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Adjustment of different Halophytes to Mediterranean Salt Marshes of North Egypt

By

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With 3 Figures

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Summary

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The present study was carried out on four halophytes; *Halocnemum strobilaceum* M. Bieb, *Arthrocnemum glaucum* Moq, *Limoniastrum monopetalum* L., and *Zygophyllum album* L., occurring in the salt marshes of the Mediterranean coast of North Egypt.

All studied species showed increased carbohydrate accumulation from the spring-summer to the autumn-winter period, and *A. glaucum* exhibited lower nitrogen levels with lesser fluctuations throughout the year than the other species. The soil at the root zone of each species was characterized by higher Cl^--concentration and greater electrolytic conductivity. *H. strobilaceum* and *A. glaucum* retained relatively higher Na, Cl and Fe levels and their cell-sap osmotic potential was lower from summer to winter than either in *L. monopetalum* or *Z. album*. The latter two species retained higher Ca levels than the former ones. *H. strobilaceum* and *A. glaucum* showed higher monovalent/divalent cation ratios than *L. monopetalum*, The cation/chloride ration increased appreciably in *L. monopetalum* from

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the spring-summer to the autumn-winter period, while tended to be stable in *H. strobilaceum* and *A. glaucum* throughout the year. *Z. album* achieved slightly higher ratios than the latter two species.

Besides the active extrusion mechanism of ions operating with different degrees in these species, there seem to be a characteristic difference among the studied four halophytes regarding the mechanism of salt adjustment. *A. strobilaceum* and *A. glaucum* exhibited tendency to achieve a balanced ionic composition and were able to develop succulence, while *L. monopetalum* depended on an active excretion process for regulating salt concentration. The extremely decreased osmotic potential of all studied species coincided, partially, to chloride accumulation. The increase of cell-sap pH from summer to winter is strongly marked particularly in *H. strobilaceum* and *A. glaucum.*

Zusammenfassung

El-Shourbagy M. N., Ahmed A. M., Osman M. E. & Hamada E. M. 1984. Anpassungen verschiedener Halophyten an die Salzmarschen der Mittelmeerküste Nordägyptens. — Phyton (Austria) 24 (1): 101—112, mit 3 Abbildungen. — Englisch mit deutscher Zusammenfassung.

An vier Halphyten der Salzmarschen an der Mittelmeerküste Nordägyptens, *Halocnemum strobilaceum* M. Bieb., *Arthrocnemum glaucum* Moq., *Limoniastrum monopetalum* L. and *Zygophyllum album* L. zeigte sich, daß vom Frühjahr zum Herbst und Winter Kohlenhydrate akkumuliert werden. *A. glaucum* wies einen geringeren N-Gehalt bei kleineren Schwankungen auf als die übrigen untersuchten Pflanzen. Der Boden in der Wurzelzone war durch höhere Cl-Konzentrationen und höhere elektrolytische Leitfähigkeit charakterisiert. *H. strobilaceum* und *A. glaucum* hielten vom Sommer zum Winter mehr Na, Cl und Fe zurück und besaßen ein niedrigeres osmotisches Potential als *L. monopetalum* oder *Z. album.* Diese Pflanzen halten mehr Ca zurück als die erstgenannten. Bei *H. strobilaceum* und *A. glaucum* war das Verhältnis einwertiger zu zweiwertiger Kationen höher und die Relation Kationen : Chloride niedriger als bei *L. monopetalum.* Das Verhältnis Kationen : Chloride stieg in *L. monopetalum* von Frühjahr-Sommer zum Herbst-Winter beachtlich an, während es in *H. strobilaceum* und *A. glaucum* das ganze Jahr über eher stabil blieb. *Z. album* erreichte etwas höhere Relationen als die beiden letztgenannten Arten.

