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ECOPHYSIOLOGICAL STUDIES ON SOME SPECIES GROWING ALONG WADI EL-NATRUN EL-ALAMEIN DESERT ROAD

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Abstract

The present study was carried out to elucidate the adaptive responses of some desert plants growing in two different habitats along Wadi El-Natrun El-Alamein Desert Road. The species characterizing the sand- gravel plain habitat include *Thymelaea hirsuta, Artemisia monosperma, Deverra tortuosa* and *Traganum nudatum*, while those characterizing the dry saline habitat are *Zygophyllum album* and *Asphodelus microcarpus*. The species of dry saline habitat attained higher values of water content, degree of succulence, calcium, magnesium and chlorides. Also, *Zygophyllum album* achieved the highest ash content and this was mainly due to accumulation of Na^+, Ca^{+2} and Mg^{+2}. In addition, Na^+ were accumulated with low concentration in species of sand and gravel plain, except *Traganum nudatum* which had high concentration of Na like species of dry saline habitat. Moreover, the studied species accumulated potassium rather than sodium, except *Traganum nudatum* and *Zygophyllum album.*

The concentration of chlorophyll b was generally greater than chlorophyll a in the studied species during the different seasons. Species of dry saline habitat tended to accumulate reducing sugars during winter. Furthermore, the concentration of total carbohydrates in all species reached the highest value in autumn followed by summer. Finally, it was found that species of dry saline habitat as well as *Traganum nudatum* established their osmoregulation at the dry season via cationic and/or anionic accumulation. Although, species characterizing the sand-gravel plain, their osmotic adjustment was established to great extent, via sugars accumulation.

Introduction

Plants are subjected to several harsh environmental stresses that adversely affect growth, metabolism and yield. Drought is a major abiotic factor that limits crop production (Lawlor and Cornic, 2002). Stress, according to Levitt (1980) means the action of environmental factors and reaction of the organism.

Water stress tolerance is seen in almost plant species but its extent varies from species to species. Although the general effects of drought on plant growth are fairly well known, the primary effects of water deficit at the biochemical and the molecular levels are not well understood (Zhu, 2002 and Chaves *et al.,* 2003).

Osmoregulation, osmotic compensation, or osmotic adjustment is the process to maintain the turgidity of plant cells by a sufficient increase in cell solutes to compensate the external osmotic stress. According to Walter (1960) osmotic adjustment enables cell enlargement and growth to continue at water potentials that otherwise are inhibitory. Accumulation of organic compounds and inorganic ions as the main osmotically active constituents of desert plants under stress conditions was reported by El-Monayeri *et al.* (1986 a and b), Youssef (1994), Migahid *et al.* (1996), Abd Alla *et al.* (1999), Mossalam *et al.* (2000), Xu *et al.* (2002) and Wang *et al.* (2004).

The present study aims to study ecophysiological adaptive responses of some desert plants growing naturally under two different habitat conditions along Wadi El-Natrun El-Alamein Desert Road.

Materials and Methods

The study area of Wadi El-Naturn El-Alamein Desert Road lies between latitude from 30°20⁻ to 31° North and longitude from 29° to 29°30⁻ East (Photo 1). Two locations were chosen to carry out the present work. The first is located at 40 Km and the second at 130 Km from the beginning of the road.

Climatic data of Wadi El-Natrun and El-Dabba regions are represented in Tables 1 and 2. It is noticed that Wadi El-Natrun area had higher temperature and somewhat higher values of wind velocity than El-Dabba region. However, El-Dabba was characterized by higher quantity of rainfall as a total as compared with Wadi El-Natrun. The highest amount of rainfall (40.6 mm/month) was detected for the year 2002 at Wadi El-Naturn and for the year 2000 (229.1 mm/month) at El-Dabba area.

The first location namely sand-gravel plain represents *Thymelaea hirsute* (L.) Endle. community and the associate species included *Artemisia monosperma* Del., *Deverra tortuosa* Desf. and *Traganum nudatum* Del. Also, *Astragalus spinosus* (Forssk.) Muschl. and *Gymnocarpos decandrum* Forssk. were recorded only in summer, while, *Helianthemum* sp.was found during autumn. Additionally, *Echinops spinosus* L., Mant. was recorded in dry form. The second location namely dry saline habitat represents *Zygophyllum album* L.F. community and its associate species was *Asphodelus microcarpus* Salzm & Viv. which was observed during autumn and winter.

