ANATOMICAL AND ECOLOGICAL OBSERVATIONS IN SUCCULENT (ARTICULATED) HALOPHYTES FROM *CHENOPODIACEAE*

OBSERVAȚII ANATOMO-ECOLOGICE LA SPECII DE HALOFITE SUCULENTE (ARTICULATE) DIN FAMILIA *CHENOPODIACEAE*

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Abstract. *Several succulent halophytes, with articulated segments have been anatomically investigated: Sarcocornia fruticosa (L.) A. J. Scott, Arthrocnemum macrostachyum (Moric.) Moris in Moris & Delponte, Salicornia ramosissima Woods (Chenopodiaceae). These species have been collected from Spain, in 2010. The nature of articulated segments is still disputed from anatomical point of view, a caulinar or foliar origin being suggested during time. We also evidenced several special structures, such as stereids ('spicular cells') and tracheoidioblasts, whose functions played within these segments, are still incompletely elucidated. These structures, as well the succulence are discussed as adaptations of halophytes to environmental conditions.*
Key words: *halophytes, anatomy, ecology.*

Rezumat. *În lucrarea de față, am supus investigației anatomice următoarele specii de halofite suculente, cu segmente articulate, din familia Chenopodiaceae: Sarcocornia fruticosa (L.) A. J. Scott, Arthrocnemum macrostachyum (Moric.) Moris in Moris & Delponte, Salicornia ramosissima Woods, colectate din Spania, în 2010. Natura segmentelor articulate este încă disputată din punct de vedere anatomic, ridicându-se problema dacă acestea au origine caulinară sau foliară. Am evidențiat şi alte structuri speciale, cum ar fi stereidele (celule „spiculiforme") şi traheoidioblastele, ale căror funcții în cadrul acestor segmente suculente sunt încă incomplet elucidate. Aceste structuri, precum şi prezența suculenței, au fost interpretate în sensul adaptărilor halofitelor la condițiile complexe de mediu.*
Cuvinte cheie: *halofite, anatomie, ecologie.*

INTRODUCTION

Halophytes are plants that naturally vegetate in saline habitats (Grigore, 2008). They are included in a very heterogeneous ecological group; for this reason, plants present very different and complex adaptive features, formed most likely during evolution, as a result of continuous influence of environmental factors (Grigore and Toma, 2010).

In the present paper, we continue the anatomical and ecological research

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regarding halophytes from Mediterranean climate, a work included in a large series (Grigore, Toma, Boşcaiu, 2011; Grigore, Toma, Ivănescu, 2011).

In the Mediterranean region, the halophytic communities represent two categories – those that belong to the maritime salt marshes and those that belong to the salt deserts (Chapman, 1974). Moreover, as already stated, Mediterranean salt marshes provide special ecological conditions, controlling the spatial distribution of vegetation; this is related to the predominance of several environmental factors and to adaptive set of halophytes (Grigore, Toma, Boşcaiu, 2011).

MATERIAL AND METHOD

In this study, three species of halophytes from *Chenopodiaceae* (sometimes included in *Amaranthaceae*) have been anatomically investigated: *Sarcocornia fruticosa* (L.) A. J. Scott, *Arthrocnemum macrostachyum* (Moric.) Moris in Moris & Delponte, and *Salicornia ramosissima* Woods. These have been collected in July of 2010, from a coastal salt marsh from Alicante (Spania).

Anatomical investigations were conducted following the method standardized by our group from Faculty of Biology, Iasi (for an extended description of this method, see: Grigore, Toma and Boşcaiu, 2010).

RESULTS AND DISCUSSIONS

Following the anatomical investigations, several observations can be delineated. In *Arthrocnemum macrostachyum*, in the external cortex of unarticulated stem long or very long brachysclereids are dispersed; these are perpendicular on the epidermis, simple or branched (especially at the ends), with a thick and lignified wall. At the limit between the external cortex and the middle one there are located very small vascular bundles, with spiral xylem vessels disposed on a circle.

There follows a special type of cork area (Fig. 1): 2-3 layers of rectangular cells, slightly tall with relatively thick and suberified walls. The phelloderm forms a thick area with cells disposed in radial rows having the tangential walls moderately thickened.

The stele comprises 3-4 rings of vascular bundles (Figs. 1, 2) embedded into the fundamental sclerenchyma mass, all resulting from the activity of the supernumerary cambia. The phloem appears like cellulosic isles surrounded by sclerenchyma and the xylem of the conducting vessels.

On the internal face of the first ring, that is, close to the medulla, there are six vascular bundles (Fig. 2) larger than the ones resulting from the activity of the supernumerary cambia, having the xylem with little libriform fibers and being separated by wide medullary rays, made of parenchyma cells with moderately thickened and lignified wall.