Neben dem mit verschiedener Wirksamkeit arbeitenden Mechanismen zur Ionenausscheidung scheinen bei den untersuchten Pflanzen verschiedene Mechanismen zur Salzanpassung zu bestehen. *H. strobilaceum* und *A. glaucum* zeigten Tendenz zur ausgeglichenen Ionenbilanz unter Bildung von Sukkulenz, während *L. monopetalum* auf aktive Ionenausscheidung angewiesen ist. Die extreme Erniedrigung des osmotischen Potentials in allen Versuchspflanzen fiel teilweise mit der Chloridakkumulation zusammen, welche durch erhöhte Konzentration neutraler Nichtelektrolyte kompensiert werden kann. Der winterliche Anstieg des Zellsaft — pH ist besonders bei *H. strobilaceum* und *A. glaucum* ausgeprägt.

(Editor transl. et abbrev.)

1. Introduction

Halophytes are unique in their ability to grow and reproduce in saline environments. Sodium chloride, normally the dominant salt is present in exceeding higher concentrations. Furthermore, survival of halophytes is accompanied by the accumulation of salt concentrations in their leaves equalling or exceeding those of sea water. Rather than attempting to modify the plant or the water to accomodate other, a more suitable and potentially effective strategy would be to study these naturally occurring halophytes that have already adapted to saline habitats through many years of evolutionary time.

It is the primary purpose of the present study to examine differences in solute regulation between different halophytic species dominating the coastal salt marshes of Egypt, namely *Halocnemum strobilaceum, Arthrocnemum glaucum, Limoniastrum monopetalum,* and *Zygophyllum album,* in attempt to provide knowledge about the mechanism of osmotic adjustment operating in these species.

2. The Study Area

2.1. Location and Physiography

The study area has two main physiographic provinces, one between Alexandria and Ras El-Hikma, and the other between Ras El-Hikma and El-Salloum. Both provinces have a northern coastal plain and a southern tableland. Four sites were selected in the most characteristic salt marshes present and referred to the region they belong; Burg El-Arab (I), Ras El-Hikma (II), Alam El-Roum (III), and El-Salloum (IV, Fig. 1). These salt marsh sites are located within the coastal plain. This plain is wide in the eastern province and narrow or missing in the western one. The ridges vary in altitude and dissected by many shallow erosional valleys, some of them end in the Mediterranean Sea

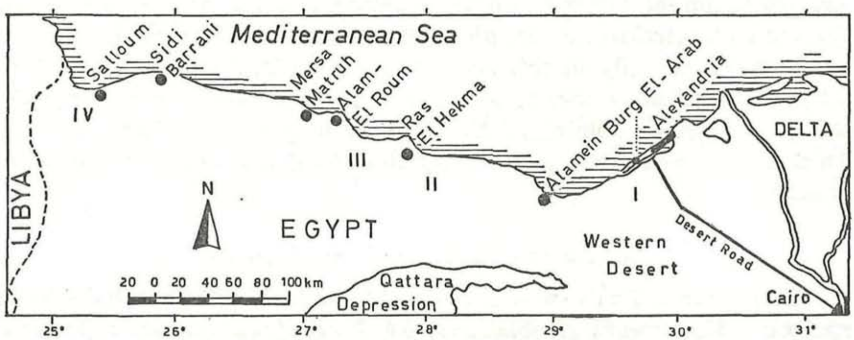

Fig. 1. Location map of the Mediterranean salt marshes in North Egypt

and the others in depressions. The southern tableland attains a maximum elevation of 200 m above sea level at El-Salloum and slopes gently northwards.

2.2. Geology and Geomorphology

The entire northern region of the Egytian Western Desert is covered by sedimentary formations that range in age from lower Miocene to Holocene (SELIM 1969). The Holocene formation is formed of beach deposits, sand dune accumulations, Wadi fillings, loamy deposits, lagoonal deposits, and limestone crusts.

2.3. Climate and Soil

The mean air temperature ranges from 13° C in January to 27° C in August, and the average annual rainfall is about 150 mm. The coastal salt marshes include closed areas near the sea shore subjected to innundation from the sea and retain stagnant water, particularly in winter, except that at El-Salloum. The soil varies from brown to light brown and grey in colour. It is sandy loam in texture with salts on the surface and lamination of gypsum throughout the profile (HAMMAD 1972). Microscopic examination revealed enrichment of carbonate granules, organic matter, and recent shell fragments.

