ANATOMICAL AND ECOLOGICAL OBSERVATIONS ON MEDITERRANEAN HALOPHYTES: *SUAEDA* Forssk. ex Scop. GENUS

CONSIDERAŢII ANATOMO-ECOLOGICE LA SPECII DE HALOFITE MEDITERANEENE: GENUL *SUAEDA* Forssk. ex Scop.

GRIGORE M. N.[1], TOMA C.[1], IVĂNESCU Lăcrămioara[1]
e-mail: mariusgrigorepsyche@yahoo.com

Abstract. *In this work, we have anatomically investigated three Suaeda species: S. vera* Forssk. ex J. F. Gmel.*, S. splendens* (Pourr.) Gren. & Godr. *and S. spicata* (Willd.) Moq. *(Chenopodiaceae). These taxa were collected from maritime and continental salt marshes from Spain, during July- November, 2010. The obtained results were correlated with some ecological data gathered in the field; they were discussed in order to establish the adaptive value of the evidenced anatomical features*

Key words: halophytes, ecology, mediterranean, succulence, successive cambia

Rezumat. *În lucrarea de faţă, am investigat din punct de vedere anatomic trei specii de halofite aparţinând genului Suaeda: S. vera* Forssk. ex J. F. Gmel.*, S. splendens* (Pourr.) Gren. & Godr. *şi S. spicata* (Willd.) Moq. *(Chenopodiaceae). Taxonii au fost colectaţi de pe sărături maritime şi continentale din Spania, în perioada iulie-noiembrie 2010. Rezultatele obţinute au fost corelate cu unele date ecologice, expeditive, din teren şi interpretate în sensul stabilirii valorii adaptative a trăsăturilor anatomice observate.*

Cuvinte cheie: halofite, ecologie, mediteranean, suculenţă, policambie

INTRODUCTION

Halophytes represent a polymorphous ecological group of plants; they include species with a complex set of anatomical features, allowing them to survive in high soil salinity conditions (Grigore, 2008a, 2008b; Grigore and Toma, 2010 a, 2010b; Grigore et al, 2010a).

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). Maritime marshes of the Mediterranean, described in general terms by Rikli (1943) lie behind coastal dunes but are subjected to salt-water inundation.

MATERIAL AND METHOD

In the present study, we have anatomically investigated three species of

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[1] ”Al. I. Cuza” University Iaşi, Romania

Suaeda (*Chenopodiaceae*): *S. vera* Forssk. ex J. F. Gmel., *S. splendens* (Pourr.) Gren. & Godr. and *S. spicata* (Willd.) Moq. The two firstly mentioned species were collected from Alicante (Spain), and the last from El Saler (Spain), in the July of 2010.

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 et al, 2010b).

RESULTS AND DISCUSSIONS

As a result of our investigations, we evidenced the successive cambia phenomenon, located on the level of axial vegetative organs (root, stem) in annual *Suaeda* species (*S. splendens* and *S. spicata*).

Thus, in *S. splendens*, the central cylinder of the **root** is very thick with a particular structure. It comprises: a central massive of secondary xylem (vessels and sclerenchyma fibers) (fig. 1), irregular in shape, surrounded by a thin ring of secondary phloem; 3 (4) concentric rings derived from the activity of additional cambia. Each ring includes: an internal, thicker region of sclerenchyma fibers, where xylemic vessels are partially incorporated and an external, thinner region of phloem, having different thickness following the root' circumference. The external ring, the last generated by the cambium activity is thinner and has only sclerenchyma fibers (with slightly lignified walls) towards interior (xylemic vessels are not yet formed) and pholemic elements towards exterior. We noticed some (4-5) layers of cambial cells, arranged in radiated ranges; these may be found between the pholemic and sclerenchyma fibers rings.

In the same species, at **stem** level, the central cylinder consists of 6-7 vascular bundles, different in size, split up by medullar parenchymatic large rays (fig. 2). The xylemic vessels near to the phloem are separated by sclerenchyma fibers. The central cylinder includes, in addition, an incomplete ring of sclerenchymatic fibers with moderately thickened and lignified walls (having scarce xylemic areas embraced in this ring) and a complete pholemic ring. Close to this, 2-3 layers of cortical small cells may be noticed. Therefore, a successive cambia already has operated.

