CSI in the rest common species. The correlations between water content with the content or stability of chlorophyll in dominant species were non-significant. In co-dominant species, only the water content in *H. arbainense* was positively correlated with CSI, while in case of *D.innoxia* had a negative correlation with chlorophyll content.

Table (2): Correlation coefficient (r.) values between total chlorophyll and its stability with water content in different studied species.

Species group	Contents	Total ch & water content	Total CSI & water content	Total ch & Total CSI	D.F
	Species				
Dominant species	<i>C. droserifolia</i>	0.381	0.265	-0.707	Wadi =3
	<i>A .pannosum</i>	-0.803	-0.766	0.377	
	<i>T .desertorum</i>	-0.535	0.254	-0.317	
	<i>C. colocynthis</i>	-0.235	-0.576	0.145	
Co-dominant species	<i>H. arbainense</i>	-0.753	0.986*	-0.632	Wadi =2
	<i>R. vesicarius</i>	-0.534	-0.102	-0.787	
	<i>D. innoxia</i>	-0.980*	-0.070	-0.137	
	<i>C. russeliana</i>	0.878	-0.870	-1.000**	

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

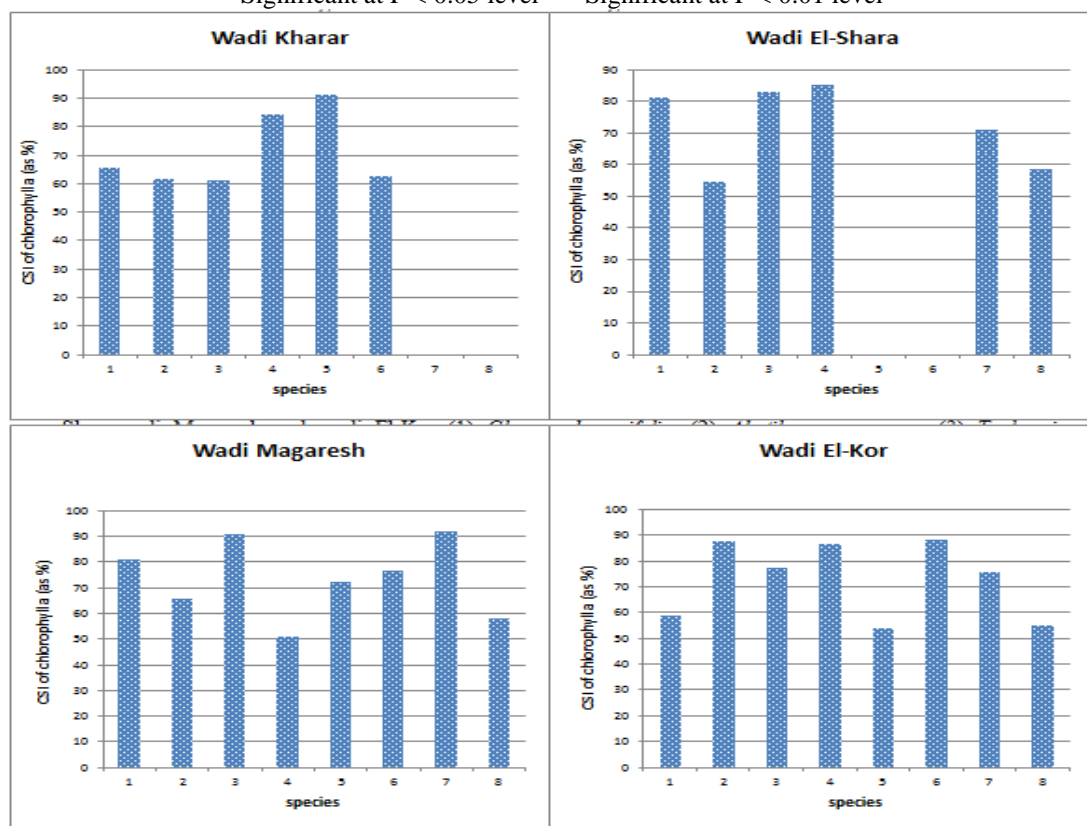


Figure (6): Average values of CSI chlorophyll (a) in different species inhabiting wadi Kharar, wadi El-Shara, wadi Magaresh and wadi El-Kor (1) *Cleome droserifolia*; (2) *Abutilon pannosum*; (3) *Tephrosia desertorum*; (4) *Citrullus colocynthis*; (5) *Heliotropium arbainense*; (6) *Rumex vesicarius*; (7) *Datura innoxia*; (8) *Caralluma russeliana*.