2.4. Vegetation

TADROS (1953) recognized a number of halophytic communities in the Mediterranean salt marshes bordering Lake Mariut, N. Egypt. At the lower level, a pure community of *Halocnemum strobilaceum* is established, but at higher level it becomes associated with *Arthrocnemum glaucum* and *Salicornia fruticosa*. In places with fine sandy soil, rich in organic matter, the Halocnemetum is succeeded either by the subassociation of Salicornieto-Limonietum or else by an association dominated by *Arthrocnemum glaucum* and *Limoniastrum monopetalum*. The next community in this succession is dominated by *Zygophyllum album*, which leads either to a steppelike nonhalophytic or to a weakly saline community dominated by *Artiplex halimus* and *Picris radiata*. This last community is very highly developed and covers large areas of land.

3. Materials and Methods

The present study was carried out on four different halophytic species; *Halocnemum strobilaceum* M. BIEB, *Arthrocnemum glaucum* MOQ, *Limoniastrum monopetalum* L. and *Zygophyllum album* L.

3.1. Plant Anaslysis:

Shoot samples were collected at random from uniform sized individuals of each species in each site according to chronological date, covering the period from April until January, washed, dried thoroughly, then divided into two lots. One was subjected immediately to solid CO_2 then expressed for the determination of cell-sap osmotic potential and pH, and the other was dried at 70° C to constant weight in an aerated oven.

The osmotic potential of the expressed shoot-sap was measured cryoscopically (Slatyer & McIlroy 1961) and the pH value was determined by means of an electric pH meter with glass-calomel electrodes.

Oven-dried samples were ground into fine powder by means of a Wiley micromill of 60-mesh sieve. The total available carbohydrate content was determined according to Smith *et al* (1964) and values were expressed as g glucose/100 g dry weight. Total nitrogen was determined by means of the modified micro-Kjeldahl method (Paech & Tracey 1956). Chloride determination was carried out after extraction from the ashed-powdered sample at 500° C with 0.1 N nitric acid by using the $AgNO_3$ titration method (Jackson & Thomas 1960). For the other elements; Na, K, Ca, Mg, P, and Fe, the "Wet ashing procedure" was applied for the oven-dried plant material (Richards 1954, Paech & Tracey 1956, Johnson & Ulrich 1959). Na und K was determined by the Perkin-Elmer flame photometer Model-149, Ca and Mg by the modified versinate titration method (Barrows & Simpson 1962), while P and Fe were measured colorimetrically. The 1,2,4-diaminonaphthol sulphonic acid method (Yeun & Pollard 1951) was used for P, and the thioglycollic acid method for Fe (Snell & Snell 1957). Results were expressed in meq/100 g dry weight.

3.2. Soil Analysis:

Soil exctracts (1 : 5) were prepared (US Salinity Lab. Staff 1954) and the electrical conductivity (EC) was determined by means of a conductivity bridge, and PH by a pH-meter as above. For elements; Na, K, Ca, Mg, and Cl the above mentioned methods were applied for the 1 : 5 soil extract and results were expressed in meq/l.

Results obtained were treated statistically using the one-sided two sample Smirnov test (Conover 1971) to detect the significant differences among and between months.

4. Results and Discussion

L. monopetalum and *Z. album* showed relatively higher Ca and lower Fe levels than either *H. strobilaceum* or *A. glaucum* (Fig. 2).

Ranwell (1972) proposed that the adaptation of halophytes to high Na environment is due to ion selection, ion excretion, ion accumulation, and ion dilution. Pollak & Waisel (1970) demonstrated that the presence of high ionic concentration in the medium stimulated the salt excretion in *Aeluropus litoralis.* They found a positive correlation between the outer NaCl concentration and the amount of Na excreted via guttation and/or the Na content of the leaves, thus excluding ex-

