Variations in Mineral Ion Composition of Soil and Some Halophytes in the Mediterranean Coastal North of Egypt
Hediat M.H. Salama
and
Akram A.H. Ali
Botany Department, Faculty of Science, Zagazig University, Zagazig, Egypt.
Salt marshes are widely distributed in the north western part of Egypt with their own distinct vegetation. Of these *Zygophyllum album*, *Suaeda pruinosa*, *Arthrocnemum glaucum*, *Halocnemum strobilaceum* (succulent halophytes) and *Limoniastrum monopetalum* (non succulent halophyte) are characteristic of two sites; Burg El-Arab and Matruh of Mediterranean Coastal salt marshes north Western of Egypt. Soil and plant samples were collected during April 1999. Soil concentrations of Na+, K+, Ca2+, Mg2+, Cu2+ and P3+ in the two habitats and the variation of these elements from five plant communities were determined. The ions of Na+, K+, Ca2+, Mg2+, Cu2+ and P3+ concentrations were higher in soil samples of Matruh habitat than that found in Burg El-Arab habitat, Mg2+ is the major cation followed by Ca2+ in the two habitats. Accumulation of Na+, K+, Ca2+, Mg2+, Cu2+ and P3+ is greater in the green parts (either of leaves or stems) than in the normal stems of the plants in the two habitats, while the dry matter was higher in stems than the green parts (leaves or stems). Members of the Chenopods contain much higher sodium and chloride than *Zygophyllum* growing in the two habitats. Lower calcium and magnesium was observed in *Arthrocnemum* and *Halocnemum* than in *Zygophyllum* in the two habitats.

**Keywords:** Halophytes, succulent, non-succulent, mineral ion composition, soil characteristics, salt marches

**Introduction**

Halophytes are highly specialized plants known to overcome the accumulation of salts in their tissues in different ways with or without a regulating mechanism (Chapman, 1974). In a previous study El-Shourbagy et al. (1984) demonstrated that four different halophytes; *Halocnemum strobilaceum*, *Arthrocnemum glaucum*, *Limoniastrum monopetalum* and *Zygophyllum album* were able to grow and reproduce in salt marshes of the Mediterranean Coast of the north Egypt. The plants of these salt marshes are subjected to diverse mineral inputs and outputs mainly as a result of the herbivore grazing behavior.

The concentration of mineral elements in the soil reflects the abundance and distribution of plant species (Ben-Shahar and Coe 1992) which consequently, influences the feeding behavior of herbivores. Besides nutritional characteristics such as fiber and protein content, it is also important to evaluate the mineral composition of the plants, since the deficiency of an element can affect the performance of Cattle a razed on the marshes and an excess can be toxic (De Vos et al. 1989). The availability of the minerals in the soil, the plant species and its genetic requirement for specific quantities of nutrients for its growth and reproduction are all known to affect the concentration in the plants (Chapin, 1980). The concentration of an element depends also on the age of the plants (Pegtel, 1987; Georgiadis and Mc Naughton, 1990), on the environmental conditions in which the plants grow (Indiati and Sharpley, 1996), and on the part of the plant analyzed (Barnes et al. 1990).

Therefore, the objectives of this work were: (a) to study the mineral composition of the soils and the associated dominant vegetation in salt marshes of differing aridity to evaluate the nutrient status for both plants and animals; (b) to quantify the changes in vegetation from different pastoral communities, pointing out the implications for the herbivores.
**Materials and Methods**

The study area is characterized by a succession of small sand dunes and rocky surface dissected by several wadis toward to Mediterranean Sea (Abu Al-Izz, 1971). In Burg El-Arab habitat, the chain of sand dunes is composed of solid oolitic limestone. Between each sand dune and other there are salty lagoons, and sometimes there is cultivable land. The surface of Matruh area is covered by a salty crust of very white color. The coastal area of Matruh habitat is characterized by alternate appearance and disappearance of sand dunes and by the lines of saline lagoons. In both the two habitats, the major plant communities distributed above the sand dunes and in some wadis between them.

Sample materials used in the present investigations were obtained from five communities of salt marsh plants naturally growing in Burg El-Arab and Matruh regions which lies between latitudes 30° to 31° N. and longitudes 27° to 30° E. (Fig.1). The sites were named after the dominant species a) *Zygophyllum album* (*Zygophyllaceae*), b) *Limoniastrum monopetalum* (*Plumbaginaceae*), c) *Suaeda pruinos*, d) *Arthrocnemum glaucum*, and e) *Halocnemum strobilaceum* (*Chenopodiaceae*). Samples were separated into assimilatory organs (leaves or stems) and stems, cleaned, air dried then ground into fine powder and subjected to analysis.