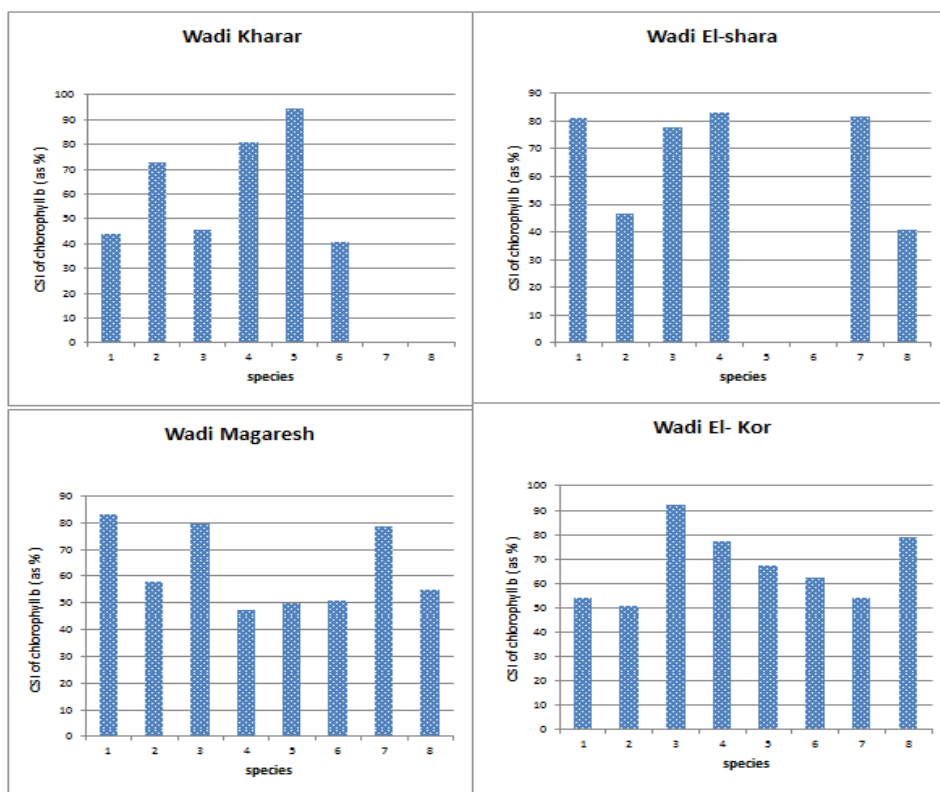


Figure (7): Average values of CSI chlorophyll (b) in different species inhabiting wadi Kharar , wadi El-Shara, wadi Magaresh and wadi El-Kor: (1) *Cleome droserifolia*; (2) *Abutilon pannosum*; (3) *Tephrosia desertorum*; (4) *Citrullus colocynthis*; (5) *Heliotropium arbainense*; (6) *Rumex vesicarius*; (7) *Datura innoxia*; (8) *Caralluma russeliana*.