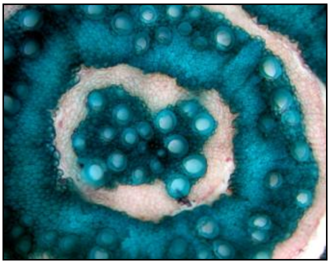

Fig.1 - Cross section through the root of *S. splendens* (X400)

Fig.2 - Cross section through the stem of *S. splendens* (X200)

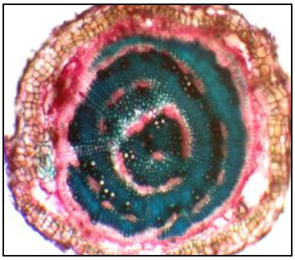

Fig.3 - Cross section through the root of *S. spicata* (X200)

In *S. spicata*, in the **root**, the external additional cambia is very dynamic, built by 4-6 layers of cells with typical radiate disposition (fig. 3). Its activity generated only a very thin pholemic ring, with sieve tubes, companion cells and few parenchyma cells; all are tangentially prolonged, strongly radially flattened and with cells walls slightly collenchymatous. The xylemic lignified body is very thick and with different organization in its thickness. It consists of an external ring, incomplete and different in size, made by sclerenchyma fibers and vessels.

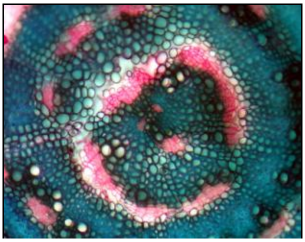
Fig.4 - Cross section through the root of *S. spicata* (X400)

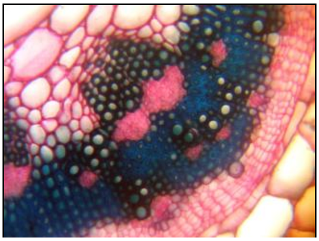
Fig.5 - Cross section through the stem of *S. spicata* (X400)

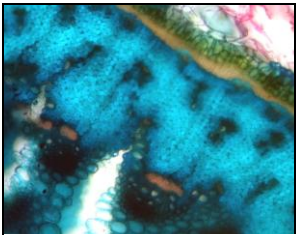
Fig.6 - Cross section through the stem of *S. vera* (X200)

In the thickness of this ring some pholemic islands are included. The lignified body also consists of a median thicker and continuous ring of sclerenchyma fibers and vessels as well an internal, thick, more or less spiraled ring of sclerenchyma fibers and vessels; here and there, several phloemic islands, forming a ring almost complete may be found. Therefore, several successive cambia were active, generating intensely lignified rings, which incorporate the phloem island-like shape. In the center of organ, the diarch central cylinder from primary structure is still visible (fig. 4).

The stele of **stem** begins with a uni-layered pericycle, made by parenchyma cells. On the periphery of central cylinder a thick ring (5-6 layers) of successive cambia is still noticeably, but it is not yet differentiated. At its internal side, from exterior to interior we can distinguish: an internal thicker ring of sclerenchyma, where vascular bundles are encompassed. Here, there and everywhere these bundles are prominent in the adjacent cambial ring, having at the periphery of phloem 1-2 layers of sclerenchyma fibers. The stele also contains a ring with 10-12 big vascular bundles (fig. 5) with phloem in direct contact with the external sclerenchyma ring and xylem with vessels and cellulosic parenchyma cells in some bundles, or with vessels and libriform fibers, in others.

In *S. vera*, a perennial species, at the **stem** level, the central cylinder has the follow configuration: several thick strands of sclerenchyma fibers near to the cortex, two layers of cells with suberized walls – located between the strands of sclerenchyma fibers and phloemic ring. The stele also contains a thin, secondary phloemic ring, having an external, very thick area of sclerenchyma and an internal area with 8 bundles, with the phloem in contact with sclerenchyma area (fig. 6).

Regarding the structure of **lamina** (a lateral vegetative organ), this has a different configuration in the three investigated taxa. However, all species have succulent lamina.

Thus, in *S. splendens*, the lamina is succulent. The palisade parenchyma consists of a single layer of flattened cells; beneath this, we noticed a layer with small, square or rectangular parenchymatic cells with thin walls (fig. 7). The central mesophyll actually represents a very thick water storage fundamental parenchyma, including huge cells, with thin walls. In the center of this tissue a small vascular bundle is noticeable, surrounded by 2-3 layers of parenchymatic cells.