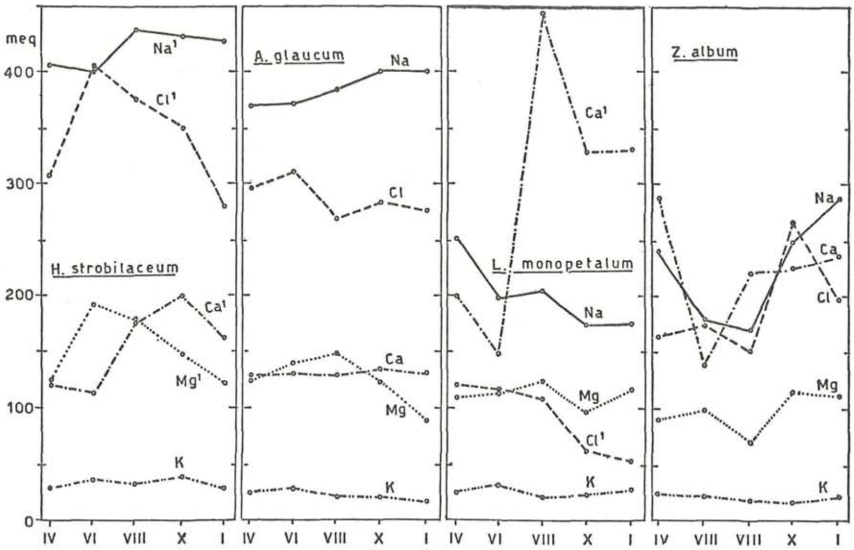

Fig. 2. Seasonal changes in Na, K, Ca, Mg and Cl concentration in the four investigated halophytes. Scale: meq/100 g. Scale in meq/100 g. (1 = Significant differences among all months at $P < 0{,}05$)

ceeding Na contents in the leaf tissues. These authors also found that Na retention in the leaves occurred at a relatively low rate and that the secretion mechanism is highly selective to Na^+, opposing K^+ and Ca^{2+}, which were retained in the leaves to a greater degree than Na. This situation could be compared with results obtained for *L. monopetalum* which retained relatively higher Ca levels than either *H. strobilaceum* or *A. glaucum.* The fact that the latter two species retained higher Na levels in all months than either *L. monopetalum* or *Z. album* may be attributed to the operation of an active extrusion mechanism which is an important factor in determining salt adjustment. Nassery & Baker (1972 a, 1972 b) showed that Na extrusion from the roots by a Na pump is an important factor in determining the degree of salt tolerance in barley which existed in varieties with high salt tolerance, where

Na efflux being greater. The authors showed that efflux mechanism being stimulated by ATP and inorganic phosphate and proposed that it is the result of an ATP-energized Na pump associated with an ATP-ase. Sodium extrusion mechanism has been also reported by JESHKE (1970) and GREENSHPAN & KESSLER (1970). It may be possible that osmotic adjustment of *H. strobilaceum* and *A. glaucum* not only related to active Na extrusion mechanism but also to the development of succulence, thus increasing ion dilution and the volume/surface area ratio. EIJK (1939) proposed that the degree of succulence is largely determined by Cl ion. In fact, both *H. strobilaceum* and *A. glaucum* were characterized by higher Cl levels and consistently lower cation/chloride ratios (CCR) throughout the year than either *L. monopetalum or Z. album* (Table 1). *L. monopetalum* showed particularly lower Cl and

Table 1

Seasonal changes in Na+K/Ca+Mg ratio (MDR), Na+K+Ca+Mg/Cl ratio (CCR), and the concentration of P and Fe (meq 100/g dry weight) in the investigated species

Species	April	June	August	October	January
MDR:					
H. strobilaceum [1])	1.9	1.5	1.4	1.6	1.5
A. glaucum	1.7	1.8	1.5	1.7	2.0
L. monopetalum	0.9	0.9	0.4	0.8	0.5
Z. album	0.8	0.9	0.6	0.8	0.9
CCR:					
H. strobilaceum	2.3	2.2	2.2	2.3	2.7
A. glaucum	2.2	2.3	2.6	2.4	2.3
L. monopetalum [1])	5.1	4.2	7.7	11.5	14.6
Z. album	4.0	2.5	3.2	3.2	3.4
P:					
H. strobilaceum [1])	0.8	0.7	0.3	0.4	0.6
A. glaucum	1.1	0.6	0.8	1.4	0.6
L. monopetalum	1.5	1.1	1.3	1.5	1.2
Z. album	1.1	1.0	0.8	0.4	0.5
Fe:					
H. strobilaceum [1])	1.1	1.3	1.2	0.4	0.8
A. glaucum [1])	1.0	0.8	0.8	0.9	0.3
L. monopetalum	0.4	0.5	0.4	0.2	0.3
Z. album	0.7	0.3	0.4	0.4	0.3