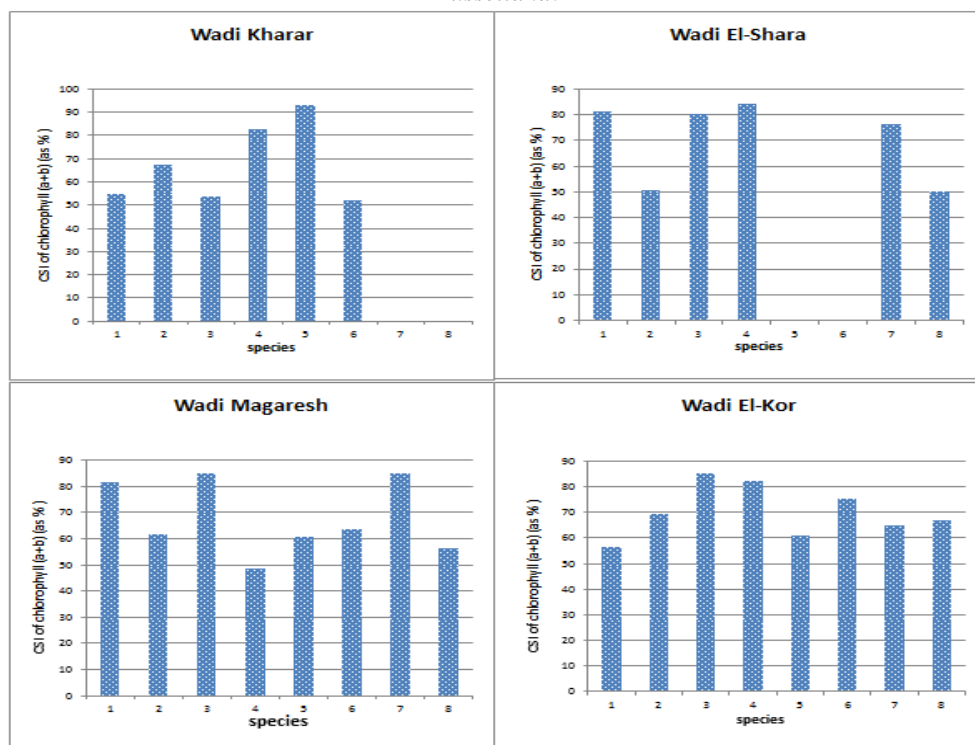


Figure (8): Average values of CSI of chlorophyll (a+b) in different species inhabiting wadi Kharar , wadi El-Shara, wadi Magaresh and wadi El-Kor: (1) *C. droserifolia*; (2) *A. pannosum*; (3) *T. desertorum*; (4) *C. colocynthis*; (5) *H. arbainense*; (6) *R. vesicarius*; (7) *D. innoxia*; (8) *C. russeliana*.

• **Magnesium :**

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 *H. arbainense* 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. (Figure 9).

F and η² 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 (η²= 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 experimented species. However, the role of species factor was minor (Table 3).

Table (3): ANOVA test showed the effect of wadis ,species and their interaction on Mg of investigated species of different floristic groups.

contents	Floristic group	Dominant species		Co dominant species.	
		F	η ²	F	η ²
Source of variance					
Mg	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