Soil analyses:

Soil samples were collected during summer (2001) and winter (2002) from depth 0-40 cm and soil analyses were carried out according to the methods described by Jackson (1967), Pearcy *et al.* (1991), Rowell (1994) and Harris (1998).

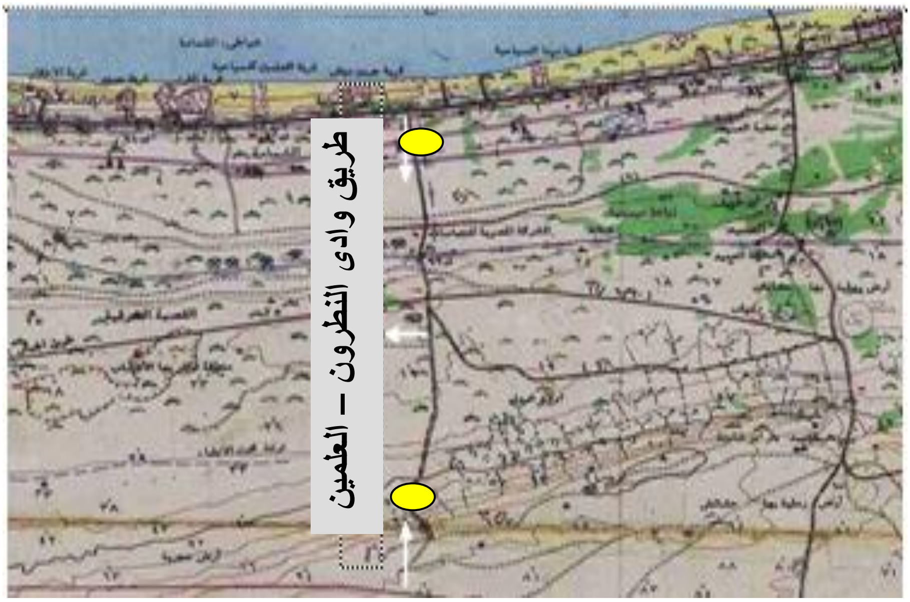

Photo 1. Location map showing the studied area

Plant analyses:

The plant materials used in the present investigation included *Thymelaea hirsute* (L.) Endle, *Artemisia monosperma* Del., *Deverra tortuosa* Desf., *Traganum nudatum* Del. (sand-gravel plain habitat) and *Zygophyllum album* L.F. as well as *Asphodelus microcarpus* Salzm & Viv. (dry saline habitat). The previous species were collected during summer, autumn (2001), winter and spring (2002). The methods adopted for plant analyses were summarized as follows: water content and degree of succulence (Slatyer & Macllory, 1961 and Dehan & Tal. 1978), photosynthetic pigments (Metzner *et al.*, 1965) and extraction and estimation of carbohydrate fractions (Chaplin & Kennedy, 1994 and Smith *et al.*, 1964).

Ash content was determined according to A.O.A.C. (1970). Estimation of certain minerals was determined according to the following methods: Chlorides (Jackson and Thomas, 1960), sodium and potassium using flame photometer, calcium and magnesium by versinate titration method (Johnson and Ultrich, 1959), while iron and phosphorus were determined as desribed by Harris (1998) and Frie *et al.* (1964), respectively.

Data obtained of the different species were exposed to the proper statistical analysis according to Snedecor and Cochran (1969), while least significant differences at 5% was used to verify the significant differences between means.

Results and Discussion

Soil characteristics:

Results in Table 3 reveal that soil moisture content increased in winter especially in sand-gravel habitat. Soil of saline habitat had higher value of electric conductivity (EC) as compared with the first one. Calcium was the dominant cation followed by magnesium, while chlorides were the dominant anions. Results showed that soil of dry saline habitat had the highest amount of total cations as well as total anions during summer.

Plant analyses:

Results recorded in Tables 4 and 5 show that species of dry saline habitat attained the highest values of water content as well as degree of succulence compared with species colonizing sand and gravel plain. It has been found that succulence of *Z.album* is due to accumulation of Na, Ca, Mg and to a less extent due to Cl, while succulence of *A.microcarpus* is related to K, Na accumulation beside Cl and P. In contrast, Ahmed and Shalaby (1985) studied *Z.album* growing under different habitat conditions of Sinai and concluded that the high degree of succulence of this species was associated with high chloride accumulation.