[1]) Significant difference among all months at $P < 0.05$.

appreciably higher CCR which increased from the spring-summer to the autumn-winter period. This may emphasize the operation of additional mechanisms to control the solute concentration of the whole plant. A number of halophytes including *L. monopetalum possess* salt glands in their leaves, which excrete salt. In this regard, HILL & HILL (1973) reported that in glands of *Limonium vulgare* Cl^- ions are pumped to the outside which causes both Na^+ ions and water to move into the extracellular compartments of the glands, and the ensuing salt solution weeps through the pores onto the surface of the leaves. Recently, HILL & HAUKE (1979) have shown that there is a specific chloride ATP-ase in leaf microsomes of salt-treated plants of *Limonium,* which is absent in salt-free plants. GREEWAY & OSMOND (1972) found that enzymes isolated from salt-sensitive *Phaseolus* and salt-tolerant *Atriplex* and *Salicornia* are equally sensitive to NaCl during assay and they suggested that cells may regulate the ionic environment of cytoplasm so that enzymes are not normally exposed to high salt levels. This suggestion may permit to explain differences between *L. monopetalum* and each of *H. strobilaceum* and *A. glaucum* in their degree to which ion concentration can be regulated within cell compartments. *L. monopetalum depended* on its active excretion process for regulating salt concentration, while the latter two species showed a superior tendency to achieve a balanced ionic composition and to maintain higher monovalent/divalent cation ratios (MDR) throughout the year (HIGINBOTHAM 1973, GREENWAY & MUNNS 1980).

The soil of each studied salt marsh was characterized by high chloride levels associated with greater EC values (Table 2). Chlorides decreased from April to June, while Na increased. The soil of *Z. album* was characterized by lower Cl levels, higher CCR, and lower Na adsorption ratio (SAR) than the other soils, particularly in June.

Results indicated a general increase in carbohydrate accumulation from summer to winter, which was more remarkable for *H. strobilaceum* and *A. glaucum* (Fig. 3). EL-SHOURBAGY & KISHK (1975) detected an increase in the total free and bound sugars in plants of *Z. album* with NaCl. Increased accumulation of carbohydrates from summer to winter may be attributed to reduced growth rate in the cooler season relative to warmer one. NIEMAN (1962) found a pronounced tendency of various crops to accumulate carbohydrates on saline media and suggested high rate of photosynthesis relative to reduced rate of growth. *A. glaucum* attained relatively lower nitrogen levels, fluctuating within narrow range, than the other halophytes. BOUCAND (1972) showed that NaCl modified the process of CO_2 assimilation and protein synthesis, which indirectly affect the activity of nitrate reductase. STROGONOV (1964) exposed barley plants to NaCl type of salinity up

Table 2

Ion concentrations (meq/l), electrolytical conductivity EC, mmohs/cm), Na+K/Ca+Mg ratio (MDR), Na+K+Ca/Cl ratio (CCR) and sodium adsorption ratio of soil solution (SAR) in the root zone of each species in April and June

	H. strobilaceum		*A. glaucum*		*L. monopetalum*		*Zygophyllum album*	
	April	June	April	June	April	June	April	June
Na	24.8	33.0	28.1	29.9	17.9	24.4	18.9	19.6
K	3.2	3.5	3.6	2.5	2.8	3.5	0.5	1.6
Ca	25.7	20.9	27.1	23.8	18.0	14.6	15.9	20.0
Mg	43.6	41.5	39.0	22.7	29.9	20.5	14.0	14.5
Cl	238.8	86.4	149.1	71.5	84.0	65.1	33.7	32.3
EC	24.2	15.3	22.5	12.2	13.7	11.5	4.1	6.0
pH	7.0	7.0	7.2	7.1	7.5	7.5	7.3	6.7
MDR	0.5	1.0	0.5	0.9	0.4	1.6	0.4	0.8
CCR	0.6	0.9	0.8	1.1	0.8	1.0	1.2	1.7
SAR	2.9	5.3	3.4	4.8	2.3	5.0	1.7	3.6