Significant at P < 0.05 level,

**Significant at P < 0.01 level

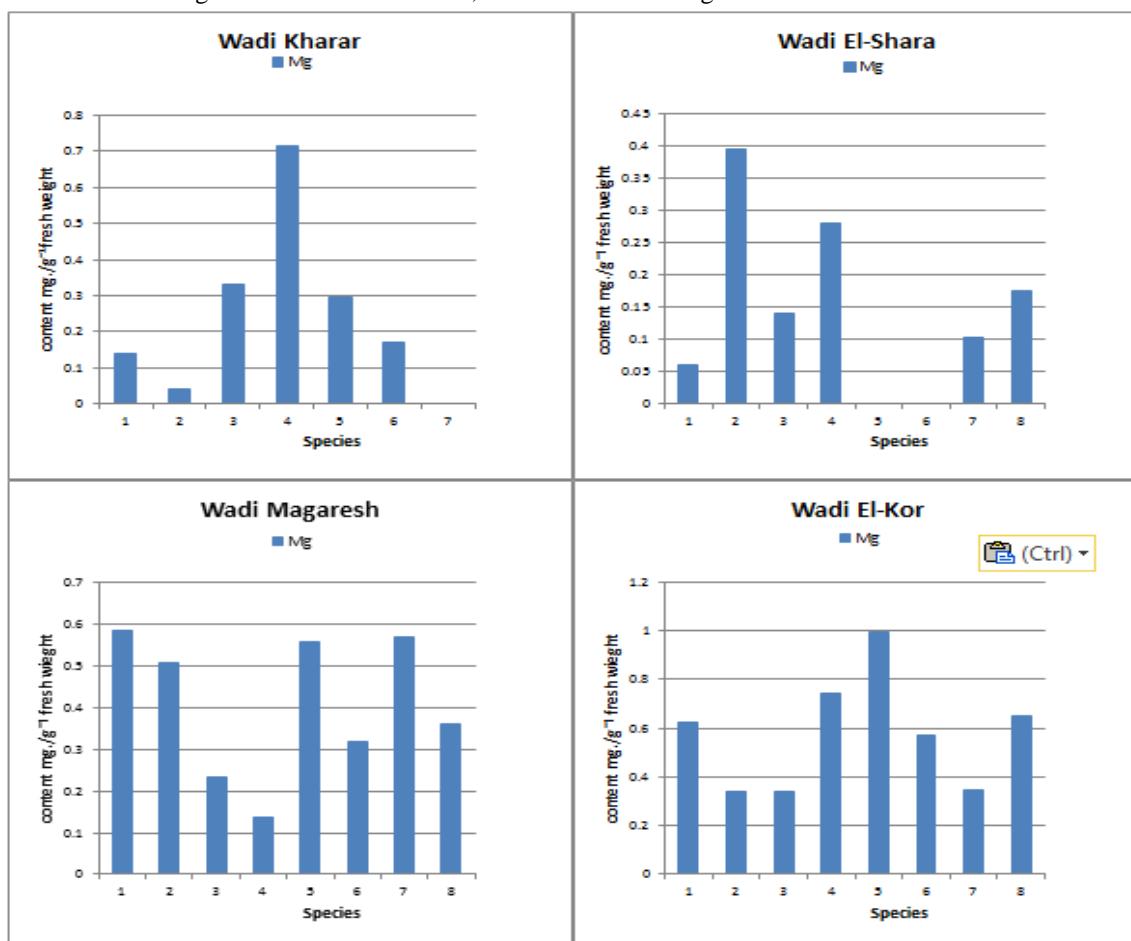


Figure (9): Average content of Mg in different species inhabiting wadi Kharar, wadi El-Shara, wadi Magaresh and wadi El-Kor: (1) *C. droserifolia*; (2) *A. pannosum*; (3) *T. desertorum*; (4) *C. colocynthis*; (5) *H. arbainense*; (6) *R. vesicarius*; (7) *D. innoxia*; (8) *C. russeliana*.

Magnesium is an essential ion in the chlorophyll formation. Therefore, the correlation of Mg with both chlorophyll content and its stability to heat was variable among investigated species (Table 4). The significant positive correlation means that increased Mg ion was accompanied by an increasing in chlorophyll content and /or its stability to heat (e.g. *H. arbainense*, *R. vesicarius* and *C. russeliana*). Whereas, the negative correlation referred to a degradation of chlorophylls and /or decreased CSI of plants (e.g. *C. russeliana*) under natural wadis conditions.

Table (4): Correlation coefficient (r.) values between total chlorophyll and its stability with Mg ion in different studied species.

Floristic group	Contents		Total ch & Mg	Total CSI & Mg	D.F
	species				
Dominant species	<i>C. droserifolia</i>		-0.460	-0.066	Wadi =3
	<i>A. pannosum</i>		0.588	-0.450	
	<i>T. desertorum</i>		0.681	-0.850	
	<i>C. colocynthis</i>		0.190	0.685	
Co-dominant species	<i>H. arbainense</i>		0.974*	-0.791	Wadi =2
	<i>R. vesicarius</i>		-0.878	0.988*	
	<i>D. innoxia</i>		0.845	0.415	
	<i>C. russeliana</i>		-1.000**	1.000**	

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

3- Water soluble metabolites :

a- Soluble sugars (S.S):

There was a differentiation in the soluble sugars content among experimented species at different wadis (Figure 10). A high content of soluble sugars (1.42 mg.g⁻¹ fresh weight) was showed in *T. desertorum*, *C. colocynthis* at W. Kharar, *C. russeliana*, *R. stricta* at W. El-Shara and in *D. innoxia* at W. El-Kor. Whereas, a lowest value of S.S (0.073 mg.g⁻¹ fresh weight) was existed in *R. vesicarius* (annual). Regardless of species, a maximum mean value of S.S. (0.68 mg.g⁻¹ fresh weight) was yielded by plants at W. Kharar ,whereas species at W. El-Shara produced a minimum S.S content (0.38 mg.g⁻¹ fresh weight). Among species, the high mean values of S.S. were showed in the dominant species and in *D. innoxia* and *C. russeliana* (co-dominant), whereas *H. arbainense* yielded a lowest S.S. content.