From each type of plant community, the soil samples were taken from the successive depths of 0 – 20 cm and 20 – 40 cm close to naturally growing plants, by using a digging tool. These soil samples were air – dried and shaken in a set of sieves having a different mesh diameter from 2 mm to 0.063 mm, using a hydrometer method according to Day (1965).

Soil – water extracts (1:5) were prepared. Determination of electrical conductivity (E.C.) was carried out by means of a direct indicating conductivity bridge (mmhos/cm). Soil pH was determined with glass electrode pH meter (Fresenius et al. 1988). The method described by Jackson (1962) was used for determination of the total soluble salts (T.S.S.) and calcium carbonate content. Soil organic matter was determined colorimetrically using the method described by Walinga et al. (1992). Chloride determination was carried out by using the AgNO₃ method according to Jackson and Thomas (1960). Sulfates were determined gravimetrically using BaCl₂, while carbonates and bicarbonates by back titration with NaOH. The nitrogen content was determined after Kjeldahl digestion.

Soil and plant samples were acid digested (hydrochloric and nitric acids) before determination of cations concentrations by atomic absorption spectrophotometry (De Ruig, 1986). The soil content and the variation of these elements were studied. Results obtained were treated statistically. Simple linear correlation coefficient (r). The variance ratio (VR) test and the two-way analysis of variance (ANOVA) were applied to steel and Torie (1980) and Davis (1986).

**Results**

**Physical properties of the soil:**

**Soil texture:**

Results of granulometric analysis of the soil samples associated with the five studied plant communities (Table 1) indicate that the soil is medium in texture especially in the surface samples (0-20 cm) at Burg El-Arab and the bottom samples (20-40 cm) at Matruh. The main bulk of the soil samples was mixed sand in both habitats. The soils
supporting the plants were loamy sand in the surface samples (0-20 cm) at Burg El-Arab and in the bottom samples (20-40 cm) at Matruh, and sandy loam in bottom samples (20-40 cm) at Burg El-Arab and surface samples (0-20 cm) at Matruh. The granulometric analysis of the soil samples show that, medium and fine sands contributed the major part of the soil in both habitats.

**Soil moisture content:**
The data show that there was a general increase in soil moisture with increasing soil depth. In general, the mean value of moisture content at Matruh is higher than at Burg El-Arab. The mean values of soil moisture content at Burg El-Arab were 12.8 % and 14.9 % in top soil (0-20 cm) and bottom layer (20-40 cm), respectively, while these values were 15.0 % and 17.8 % in surface layer (0-20 cm) and bottom layer (20-40 cm), respectively, at Matruh (Table 2).

The results of soil moisture content clearly indicate the availability of soil moisture in the 20 – 40 cm layers in two habitats. This layer (20-40 cm) is exploited by the root system of plant communities and is expressive of the soil moisture condition under which the plant flourishes. This layer is further protected from the evaporating power of the atmosphere by the upper layer.

**Chemical properties of the soil:**
**Organic matter:**
Generally, the soil supporting plant communities in Burg El-Arab and Matruh habitats was poor in organic matter content. It ranged between 0.15 % and 0.22 % in surface layers (0-20 cm) at Burg El-Arab and Matruh, respectively, and between 0.09 % and 0.11 % in bottom layers (20-40 cm) at Burg El-Arab and Matruh, respectively, (Table 2).

The variation of organic matter could be attributed to many factors including the sandy texture, good aeration and the insufficient farm and management practices. All these factors may be responsible for accelerating organic matter decomposition and consequently for the low content of organic matter in such soil.

Organic matter content (Table 2) was slightly higher at Matruh than Burg El-Arab. This study revealed that, the vertical distribution of organic matter in the soil profiles tested have shown that the organic matter content usually gradually decreases with depth.

Regarding soil reaction, the pH value of soil samples ranged between 7.7 and 7.9 at Burg El-Arab and between 8.0 and 8.3 at Matruh. These results indicate that the soils in the two habitats are moderately alkaline. Electrical conductivity (E.C.) ranged between 2.6 and 2.8 mmhos/cm at Burg El-Arab, while at Matruh, it ranged between 4.9 and 5.0 mmhos/cm (Table 2).

The total nitrogen content of the soils was higher in the Matruh habitat than in Burg El-Arab habitat: this may be due to the denser vegetation and the incorporation of decomposed plants (Table 2).