Tables 4 and 5 indicate that the highest ash content was recorded in *Z.album* during the studied period and this was associated with increase in degree of succulence and accumulation of Na^{+}, Ca^{+2} and Mg^{+2} ions. In this connection, El-Monayeri *et al.* (1981) reported that the rise of total ash content of two *Zygophyllum* species during summer months may be due to the increase of total ions accumulation as a result of increase water saturation deficit as a function of increase soil moisture stress conditions.

Regarding mineral composition, species inhabited dry saline habitat had higher concentrations of chlorides compared to species of site 1. In addition, sulphates reached the highest value in *Z.album* (0.38%) during summer and this was accompanied by the highest sulphates concentration in the soil. Also, Na ions were accumulated with low concentration in species characterizing sand-gravel habitat , except *T.nudatum* which possessed high concentration of Na like species of dry saline habitat (Tables 4 and 5).

Results reveal that the studied species accumulated K rather than of sodium except *T.nudatum* and *Z.album*. This result is in accordance with those obtained by Al-Tantawy (1983) and Ismaeil & Al-Oliyan (1999). In addition, it can be observed that K^+/Na^+ ratio in most species was more than unity during the different seasons. These plants can be described as key elements in salinity tolerance. Yeo (1998) stated that one of the key elements in salinity tolerance is the capacity to maintain a high cytosolic K^+/Na^+ ratio.

Data in Table 5 show that *Z.album* achieved the highest concentration of calcium and magnesium ions. In this context, Bannister (1976) reported that accumulation of high concentration of Ca and Mg, which is considered as a protective adaptive response of desert plants, counteracts the harmful effects of Na and Cl. Detailed investigation in recent years have indicated that Ca^{+2} control water use efficiency by initiating stomatal closure (Atkinson, 1991), thus, the increased Ca concentrations in stressed plants may be responsible for the drastic reduction in stomatal conductance. Despite the observed osmotic adjustment and partial maintenance of leaf turgor, the rapid increase in Ca concentration can also influence tissue elasticity, as it is generally assumed that calcium increases the rigidity of the cell wall (Marigo and Peltier, 1996).

Concerning variations in photosynthetic pigments, it is markedly observed from Tables 4 and 5, that concentration of chlorophyll b was generally greater than that of chlorophyll a in the studied species and during different seasons, chl. a/b ratio was inverted. Similar result was obtained by Morsy (1996) in his study on *Capparis cartilaginea,* found that concentration of chlorophyll b was greater than chlorophyll a in both autumn and spring. In this connection, Wingler *et al.*(1999) reported that the combined effects of heat and light stress on photosynthesis superimposed with drought will be more complex. Under unfavourable conditions, plants are known to loss chlorophyll (Havaux and Tardy, 1999) or direct the absorbed light to other processes, like thermal dissipation to protect the photosynthetic apparatus (Deming-

Adams and Adams, 1996). Moreover, drought not only causes dramatic loss of pigments, but also leads to disorganization of thylakoid membranes (Ladjal *et al.*, 2000).

It is worthly to mention that concentration of chlorophyll a exceeded that of chlorophyll b in each of *T. hirsute, A. monosperma, D.tortuosa* (sand-gravel habitat) and *Z.album* (dry saline habitat) in spring and *D.tortuosa* in autumn. Chlorophyll a/b ratio of the concerned plants was 1.3, 1.16, 1.1, 2.39 and 1.42, respectively. Concomitant with the correction of chl. a/b ratio in such plants, the attainment of the highest concentration of carotenoids, to which the previous results may be explained.

Concerning carbohydrate fractions, results in Tables 4 and 5 reveal that plants inhabited the dry saline habitat showed a higher increase of reducing sugars in winter and this could be ascribed to an increase in their biosynthesis or a decrease in their degradation. Also, it is observed that the concentration of soluble sugars took the same trend as non-reducing sugars since, the increase in soluble sugars was due to the increase in non-reducing sugars. In this connection, Pelah *et al.* (1997) stated that drought tolerance can be partly attributed to the accumulation of soluble sugars, as they are able to protect the structural integrity of membranes during dehydration by preventing membrane fusion, transition phase and separation phase (Crowe *et al.*, 1988; Crowe & Crowe, 1992).