F values indicate that, wadi as a single factor and its interaction with species factor had a significant effect on soluble sugars of dominant and co-dominant species (Table 5). The same was true in case of the species factor effect on S.S. in co-dominant species. Meanwhile, the role of thi and s interaction was predominant on S.S. in species of different groups ($\eta^2 = 0.60$ and 0.58), the wadi factor had a secondary role on S.S. of dominant and co-dominant species ($\eta^2 = 0.35$ and 0.24 , respectively).

2-Total soluble proteins (S.P.):

Obviously, the dominant species gained high contents of soluble proteins, especially in *T. desertorum* at various locations. Regardless of single species, all species inhabited W. Magaresh and W. El-Kor had a maximum mean value (0.06 mg.g⁻¹ fresh weight) of S.P., while a minimum mean value was in species inhabited wadi El-Shara (Figure 11).

F values (Table 5), showed that, wadi, species and their interaction had no significant effect on the soluble proteins of dominant species. Conversely, the wadi factor and its interaction with species had a significant effect on S.P. in co-dominant species. The interaction role was the dominant, while the role of wadi was subsidiary on S.P. contents in case of co-dominant species.

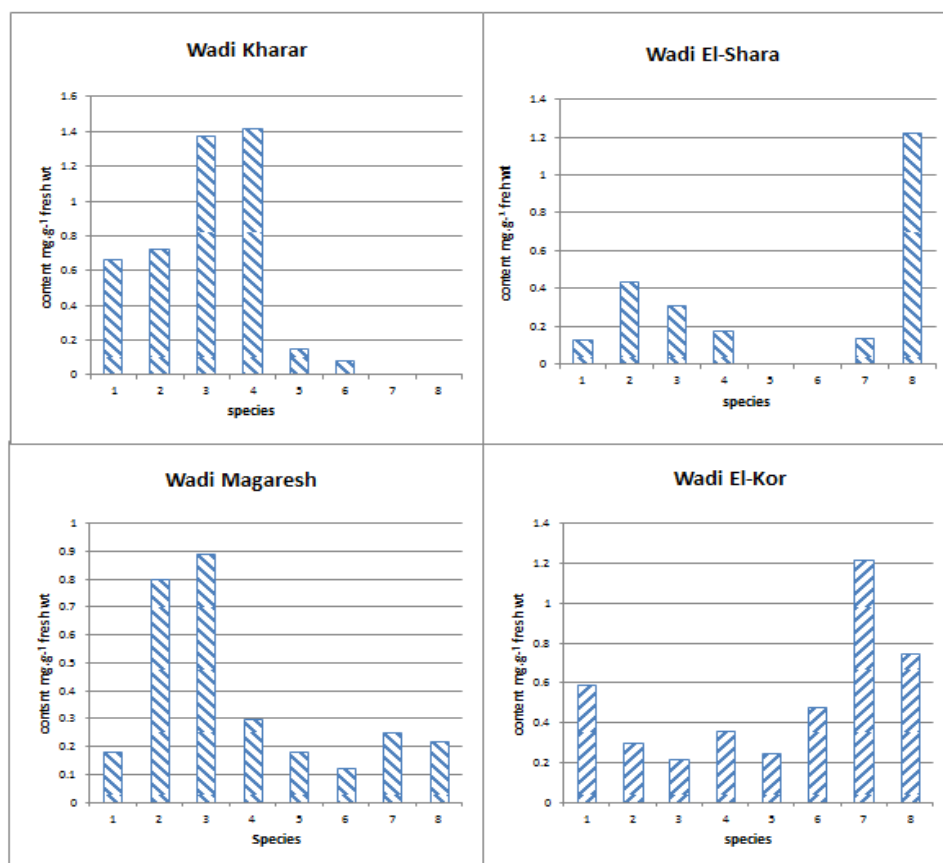


Figure (10): Average values of soluble sugars in different species inhabiting wadi Kharar , wadi El-Shara, wadi Magaresh and wadi El-Kor : (1) *C. droserifolia*; (2) *A.pannosum*; (3) *T. desertorum*; (4) *C. colocynthis*; (5) *H. arbainense*; (6) *R.vesicarius*; (7) *D. innoxia*; (8) *C. russeliana*.