In the cortex of articulated (succulent) segment, there are many stereides (Fig. 3), perpendicular on the epidermis, partially embedded in the water-storage parenchyma. These stereides have been also evidenced by De Fraine, (1912), who called them "spicular cells". This author considers the stereides and

tracheoidioblasts (see below) as homologous structures. Mangin (1882), Monteil (1906) and Mateu Andrés (1989) also evidenced them in *A. macrostachyum*. It is interesting that Chermezon (1910) did not explicitly mentioned stereides in *A. macrostachyum*, but these can be easily observed in a drawing made by Chermezon (fig. 45, p. 245, in the quoted work).

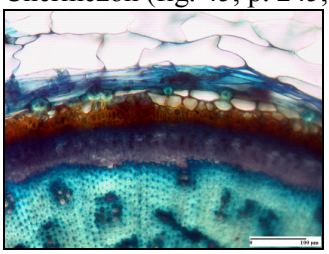

Fig. 1 - Cross section through the unarticulated stem of *Arthrocnemum macrostachyum*

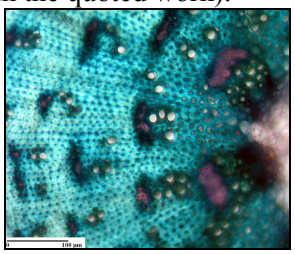

Fig. 2 - Cross section through the unarticulated stem of *Arthrocnemum macrostachyum*

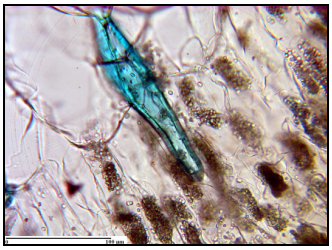

Fig. 3 - Cross section through the articulated segment of *Arthrocnemum macrostachyum*

In *Sarcocornia fruticosa*, the central cylinder of the root is affected by successive cambia phenomenon (Fig. 4). The stele consists of five lignified rings, with phloem isles; in the lignified part of each ring, vessels towards outside and sclerenchyma fibres towards inside are noticed (Fig. 4). When analysing more thoroughly, they seem to be vascular bundles surrounded by sclerenchymatic fibres with extremely thick and intensely lignified wall. In the central part, four xylem and phloem bundles can be found (Fig. 4).

The stele of unarticulated stem is very thick, resulting mainly from the activity of the supernumerary cambia. In the central area, 5-6 internal vascular bundles, with little phloem (sieved tubes and companion cells) and a little more xylem (lignified parenchyma cells and vessels) can be observed; on the internal face of each bundle there is a cellulosic parenchyma arch, in whose thickness are visible several vessels or remains of primary xylem which have a little thickened and poorly lignified wall (Fig. 5).

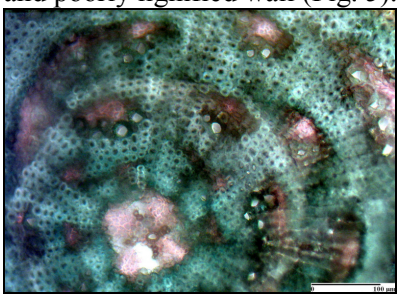

Fig. 4 - Cross section through the root of *Sarcocornia fruticosa*

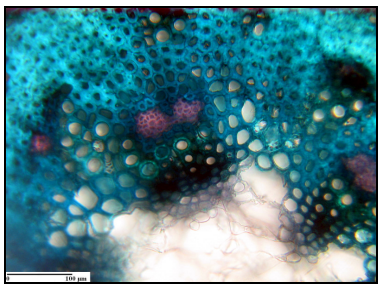

Fig. 5 - Cross section through the unarticulated stem of *Sarcocornia fruticosa*

The cortex of succulent (articulated segment) is very thick and consists of an assimilating external area, formed by 2-3 layers of long palisade cells (Fig. 6); among them, very long, poorly branched brachysclereids (Fig. 7) are present,

perpendicular in relation with the epidermis and partially embedded in water storage parenchyma. The central, internal area is thicker, forming an aqueous parenchyma (Fig. 6), consisting of large cells, many of them radially prolonged; the internal layer has small cells, where sclereides, of different shape and size can be noticed.

According to some botanists (Chermezon, 1910) this internal cortical layer would represent the upper epidermis of leaf fused with the stem.

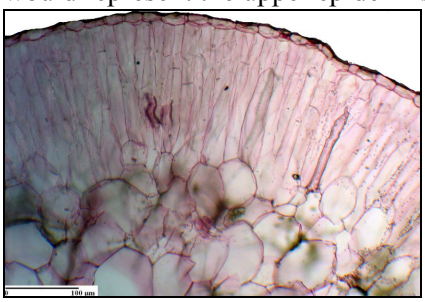

Fig. 6 - Cross section through the articulated segment of *Sarcocornia fruticosa*

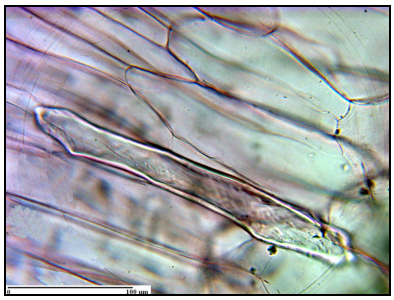

Fig. 7 - Cross section through the articulated segment of *Sarcocornia fruticosa*

In the root of *Salicornia ramosissima,* the stele comprises a very thin ring of secondary phloem (sieved tubes, companion cells and phloem parenchyma cells, some with druses of calcium oxalate) and a central compact body of secondary xylem, completely lignified, and crossed by numerous medullary rays.