It is observed form Tables 4 and 5 that concentration of total carbohydrates in all studied species reached the highest value in autumn, followed by summer. The reduction in total carbohydrates in summer compared to that in autumn, matches with the results of photosynthetic pigments.

From the previous results, it can be observed that some species established their osmoregulation at the dry season via cationic and anionic accumulation as was the case in plants inhabited dry saline habitat (*Z.album* and *A.microcarpus*) as well as *T. nudatum* (sand-gravel plain habitat). However, *T.hirsuta*, *A.monosperma* and *D.tortuosa* showed an increase in each of reducing, non-reducing sugars as well as soluble and total carbohydrates in either summer or autumn (dry seasons) so, their osmotic adjustment was occurred, to a great extent, via sugars accumulation. Concomitantly with these results, El-Monayeri *et al.* (1986 a) reported that *Z.album* depends primarily on the accumulation of electrolytes in its osmotic adjustment. However, Ahemd and Girgis (1979), Girgis *et al.* (1979) and Marie (1988) revealed that *Z.album* depends to some extent, besides electrolytes, on non-electrolytes in developing its osmotic pressure.

El-Monayeri *et al.* (1986 b) found that *A.monosperma* and *D.tortuosa* accumulated high amounts of carbohydrates and nitrogenous compounds and retained relatively low contents of Cl, SO_4, Na, Mg and K. Also, they added that the non-succulent xerophytes in maintaining high osmotic gradient, depend greatly on organic non-electrolytes such as soluble carbohydrates and nitrogenous compounds. Abd El-Rahman *et al.* (1976) revealed that the greater portion of total osmotic potential of halophytes was mainly due to electrolytes, whereas in xerophytic and hydrophytic species, a great portion of total osmotic pressure was due to non-electrolytes including sugars and other constituents.

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الملخص العربي

دراسات بيئية فسيولوجية على بعض النباتات النامية على امتداد طريق وادى النطرون – العلمين الصحراوى

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** مركز بحوث الصحراء

استهدف هذا البحث دراسة الاستجابة التأقلمية لبعض النباتات الصحراوية النامية على امتداد طريق وادى النطرون – العلمين. وقد تم اختيار نباتات الميتنان، العادر، الفصيح والضمران والتى تنمو فى بيئة السهل الرملى الحصوى ونباتى الرطريط وبصل العنصل الممثلة للبيئة الملحية الجافة.

أظهرت النتائج أن نباتات البيئة الملحية الجافة تميزت بمحتوى مائى ودرجة عصارية مرتفعة وكذلك زيادة تركيزات كل من الكالسيوم ، الماغنسيوم والكلوريدات. كما وجد أن نباتات الدراسة راكمت البوتاسيوم بمعدل أكبر من الصوديوم ما عدا نباتى الضمران والرطريط.

أشارت النتائج الى زيادة تركيز كلورفيل "ب" عن تركيز كلورفيل "أ" فى معظم نباتات الدراسة. ووجد أن تركيز السكريات المختزلة يزيد بشكل ملحوظ خلال فصل الشتاء فى نباتات البيئة الملحية. كما أوضحت النتائج أن تركيز السكريات الكلية وصل الى اعلى قيمة له خلال فصل الخريف يليه فصل الصيف.

وجد أن نباتات البيئة الملحية الجافة وكذلك نبات الضمران تعتمد فى انضباطها الأسموزى على تراكم الكاتيونات والأنيونات بينما النباتات التى تنمو فى بيئة السهل الحصوى الرملى اعتمدت فى بناء جهدها الأسموزى على السكريات.

Table 1. Climatic factors of Wadi El Natrun and El-Dabba (Average of 5 years 1998-2002).