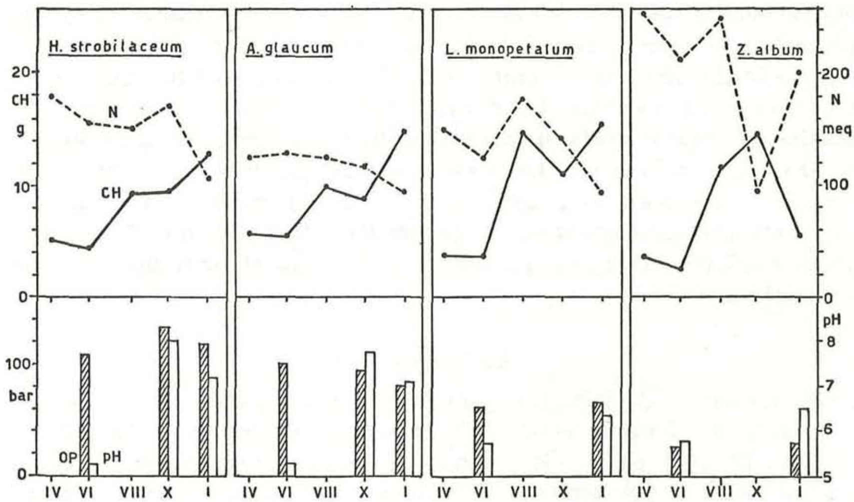

Fig. 3. Changes in total carbohydrate content (CH, straight lines in the upper fields, in g/100 g dry weight, scale on the left), total nitrogen (N, broken lines, in meq/100 g dry weight, scale on the right), cell-sap osmotic potential (lower fields, OP, hatched columns, in bars, scale on the left) and pH (blanc columns, scale on the right) in the four investigated halophytes. (1 = significant difference among all months at $P < 0,05$)

to toxic levels and detected a decrease or unchange in the amount of numerous amino acids.

Measurements of the osmotic potential of expressed cell sap of the studied halophytes yielded values between -62 and -117 bars. Each of *H. stobilaceum* and *A. glaucum* showed relatively lower osmotic potential than the others. ABDEL RAHMAN (1965) measured the shoot-osmotic pressure of salt marsh plants in Egypt and found that the partial OP of Cl ions are higher than the total OP of many xerophytes. Shoot cells of the four studied halophytes showed considerable selectivity in relation to which ions were accumulated. Na and Cl ions may account for most of the osmotic potential, depending on the species and time of the year, other ions such as Ca and Mg contribute little to the osmotic potential (RAINS 1972, FLOWERS *et al.* 1977, ZIMMERMANN 1978). In these studied halophytes the solute concentrations in both the protoplast and the vacuole would be such that osmotic equilibrium existed between the two compartments. GREENWAY & OSMOND (1972) and WEINBERG (1967) suggested that high Cl^- concentration in the vacuole may be compensated by increased concentration of other solutes in the cytoplasm which might be either neutral compounds or ions of less inhibition to enzymic activity than Cl. The possibility of the performance of some organic substances as carbohydrates (GREENWAY 1973, SANTARIUS 1973) and glycinebetaine (WYN JONES *et al.* 1977) cannot be excluded from the protective or osmotic functions in the cytoplasm when the ion concentration in the vacuoles becomes high. Measurements of the cell sap pH showed an increase from summer to winter indicating a diminished production of organic acids in this period (OSMOND 1967). The alteration is more distinct in both *H. strobilaceum* and *A. glaucum* than in the other investigated species. Disregarding the fact, that pH is known to have effect on carboxylation reactions (HIATT 1967, 1968) and on HCO^-_3 levels (JACOBY & LATIES 1971), the presented data do not allow to draw further conclusions.

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