In the thickness of the xylem body, one can distinguish 4-5 rings of different thickness, with larger vessels in their internal side, all with very much libriform made of fibres with an extremely thick and heavily lignified wall. The root axis has narrower vessels, scattered irregularly in the libriform mass.

From the analysis of this material, one can estimate the number of supernumerary cambia (Fig. 8) that have generated the ring-shaped conductive tissues, without noticing the different vascular bundles or the complete rings of xylem and phloem.

The stele of unarticulated stem is thick, with a structure more similar to the one of the root, predominant being the sclerified and lignified part. In fundamental mass represented by a significant quantity of libriform (fibres with an extremely thick and lignified wall) numerous and very small islands of phloem, and very few vessels (which differentiate by the fibrous elements only that they are slightly wider) can be observed (Fig. 9).

The stele also comprises an internal ring of small vascular bundles, with a "V"-shaped xylem, in the arms of which is localized the phloem), separated by parenchymatous-cellulosic medullary rays.

The centre of the stem is occupied by an air-storing cavity of irregular outline.

As in the root, the presence of the phloem islands embedded in the compact

mass of xylem (in which clearly predominates the libriform) shows the same activity as of several supernumerary cambia, although initially the structure was a primary one, with vascular bundles around the medulla.

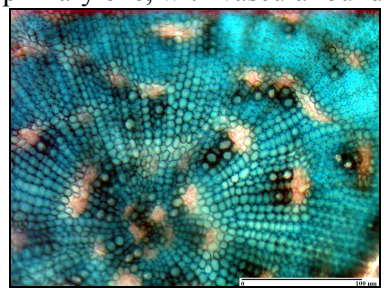

Fig. 8 - Cross section through the root of *Salicornia ramosissima*

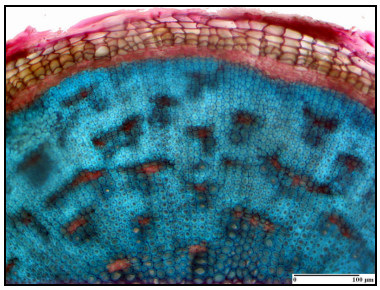

Fig. 9 - Cross section through the unarticulated stem of *Salicornia ramosissima*

The cortex of articulated segment is very thick, with cells of different size and consists of an external zone, thinner, with 2 layers of palisade layers (Fig. 10), rich in chloroplasts. Internal zone is thicker, of water-storage parenchyma (Fig. 11) with approximately 7 layers of colourless cells, out of which 2-3 layers of very large cells (large and long), followed by 3-4 layers of smaller and smaller polygonal cells. In the thickness of palisade tissue, tracheoidioblasts can be observed (Fig. 11); their roles have been largely discussed (Grigore şi Toma, 2010).

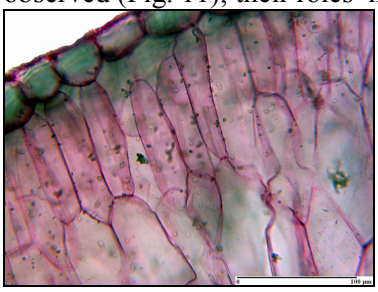

Fig. 10 - Cross section through the articulated segment of *Salicornia ramosissima*

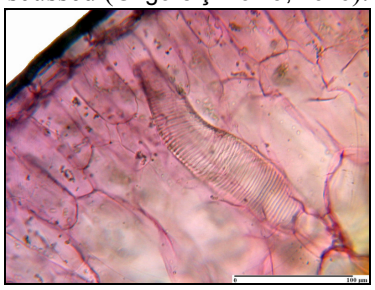

Fig. 11 - Cross section through the articulated segment of *Salicornia ramosissima*

Ecologically, *Arthrocnemum* and *Sarcocornia* develop dominant plant communities in several Mediterranean salt marshes; these species are confined to lower, humid and even flooded (in rainy season) areas of salt marshes (Grigore, Toma, Boşcaiu, 2011). Scattered among these shrubs *Salicornia* can be found; it is an annual plant, with similar ecological preferences as the other two species.

All the species are succulent, at the level of articulated segments; succulence is a typical adaptation in halophytes, with role in dilution of concentrated salts and water storage, since these habitats are affected by physiological drought (Grigore and Toma, 2010).

The presence of streides and tracheoidioblasts may be correlated with supporting function, since the mechanical tissues are less developed in the succulent segments.

CONCLUSIONS

The adaptations of these three halophytes with articulated stems (succulent segments) can be included in the general structural frame characteristic for *Chenopodiaceae*. In addition, these adaptations reveal the close affinity for environmental factors, an interrelation built during co-evolution process plant-saline environment.

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