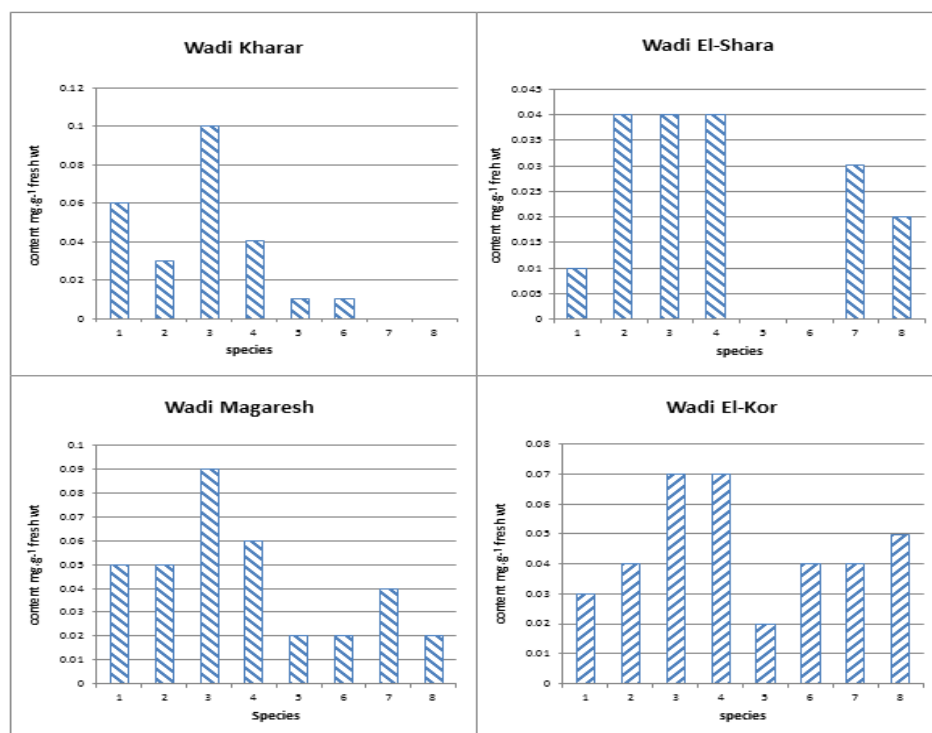


Figure (11): Average values of Soluble proteins in different species inhabiting wadi Kharar , wadi El-Shara, wadi Magaresh ,wadi El-Kor. : (1) *C. droserifolia*; (2) *A.pannosum*; (3) *T. desertorum*; (4) *C. colocynthis*; (5) *H. arbainense*; (6) *R.vesicarius*; (7) *D. innoxia*; (8) *C. russeliana*.

Table (5): ANOVA test showed the effect of wadis ,species and their interaction on soluble sugars , soluble proteins and Mg of investigated species of different floristic groups

Floristic group	contents	Total chl & soluble sugar	Total CSI & soluble sugar	Total chl & soluble protein	Total CSI & soluble protein	D.F
	species					
Dominant species	<i>C.droserifolia</i>	0.636	-0.994**	-0.358	-0.272	Wadi =3
	<i>A.pannosum</i>	-0.420	0.046	0.722	-0.308	
	<i>T.desertorum</i>	-0.458	-0.793	0.788	-0.517	
	<i>C.colocynthis</i>	-0.661	0.292	0.707	-0.247	
Co-dominant species	<i>H.arbainense</i>	0.990**	-0.723	0.384	-0.958*	Wadi =2
	<i>R.vesicarius</i>	-0.976*	0.903	-0.853	0.993**	
	<i>D.innoxia</i>	0.635	-0.848	0.955*	0.162	
	<i>C.russeliana</i>	0.324	-0.355	-0.921	0.914	

Significant at P < 0.05 level,

**Significant at P < 0.01 level

Correlation between chlorophyll content and CSI with experimented metabolites:

The most significant correlations between chlorophyll content and soluble sugars in the co-dominant species were positive (Table 8) with some exceptions. The same was true with soluble proteins. However, there were no significant correlations existed between total chlorophyll with both soluble sugars and soluble proteins of the dominant species. On the other hand, the total CSI was negatively correlated with soluble sugars of *C. droserifolia*. The same correlation was found between CSI and S. proteins of *H. arbainense*, while mean, a positive correlation existed in case of *R. vesicarius* (co-dominant species).