**Total soluble salts (T.S.S.):**
The data in Table 2 show that concentrations of total soluble salts (T.S.S.) in the soil samples supporting the plant species in the two habitats were relatively low, ranging from 0.06 % to 1.3 % at Burg El-Arab and between 0.09 % and 1.5 % at Matruh.

**Calcium carbonate:**
The percentage of calcium carbonate is higher at Matruh than at Burg El-Arab (Table 2). Its values range from 13.33 % to 15.20 % in the examined two profiles of Matruh habitat. In Burg El-Arab habitat the value ranges from 9.82 % to 10.91 %.

**Anions content:**
The anions content of the soil samples from two habitats were relatively low (Table 2). The highest value of HCO$_3^-$ (0.43 %) was recorded at Matruh while the minimum value (0.12 %) was recorded at Burg El-Arab. On the other hand, all examined soil specimens were free from carbonates.

The value of chloride content ranges between 0.15 % and 0.17 % in the two profiles at Burg El-Arab and between 0.14 % and 0.18 % in the two profiles at Matruh.

The sulfate content of Matruh habitat was higher than those at Burg El-Arab. Its value varied from 0.15 % to 0.16 % in the two profiles at Matruh and from 0.12 % to 0.14 % in the two profiles at Burg El-Arab.

**Cations content:**
Magnesium constituents form the major component of the soil in the two habitats, and its ion concentration was relatively high. It ranged between 2.72 % and 2.05 % at Burg El-Arab and between 4.12 % to 4.40 % at Matruh habitat (Table 2). Calcium constituents form the second major component of the soil after Mg$^{2+}$ ion, its ion concentration in soil samples supporting plant species at the two studied areas was relatively high (between 1.91 % and 1.31 % at Burg El-Arab and between 2.03 % and 2.01% at Matruh ;Table 2).

Sodium ion ranges between 1.23 % and 0.83 % at Burg El-Arab and between 3.35% and 2.19 % at Matruh habitat. Potassium ion ranges between 1.51 % and 1.03 % at Burg El-Arab, and between 3.92 % and 2.65% at Matruh habitat. Phosphorus like the most of the determined elements fluctuated in the two different habitats, its value was higher in Matruh habitat than in the Burg El-Arab habitat. It ranged between 138.0 ppm and 94.0 ppm in Matruh habitat and between 77.0 ppm and 62.0 ppm in Burg El-Arab habitat. The copper constituents form the minor component of the soil in the two habitats, its ion concentration was relatively low. It ranged between 0.31 % and 0.22 % at Burg El-Arab and between 0.25 % and 0.30 % at Matruh habitat.

**Plant analysis:**
**Ash content:**
Results presented in Tables 3 and 4 show that the ash content is higher in green stems and leaves than the stems in the two habitats. Moreover, the average ash content is higher in the organs of plant communities at Matruh than at Burg El-Arab. The ash content in Chenopods species is higher in its green parts than in Zygophyllum species in both the studied habitats. The highest ash content was recorded in the green stems of Halocnemum being 47.7 % in Matruh and 46.0 % in Burg El-Arab habitats. However a lower value of ash content was recorded in the stems of Zygophyllum (12.3 % at Matruh and 11.2 % at Burg El-Arab).

**Dry matter:**
Dry matter percentage varies considerably in the different species studied (Tables 3,4). The dry matter fraction of the stem in all species in the two habitats was higher than that recorded in the assimilatory organs. In Burg El-Arab habitat, the highest value is recorded in Limoniastrum monopetalum (54.3 %) while the lowest (34.9 %) is recorded in Zygophyllum album. In the Matruh habitat, the highest value is recorded in Halocnemum storbilaceum ( 51.1 %) and the lowest (34.1 %) in Zygophyllum album also.

**Total carbonate:**
The magnitude of variation in the total carbonate content varies from one plant species to another (Tables 3,4). In both habitats, carbonate content in the stem of the
different plant species is higher than in the assimilatory organs, except in case of *Zygophllum* (at Matruh habitat only) and *Limoniastrum* (in both studied habitats), where the total carbonate content of the stem is less than that of the leaves.

**Anions:**
Chloride ion content varies markedly between assimilatory organs and stems in both habitats (Table 3,4). In *Zygophllum*, the chloride ion content is relatively low when compared to the other species. Data in Tables 3 and 4 show that the highest value in sulfate content was recorded in the assimilatory organs rather than the stems, in both habitats. The highest value is recorded in *Zygophllum* leaves (17.2 % and 18.1 % in Burg El-Arab and Matruh habitats respectively), while the lowest value is recorded in *Halocnenum* stems of the two habitats (1.10 %).