Months	Wadi El-Natrun						El-Dabba					
	Temperature °C			Relative humidity %	Rainfall (mm/month)	Wind velocity (Km/h)	Temperature °C			Relative humidity %	Rainfall (mm/month)	Wind velocity (Km/h)
	Max.	Min.	Mean				Max.	Min.	Mean.			
January	19.42	8.20	13.80	70.20	5.86	13.60	18.58	9.04	13.81	60.80	36.5	10.70
February	20.94	8.96	14.95	66.80	5.68	15.80	19.44	9.34	14.39	67.80	14.98	11.04
March	24.06	10.30	17.18	63.80	1.08	18.03	21.08	10.70	15.89	68.00	9.89	11.04
April	28.80	13.50	21.15	62.00	0.07	16.60	24.38	13.16	18.70	67.40	0.94	10.70
May	32.00	16.48	24.24	60.60	2.45	16.60	26.60	16.64	21.62	71.00	2.28	10.30
June	34.06	19.22	26.64	62.60	0.00	17.70	28.50	19.72	24.11	72.80	0.00	11.4
July	36.74	21.56	29.15	63.80	0.00	16.60	31.22	22.14	26.68	72.40	0.00	11.4
August	36.16	22.34	29.30	66.80	0.00	16.20	31.72	23.00	27.36	72.20	0.70	10.30
September	34.28	20.64	27.46	65.80	0.86	16.60	31.14	21.62	26.38	68.20	1.14	9.20
October	29.56	17.36	23.46	69.40	0.85	15.80	27.98	18.78	23.38	67.40	14.24	9.20
November	25.78	13.46	19.62	69.80	0.22	13.30	24.80	14.72	19.76	65.80	6.68	9.60
December	21.38	9.90	15.64	69.00	3.66	13.30	18.50	10.48	14.49	67.60	26.76	10.30

Table 2. Monthly rainfall (mm/month) at Wadi El Natrun and El-Dabba during the period of 1998-2002.

Months	Wadi El-Natrun					El-Dabba				
	Amount of rainfall (mm/month)					Amount of rainfall (mm/month)				
	1998	1999	2000	2001	2002	1998	1999	2000	2001	2002
January	0.50	3.30	8.00	2.70	14.8	7.60	10.8	102.8	6.20	55.1
February	2.70	6.00	1.00	1.30	17.4	29.8	11.2	19.7	7.80	6.40
March	2.80	0.20	0.90	0.60	0.90	31.6	Trace	16.4	0.10	1.20
April	0.00	0.00	0.00	Trace	0.20	0.10	0.00	0.40	0.10	4.10
May	12.1	0.00	0.00	Trace	0.00	7.50	0.00	3.80	0.10	0.00
June	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	0.00	0.00	0.00	0.00	0.00	0.00	3.50	0.00	0.00	0.00
September	0.00	0.00	4.30	0.00	0.00	0.00	0.00	5.30	0.00	0.40
October	Trace	0.00	1.70	1.00	1.40	0.60	0.90	44.4	4.70	20.6
November	0.20	0.00	0.30	0.30	0.30	15.6	1.30	9.6	3.50	3.40
December	1.90	0.50	7.80	2.50	5.60	7.10	19.8	26.7	47.9	32.3
Total	20.2	10.0	24.0	8.40	40.6	99.9	47.5	229.1	70.3	123.5

Table 3. Physical and chemical analyses of the soil associated with the studied species. A : Physical analyses.

Location & Soil depth (cm)	Season	Granulometric analyses						Soil texture	Soil moisture %	Saturation point %
		Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt & clay			
(1) 0–40 sand and gravel plain	Summer	1.5	16.8	46.8	28.9	5.6	0.45	Medium sand	0.33	23.0
	Winter	3.2	7.9	28.5	22.8	20.2	17.4	Medium sand	4.05	19.0
(2) 0–40– Dry saline habitat	Summer	6.8	15.4	28.8	26.2	17.4	5.4	Medium fine sand	0.87	21.5
	Winter	2.0	4.1	11.8	27.1	24.8	30.2	Fine sand-clay	1.81	22.0

B: Chemical analyses

Location & soil depth (cm)	Season	EC mmhos/Cm	pH	Organic carbon %	Total carbonates %	Cations (meq/L)				Total cations meq/L	Anions (meq/L)				Total anions meq/L
						Na	K	Ca	Mg		HCO_3	CO_3	Cl	SO_4	
(1) 0–40 sand and gravel plain	Summer	1.09`	7.36	0.67	24.0	4.34	0.89	10.0	6.5	21.7	0.72	Nil	2.8	0.32	3.84
	Winter	0.67	6.68	0.33	24.3	3.65	0.74	9.0	7.0	20.4	0.59	Nil	17.4	0.21	18.2
(2) 0–40 Dry saline habitat	Summer	5.20	7.09	0.84	24.7	0.29	0.51	9.5	50	60.8	0.25	Nil	4.24	37.9	42.4
	Winter	2.65	7.68	0.16	24.3	0.12	1.08	9.0	3	13.2	0.45	Nil	3.4	0.28	4.13

Table 4: Seasonal variations in water content, succulence, minerals, pigments and carbohydrates fractions of species of sand and gravel plain.