Table (6): Correlation coefficient (r.) values between total chlorophyll and its stability(CSI) with soluble sugars, soluble proteins in different studied species.

contents	Floristic group		Dominant species		Co dominant species.	
	Source of variance		F	η2	F	η2
	Wadi	species				
Soluble sugars	Wadi		15.808**	0.353	5.630*	0.238
	species		1.077	0.047	3.841*	0.182
	Wadi x species		16.049**	0.601	11.843**	0.581
Soluble proteins	Wadi		0.310	0.044	4.289*	0.222
	species		2.222	0.261	3.230	0.222
	Wadi x species		1.183	0.696	3.676*	0.556

*Significant at P < 0.05 level,

**Significant at P < 0.01 level

IV. Discussion

Drought and extreme temperatures cause a water deficit in plants. Data presented clarified that, succulent and annuls species had a high values of water content. Low water content was detected in the xerophyte *A. pannosum*, particularly at W. El-Kor which was inhabited by species had a low mean values of water content. The F and η² values indicated that, the water content in plants was mainly affected by the interaction (wadi x species). While the species factor played the secondary role.

The intrinsic photo synthetic water use efficiency tended to rise than decline as the water stress increases in natural habitats (Pennings *et al.*, 2005). Therefore, the arid climate affects the synthesis of essential pigments of plants. Richardson *et al.* (2002) reported that, the chlorophyll *a* and chlorophyll *b* are the most important of these pigments, and are thus virtually for the oxygenic conversion of light energy to the stored chemical energy that power of the biosphere . Obviously in this work, the high mean values of both chlorophyll *a* and chlorophyll *b* exerted by species inhabited W. El-Kor, and a low mean values was produced by species at W. El Shara. Generally, the results hitherto showed an increase in chlorophyll *a* content more than that of chlorophyll *b* and the succulent *C. russeliana* exhibited low levels of pigmentation. Among species, *T. desertorum* had high contents of chlorophyll *a* and chlorophyll *b*, as well as the total chlorophyll (chlorophyll *a* and chlorophyll *b*). This mechanism of resistance to PSII against photo damage may contribute to plant protection against chlorophyll destruction (Sharma and Hall, 1992; Farghali, 1998; Farghali and Rayan, 2005). In agree with Farghali (1998), Liu and Guan (2012) believe that the abundance of sunlight and lack of water in arid environments selects for plants with reduced Chl *a* content in the photosynthetic reaction center and for

reduced size of the antenna chlorophyll protein complex so as to reduce the absorbed light energy and the generation of free radicals.