**Cations:**
Sodium content is higher in leaves and assimilatory organs in all plant species than in stems in the two habitats (Tables 3,4). In *Arthrocneum* and *Halocnenum*, assimilatory organs exhibit the highest values (10.10 % 9.10 % and 8.50 %, 8.10 % in Matruh and Burg El-Arab habitats respectively). The lowest values are recorded in *Suaeda* stems (0.40 % and 0.55 % in Matruh and Burg El-Arab habitats respectively).

Potassium content is relatively lower than sodium in all studied plant species, with narrow range between the assimilatory organs and stems in the two habitats. In *Arthrocneum* and *Halocnenum* assimilatory organs, the highest values are recorded in the two habitats (1.80 % and 3.20 %) but in *Suaeda* leaves the lowest values are recorded (0.40 % and 0.50 %) in Matruh and Burg El-Arab habitat respectively.

Tables 3 and 4 show that the calcium content is higher than potassium in all plant species in both habitats. The leaves and assimilatory organs contain higher values of Ca²⁺ content than in stems of all plant species, while the lowest value of Ca²⁺ was recorded in the stems of *Zygophyllum* (1.20 %) in Matruh and in the stems of *Halocnenum* (1.50 %) in Burg El-Arab habitat. The highest value of Ca²⁺ content was recorded in *Limoniastrum* leaves (being 9.10 % and 8.30 % in Matruh and Burg El-Arab respectively).

Magnesium content is high in *Zygophyllum* leaves in the two habitats being 4.20 % in Burg El-Arab and 5.30 % in Matruh habitat. In *Limoniastrum* the average value of magnesium is ranging between 1.10 % for leaves and 0.41 % for stems in Burg El-Arab. In Matruh habitat the average value is ranging between 1.50 % for leaves and 0.30 % for stems of *Limoniastrum*. Meanwhile, no marked variation is observed in the average values between stems and assimilatory organs in case of *Arthrocneum* and *Halocnenum* in the two habitats.

The least represented cation was copper, the values of which varied from 0.70 % to 0.80 % in *Limoniastrum* leaves in Burg El-Arab and Matruh habitats respectively, and from 0.01 % in *Halocnenum* stems to 0.30 % in *Suaeda* stems for Burg El-Arab and Matruh habitats respectively.

It is clear from that higher values of P³⁺ were attained in leaves and assimilatory organs of all plant species in the two habitats and the lower values were attained in stems. The highest values of P³⁺ were recorded in *Suaeda* leaves being 140.0 ppm in Matruh and 138.0 ppm in Burg El-Arab and the lowest values were recorded in *Halocnenum* stems being 8.80 ppm in Burg El-Arab habitat.

**Discussion**
A large spatial heterogeneity was found in the chemical composition of soils and plants considering the two habitats studied. Soils supporting plant species in the Matruh habitat showed the highest concentrations for the elements analyzed.

The soil associated with plant communities is loamy sand at surface layer at Burg El-Arab and sandy loam at Matruh, while at bottom layer it was sandy loam in Burg El-Arab and loamy sand in Matruh habitat.

The soil Ca$^{2+}$ and pH have a great effect on the vegetation and characteristic flora (Alonso and Garcia, 1997). It was noticed that in the two habitats, the mean value of soil moisture content increased with increasing depth. Shalaby et al. (1981) reported that in desert soils below a certain depth there was a permanently wet layer so as to supply deep – rooted perennials with available water all the year round. These results are also in agreement with Salama (1989).

The pH values were all alkaline in both habitats with range 0f 7.7 and 7.9 in the soil from Burg El-Arab region and 8.0 to 8.3 in the soil from Matruh region. The soil pH reflects the calcium carbonate contents. The pH were alkaline in Matruh soils ranging from 8.0 to 8.3 respectively which exhibited the highest concentration of calcium carbonate 13.33 % and 15.20 % respectively. On the other hand Burg El-Arab soils showed that slightly alkaline (pH 7.7 and 7.9) contained the least amount of calcium carbonate (9.82 % and 10.91 %) respectively. These results agree with Al-Falih, (2001).

All soil samples in the two habitats contained a low percentage of organic matter (Table 2). The effects of organic matter on phosphate availability were negligible because all soils contained low percents, consistent with the finding of studies on Saudi Arabian soils (Abdel-Hafez, 1981; Ali and Abou-Heila, 1984; Al-Falih, 1996).

The concentration of total soluble salts (T.S.S.) in soil samples supporting plant communities in both localities were relatively low and varied within a narrow range, from 0.06 % to 1.30 % at Burg Al-Arab and between 0.09 % to 1.50 % at Matruh habitat.