Plant	*Thymelae hirsute*					*Artemisia monosperma*				
season / Measurements	S	A	W	Sp	L.S.D.	S	A	W	Sp	L.S.D.
Water content %	32.5	39.6	47.2	51.2	3.58	43.2	62.0	58.3	66.3	13.4
Succulence	1.48	1.63	1.89	2.05	0.17	1.76	2.67	2.42	2.79	0.68
Minerals (%)										
Ash	6.97	6.84	7.39	7.73	-	13.5	11.0	16.1	11.7	-
Cl^{-}	0.30	0.19	0.14	0.38	0.07	0.28	0.39	0.28	0.45	0.08
SO_4^{--}	0.11	0.09	0.11	0.23	0.02	0.07	0.15	0.14	0.23	0.02
Na^{+}	0.73	0.40	0.36	0.60	0.32	0.60	1.70	0.60	0.60	-
K^{+}	0.51	0.44	0.47	0.70	-	0.94	1.30	1.16	3.03	-
K/Na	0.70	1.10	1.31	1.16	-	1.57	0.76	1.94	5.05	
Ca^{++}	1.96	1.60	1.24	1.60	-	0.62	1.70	1.56	3.26	0.74
Mg^{++}	1.07	1.25	0.77	0.87	-	0.42	1.00	3.33	0.36	-
P^{+++}	0.14	0.08	0.08	0.10	-	0.12	0.12	0.11	0.16	-
Fe^{+++}	0.18	0.14	0.11	0.10		0.12	0.02	0.17	0.07	0.07
Pigments (mg/g Fresh wt.)										
Chlorophyll "a"	0.94	1.06	1.29	0.40		1.09	0.37	0.87	0.76	
Chlorophyll "b"	1.29	1.66	1.93	0.30		1.39	0.61	1.24	0.66	
A + b	2.23	2.72	3.22	0.70		2.48	0.98	2.11	1.42	
Carotenoids	0.04	0.15	0.14	0.03		0.07	0.04	0.07	0.56	
Total Pigments	2.27	2.87	3.36	0.73		2.55	1.02	2.18	1.98	
a/b	0.73	0.64	0.67	1.30		0.78	0.61	0.70	1.16	
Carbohydrates %										
Reducing sugars	0.07	0.35	0.33	0.31	-	0.14	0.27	0.17	0.20	0.13
Non-reducing sugars	4.30	2.25	2.50	2.89	-	1.50	2.30	2.09	0.70	-
soluble sugars	4.40	2.60	2.80	3.20	-	1.60	2.70	2.20	0.90	-
Insoluble sugars	12.8	19.8	8.30	9.50	-	16.8	13.8	14.6	13.2	-
Total carbohydrates	17.2	16.8	11.1	12.8	3.94	18.5	18.7	16.8	14.1	-

Table 4: Continues.