On other hand, the chlorophyll *a/b* ratio slightly changed among studied species, where a low value was detected in *T. desertorum*. This means that, increased chlorophyll fractions corresponding to decreasing of chlorophyll *a/b* ratio. Furthermore, the mean values of this ratios could be emphasized this view where the high chlorophyll *a/b* ratio was yielded by species at W. El-Shara and a low value was found in species at W. El-Kor. Farghali (1998) concluded that, the adaptation of plants in their natural habitats to enduring drought and high temperatures are due to decreased chlorophyll *a/b* ratios balanced by increased chlorophyll stability to heat (CSI). This was true in case of CSI of chlorophyll *a* in most species inhabited W. Al Noman tributaries. The succulent *C. russeliana* had a low CSI of chlorophyll *a*. Whereas, *T. desertorum* yielded a high CSI of chlorophyll *a*, the stability of chlorophyll *b* to heat was decreased. This was true in case of *R. vescarius* (annual), which means that the species strategies against chlorophyll destruction depend on the alternation of CSI between chlorophyll *a* and chlorophyll *b*. Thus PSII appears to be most heat sensitive within the photosynthetic apparatus of plants in arid and semi-arid regions (Aro *et al.*, 1993). Therefore, the total CSI of both chlorophyll *a* and chlorophyll *b* was slightly changed among investigated species. In general, the increase in CSI and/or chlorophyll accumulation is indicative of high efficiency of photosynthetic apparatus under extreme conditions (Farghali, 1998; Farghali and Rayan, 2005). In some instances of the studied species, the chlorophyll content was positively correlated with CSI. Conversely, the negative correlation between chlorophyll content and its stability to heat in such species as *C. russeliana* means that, CSI depends on the resistance of chloroplast membrane to heat, and consequently it is helpful in indicating adaptations in such species (Ristic and Cass, 1992). The chlorophyll content greatly affected by the single factors (wadi and species) factors and their interaction which had a highly significant effects with some exceptions. In general, this interaction had a dominant role on the chlorophyll *a*, chlorophyll *b*, chlorophyll *a/b* and total chlorophyll content in different floristic groups. The role of secondary was variable, where the species factor had a role on chlorophyll parameters mentioned above in different groups, except in case of dominant species, the chlorophyll *a* and total chlorophyll contents were affected by the wadi factor. Whereas the interaction (wadi x species) had a highly significant, and the predominant role on the CSI of dominant and co-dominant species.

Chlorophyll content gives an indicator measure of nutrient status (Moran *et al.*, 2000; Richardson *et al.*, 2002). Hence, Mg participates in chlorophyll building and enhancing pigment content. Accordingly, a significant positive correlation between chlorophyll content and Mg^{+2} in tested species (e.g. *H. arbainense*) was due to consumption of Mg ions during chlorophyll construction. Conversely, negative correlation, (e.g. *C. russeliana*) means a destruction of chlorophyll content may be due to excessive excitation energy when high temperature was combined with high light (Chen *et al.*, 2004; Farghali and Rayan, 2005). Sometimes, the increased thermo stability of chlorophyll in wild species under drastic conditions was accompanied by increased Mg^{+2} ions (e.g. annual *R. vescarius* and succulent *C. russeliana*) and *vice versa*.

The adaptation of plants to heat stress induced accumulation of metabolites that serve as compatible solutes in chloroplasts which were related to enhance thermostability (Hasegawa and Bressan, 2000). This was true in case of succulent *C. russeliana* which had highest values of soluble sugars with increased CSI. Regardless of species, a high amount of soluble sugars was found in species inhabited W. Kharar, whereas the lowest mean values existed in species at W. El-Shara. Hence, the (wadi x species) interaction had a major role on the soluble sugars of different species. The wadi factor played the secondary role on soluble sugars of dominant and co-dominant species. There were positive correlations between soluble sugars and chlorophyll content in most studied species contributed to high efficiency of chlorophyll molecules (Rayan, 2004). The soluble sugars in such species as *R. vescarius* were negatively correlated with chlorophyll contents may be due to translocation of sugars to fruits, or to different plant parts, or carbon partitioning between sucrose and starch (Farghali and El-Sharkawi, 1990; Keutgen and Chen, 2001).

Apparently, the metabolic constituents in the investigated species exhibited the following pattern: soluble sugars > soluble proteins. The interaction (wadi x species) had a significant effects on soluble proteins in co-dominant species, while a non-significant effect in case of soluble proteins in dominant species. Therefore this interaction played the main role on the soluble proteins. The subsidiary role on this nitrogen fraction in co-dominant species was exerted by the wadi factor. A positive correlation was shown between chlorophyll content and soluble proteins in *D. innoxia* (annual). This may explained that these species may tolerate drought in an account for reductions in chlorophyll content which in turn may cause changes in soluble proteins (Rayan and Farghali, 2007). While, CSI and proteins in *R. vescarius* (annual) was positively correlated, there were a negative correlations in case of *H. arbainense*. This means that, the adaptation of these plants to heat stress induced accumulation of water binding molecules and compatible solutes in chloroplasts which related to enhance thermostability (Hasegawa and Bressan, 2000). The pigmentation of many species was well established and balanced by the thermo stability of chlorophyll against high irradiance, heat and water stresses. Accordingly, the application of any cropping projects at desert wadis 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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