Sulfate content in soil samples in the two studied areas showed that the lower values were detected in Burg El-Arab habitat. Soluble carbonates were not detected in the two habitats, while bicarbonates fluctuated within a narrow range, it ranges between 0.33 % and 0.43 % as maximum values and between 0.12 % and 0.13 % as its minimum values at Matruh and Burg El-Arab habitat, respectively. In general *Zygophyllum* tended to accumulate the divalent ions Ca$^{2+}$, Mg$^{2+}$ and SO$_4^{2-}$ in a relatively high concentration in its tissues, but the *Chenopodes* tended to accumulates the monovalent ions Na$^+$, K$^+$ and Cl$^-$ which help the species to be highly tolerant to the high concentration of monovalent ions in saline soil.

Na$^+$, K$^+$, Ca$^{2+}$, Mg$^{2+}$, Cu$^{2+}$ and P$^{5+}$ concentrations were higher in soil samples of Matruh habitat than in the Burg El-Arab habitat. Mg$^{2+}$ is the major element followed by Ca$^{2+}$ in both habitats.

During the present study collected plants are divided into three groups, one with succulent leaves (*Zygophyllum* and *Suaeda*) and the second with succulent green stems (*Arthrocnemum* and *Halocnemum*), while the third one was non succulent plant (*Limoniastrum*).

Ash content considered as a good criterion of the total mineral ions content of the plant material, exhibited higher values in the assimilatory organs of the studied plants than in their stems in the two habitats. This may be due to the succulence, which increased the volume of vacuoles in cells, allowing the storage of more electrolytes. Similar results were reported by Fahmy (1986); El-Shourbagy et al. (1991) and Batanouny et al. (1991).
The dry matter percentage in all species stems is higher than that of leaves or assimilatory organs in the two habitats. This may be attributed to the presence of more lignified and supporting cells in the stems than in the assimilatory organs.

The total carbonate is found to be accumulated in stems more than in the green parts. Concerning the anions content, results demonstrated that the chloride ion is the most common ion in the assimilatory organs (leaves or stems) in all studied species in the two habitats. Also, sodium displayed higher value in leaves and green stems of all species than the stems in the two habitats. Sen et al. (1982) reported on the ability of succulent halophytes to accumulate NaCl in high concentration to compensate for the cationic balance.

Data also show that the high value in sulfate content is recorded in the leaves of *Zygophyllum* in the two habitats. Similar results were reported by Abo Sitta and Al-Taisan (1995) who observed a higher value of sulfate than chloride in *Zygophyllum qatarense*.

The studied plant species in the two habitats exhibit a preference for sodium over potassium a characteristic which distinguishes halophytes from glycophytes Abo Sitta and Al-Taisan (1995). Also, the Na\(^+\)/K\(^+\) ratios was found to be much higher in *Chenopod* species in the two habitats, thus reflecting a preference to sodium over potassium.

The calcium content was higher than potassium in all plant organs in the two habitats, this may be due to the formation of oxalate (Osmond, 1967).

Results show that the *Chenopod* species in the two habitats accumulate low value of magnesium within their tissues either in photosynthetic organs or in their stems, meanwhile *Zygophyllum* accumulate the highest value in their leaves and stems. The content of magnesium in the assimilatory organs was higher than the stems of the different species in the two habitats. This may be attributed to the presence of chlorophyll to which the magnesium ions are bound (Stocking and Ongun, 1962). Cu\(^{2+}\) is the least element detected in all plant species collected from the two habitats (Tables 3,4). P\(^{3+}\) content was higher in plant organs collected from Matruh habitat than that collected from Burg El-Arab habitat.

There were correlation between the mineral content of soil and plant materials in the two habitats, soil Mg\(^{2+}\) is relatively well correlated with plant Mg\(^{2+}\). The second correlation appeared between soil and plant K\(^+\). This element was described by Pinto Tobalina et al. (1991) as the only one together with P\(^{3+}\), which showed a correlation between soil and plants. Thus, the total metal concentrations in soil are not a good analytical criteria to asses metal content in plants (Gupta, 1989).

In conclusion, the data here suggest that the mineral composition of soil is not likely to be a limiting factor for the plant growth. The vegetation data are in the range considered as typical with concentrations unlikely to limit animal productivity. However, since the herbivores move through the whole area and feed on the different plant communities, they can avoid deficiencies with a varied diet. It can be concluded that the mineral composition of these area is adequate for animal consumption.

**References**