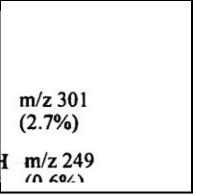
Plant	*Derverra tortuosa*					*Tragnum nudtum*				
season / Measurements	S	A	W	Sp	L.S.D.	S	A	W	Sp	L.S.D.
Water content %	27.1	36.7	55.6	70.8	8.1	59.0	61.8	48.5	62.7	-
Succulence	1.24	1.58	2.25	3.43	0.41	2.43	2.68	1.57	2.77	0.85
Minerals (%)										
Ash	9.05	8.74	7.12	8.52	-	23.0	19.2	20.7	19.2	-
Cl^{-}	0.24	0.23	0.16	0.45	0.10	0.48	0.26	0.24	0.55	0.16
SO_4^{--}	0.16	0.12	0.15	0.23	0.03	0.15	0.12	0.14	0.23	0.04
Na^{+}	0.50	0.40	0.40	0.50	0.05	8.30	4.20	3.07	5.40	0.96
K^{+}	0.98	0.80	0.87	3.11	1.63	1.29	0.95	0.73	1.65	-
K/Na	1.96	2.00	2.18	6.22		0.16	0.23	0.24	0.31	
Ca^{++}	1.50	1.50	1.17	1.58	-	2.60	1.70	1.58	1.96	-
Mg^{++}	0.49	0.49	0.90	0.85	-	2.44	1.25	1.38	3.01	-
P^{+++}	0.12	0.08	0.12	0.18	-	0.08	0.09	0.05	0.10	-
Fe^{+++}	0.04	0.03	0.04	0.03	-	0.07	0.04	0.11	0.08	-
Pigments (mg/g Fresh wt.)										
Chlorophyll "a"	0.41	0.37	0.34	0.22		0.52	0.63	0.62	0.22	
Chlorophyll "b"	0.64	0.26	0.53	0.20		0.81	0.96	0.97	0.33	
A + b	1.05	0.63	0.87	0.42		1.33	1.59	1.59	0.55	
Carotenoids	0.04	0.10	0.03	0.16		0.06	0.08	0.11	0.001	
Total Pigments	1.09	0.73	0.90	0.58		1.39	1.67	1.70	0.55	
a/b	0.64	1.42	0.64	1.10		0.64	0.66	0.64	0.67	
Carbohydrates %										
Reducing sugars	0.27	0.21	0.11	0.26	-	0.21	0.21	0.13	0.18	-
Non-reducing sugars	3.80	3.13	2.00	1.90	-	0.11	1.30	2.00	0.40	0.87
soluble sugars	4.07	3.30	2.10	2.20	-	0.32	1.50	2.10	0.57	0.77
Insoluble sugars	18.1	29.4	11.9	12.7	10.6	14.2	30.0	14.3	10.1	9.67
Total carbohydrates	22.1	37.6	14.0	14.9	7.16	14.5	31.5	13.4	13.7	3.2

L.S.D. = least significant difference S= summer A= autumn W= winter Sp= spring.

Table 5: Seasonal variations in water content, succulence, minerals, pigments and carbohydrates fractions of species of dry saline habitat.

Plant	*Zygophyllum album*					*Asphodelus microcarpus*				
Season / Measurements	S	A	W	Sp	L.S.D.	S	A	W	Sp	L.S.D.
Water content %	64.5	79.6	78.7	76.7	-	-	87.5	84.2	-	-
Succulence	2.86	4.93	5.13	4.3	-	-	8.04	6.4	-	-
Minerals (%):										
Ash	25.8	30.5	27.1	29.4	-	-	13.8	18.5	-	-
Cl	1.47	0.93	0.74	1.66	0.57	-	1.08	0.81	-	-
SO_4	0.38	0.25	0.30	0.29	0.03	-	0.15	0.15	-	-
Na^+	6.90	4.40	2.90	5.10	1.11	-	2.3	1.09	-	-
K^+	0.50	0.59	0.39	0.59	-	-	2.97	2.21	-	-
K/Na	0.10	0.13	0.13	0.12		-	1.30	2.03	-	-
Ca^{++}	5.04	2.70	2.63	4.04	-	-	1.18	2.15	-	-
Mg^{++}	3.71	2.00	4.49	4.25	-	-	1.11	1.41	-	-
P^{+++}	0.12	0.08	0.08	0.12	-	-	0.45	0.33	-	-
Fe^{+++}	0.13	0.05	0.10	0.02	0.05	-	0.09	0.10	-	-
Pigments (mg/g fresh wt)										
Chlorophyll a	0.95	0.67	1.22	0.55		-	1.16	1.08	-	
Chlorophyll b	1.05	0.85	1.65	0.23		-	1.33	1.26	-	
A + b	2.00	1.52	2.87	0.78		-	2.49	2.34	-	
Carotenoids	0.07	0.15	0.07	0.17		-	0.08	0.14	-	
Total pigments	2.07	1.67	2.94	0.95		-	2.57	2.48	-	
a/b	0.90	0.79	0.74	2.39		-	0.87	0.86	-	
Carbohydrates %										
Reducing sugars	0.06	0.28	0.70	0.15	0.29	-	1.17	1.62	-	-
Non-reducing sugars	2.14	1.92	5.57	3.01	-	-	2.40	2.61	-	-
Soluble sugars	2.20	2.20	5.60	3.17	-	-	3.60	4.20	-	-
Insoluble sugars	20.1	34.8	16.8	8.40	3.33	-	27.7	10.5	-	16.2
Total carbohydrates	22.2	36.9	21.2	11.6	4.06	-	31.3	14.7	-	-

L.S.D. = least significant difference S= summer A= autumn W= winter Sp= spring.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