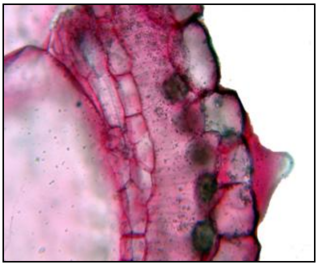

Fig.7 - Cross section through the lamina of *S. splendens* (X400)

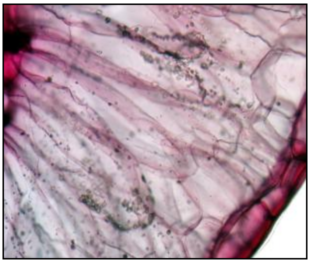

Fig.8 - Cross section through the lamina of *S. spicata* (X200)

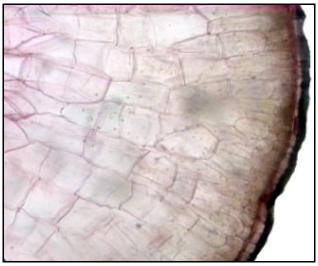

Fig.9 - Cross section through the lamina of *S. vera* (X200)

In *S. spicata*, the mesophyll comprises 1-2 hypodermal layers of small chlorenchymatic cells rounded or rectangular in shape – projected on epidermis. We also found a layer of huge cells, prolonged towards epidermis, forming a water storage tissue (fig. 8). Between vascular bundles, 1-2 layers of rounded big cells may be noticed.

The lamina of *S. vera* is also succulent. The mesophyll is centric-homogeneous with prolonged cells perpendicular to epidermis (only those of external layers are shorter, chlorenchymatic); these tissues form a water storage tissue (fig. 9).

Referring especially to **ecological implications** of above mentioned adaptations, we can include here some comments. All *Suaeda* species vegetate in saline environments (Edmondson, 1993). We collected *S. spicata* from a wet saline habitat, sometimes exposed also to flooding, due to local soil properties and climatic conditions. The other taxa vegetate also in saline areas, but more dry and elevated that the central part of salt marsh, where the soil salinity is higher.

The successive cambia phenomenon, evidenced by us in these species is considered in “classic” plant anatomy as a structural anomaly. But we dealt with it as an adaptation with an ecological and even evolutive significance in halophytes from *Chenopodiaceae* (Grigore and Toma, 2006, 2007).

The succulence of lamina, in all analyzed species may be correlated, no doubt, with environmental factors occurring in the ecosystems where these species grow. Succulence is regarded as a xeromorphic feature and it is explained by physiological drought theory (Grigore, 2008b; Grigore and Toma, 2010a). Although prefigured by early ecological and anatomical observations (Wiesner, 1889; Henslow, 1895; Schimper, 1903; Warming, 1909; Clements, 1920; McDougall, 1941), this theory has been marginalized for many decades. Recently, we reopened this idea and developed it (Grigore and Toma, 2010a). Succulence may be involved in dilution of salts in excess which might accumulate in plant' organs; it also assures the erect position of vegetative organs in halophytes with less developed stereom (Grigore, 2008b). The evolutive significance of succulence has been recently put into discussion, in the whole general context of adaptive mechanisms in halophytes (Grigore, 2011).

The foliar succulence has been also evidenced in other *Suaeda* species, by Chermezon (1910), Mateu Andres (1989), Polić et al. (2009), Grigore and Toma (2010a).

In addition, *S. splendens* presents Kranz anatomy, a feature related to C_4 photosynthetic pathway (Grigore, 2008b; Grigore and Toma, 2010a). Anyway, *Suaeda* species have a large diversity in this regard: some of them present C_3 pathway while others, C_4 (Frey and Kurschner, 1983; Gamaley, 1985; Fisher et al., 1997; Muhaidat et al., 2007). The other two investigated *Suaeda* species seem to display a foliar anatomy related to C_3 photosynthesis - the *austrobassioid* type evidenced and described by Fisher et al. (1997), Jacobs (2001) and Polić et al. (2009). However, 58 % of *Suaeda* species have C_4 photosynthetic pathway (Sage et al, 1999).

CONCLUSIONS

Anatomical features evidenced in *Suaeda* species are particular and relevant for halophytes belonging to *Chenopodiaceae.* They reflect a close relation between form, structure and function and ecological factors.

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REFERENCES

1. **Chapman V. J., 1974** – *Salt marshes and salt deserts of the world* (second ed.). Lehre, Verlag von J. Cramer
2. **Chermezon H., 1910** – *Recherches anatomiques sur les plantes littorales.* Ann. Sci. Nat., sér.9, Bot., 20 : 117-129, 270-274, 299-307
3. **Clements F. E., 1920** – *Plant indicators. The relation of Plant Communities to process and practice.* Carnegie Institution of Washington
4. **Edmondson J.R., 1993** - *Chenopodiaceae*. In: Tutin, T.G., Burges, N.A, Chater, A.O., Edmondson, J.R., Heywood, V.H., Moore, D.M., Valentine, D.H., Walters, S.M., Webb, D.A. (Eds.) *Flora Europaea,* vol. 1 (second ed.), Cambridge University Press, pp. 108-130.
5. **Fisher D. D., Schenk H. J., Thorsch J. A., Ferren W. R. Jr., 1997** – *Leaf anatomy and subgeneric affiliation of C_3 and C_4 species of Suaeda (Chenopodiaceae) in North America*. Am. J. Bot., 84 (9): 1198-1210

6. **Frey W., Kurschner H., 1983** – *Photosyntheseweg und Zonierung von Halophyten an salzseen in der Turkei, in Jordanien und in Iran*. Flora, 173: 293-310
7. **Gamaley I. B., 1985** - *Variaţii kranţ - anatomii u rastenij pustyni Gobi i Karakumi (The variations of the Kranz-anatomy in Gobi and Karakum plants).* Bot. J. SSSR*,* 70: 1302-1314
8. **Grigore M. N., 2008a** - *Halofitotaxonomia. Lista plantelor de sărătură din România.* Edit. Pim, Iaşi
9. **Grigore M. N., 2008b** – *Introducere în Halofitologie. Elemente de anatomie integrativă.* Edit. Pim, Iaşi
10. **Grigore M**. **N., 2011** - *Evolution of anatomical adaptive strategies in halophytes. Hypotheses and scenarios.* Biosystematics Berlin 2011 (21-27 February 2011), Botanic Garden and Botanical Museum Berlin-Dahlem, Freie Universität Berlin, Germany: 145
11. **Grigore M. N., Toma C., 2006** - *Ecological anatomy elements related to Asteraceae halophytes species*. Stud. Com. Muz. Şt. Nat. „Ion Borcea" Bacău, 21: 94-98
12. **Grigore M. N., Toma C., 2007** – *Histo-anatomical strategies of Chenopodiaceae halophytes: adaptive, ecological and evolutionary implications*. WSEAS Transactions on Biology and Biomedicine, 12, 4: 204-218
13. **Grigore M. N., Toma C., 2010a** - *Halofitele. Aspecte de anatomie ecologică*. Edit. Univ. „Al. I. Cuza", Iaşi
14. **Grigore M. N., Toma C**., 2010b - *Structuri secretoare de săruri la halofite. O abordare integrativă.* Edit. Academiei Române, Bucureşti
15. **Grigore M. N., Toma C., Boşcaiu M**., **2010 a** – Dealing with halopytes: an old problem, the same continuous exciting challenge. An. Şt. Univ. „Al. I. Cuza", s. II.a. Biol. Veget., 56 (1): 21-32
16. **Grigore M. N., Toma C., Boşcaiu M**., **2010b** – *Ecological implications of bulliform cells on halophytes, in salt and water stress natural conditions*. An. Şt. Univ. „Al. I. Cuza", s. II.a. Biol. Veget., 56 (2): 5-15
17. **Henslow G., 1895** – *The origin of Plant-Structures by Self-Adaptation to the environment*. London, Kegan Paul, Trench, Trübner, & Co, Ltd, Paternoster House, Charing Cross Road
18. **Jacobs S.W.L., 2001** - *Review of leaf anatomy and ultrastructure in the Chenopodiaceae (Caryophyllales).* J. Torrey Bot. Soc., 128: 236-253
19. **Mateu Andrés I., 1989** – *Anatomia foliar en plantas de saladares mediterraneos costeros.* Dicotiledoneas. Candollea, 44: 435-452
20. **McDougall W. B., 1941** - *Plant Ecology* (third ed.). Lea & Febiger, Philadelphia
21. **Muhaidat R., Sage R. F., Dengler N. G., 2007** - *Diversity of Kranz anatomy and biochemistry in C_4 eudicots*. Am. J. Bot., 94 (3): 362-381
22. **Polić D., Luković J., Zorić L., Bŏza P., Merkulov L., Knežević A., 2009** – *Morpho-anatomical differentiation of Suaeda maritima (L.) Dumort. 1827. (Chenopodiaceae) populations from inland and maritime saline area.* Centr. Eur. J. Biol., 41 (1): 117-129
23. **Rikli M., 1943** – *Das Pflanzenkleid der Mittelmeerlander*, vol. 1, Bern
24. **Sage R. F**., **Li M**., **Monson R. K., 1999** – *The taxonomic distribution of C_4 photosynthesis. In: Sage R. F., Monson R. K. (Eds) C_4 Plant Biology*, Academic Press, San Diego, London, Boston, New York, Sydney, Tokyo, Toronto: 551-584
25. **Schimper A. F.W., 1903** - *Plant geography upon a physiological basis*. Clarendon Press, Oxford
26. **Warming E., 1909** – *Oecology of Plants. An introduction to the study of plant-communities.* Clarendon Press, Oxford
27. **Wiessner J., 1899** – *Uber die Formen der Anpassung der Blatter an die Lichtstarke.* Biol. Centralbl., 19: 1-14