Scientific Papers. Series A. Agronomy, Vol. LVIII, 2015
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

CONTRIBUTION TO THE KNOWLEDGE OF MORPHO-ANATOMICAL CHARACTERISTICS IN SOME AUTOCHTHONOUS AQUATIC PLANTS

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Abstract

In an aquatic environment, plants undergo some major adaptative changes that are reflected in their hydromorphic structure. Thus, the aquatic plants have modified appearance, organ's forms and functions.
This paper highlights the morpho-anatomy and adaptations of some plant species from the Romanian flora (Ceratophyllum submersum, Lemna trisulca, Ranunculus sceleratus and Salvinia natans), so that in future studies we might establish the links between the growth conditions and vegetative structures.

Key words: *aquatic plants, morpho-anatomic features, adaptative changes.*

INTRODUCTION

The water plants can be divided into several groups: submerged (oxygenators), deep-water plants, floating plants and marginals (Robinson, 2004). Aquatic plant species have different forms that are associated with different environmental conditions, since they are modified for living in excess of water. Thus, the morpho-anatomical characteristics of those plants are related to their habit, reflecting the plasticity of their organs (Scremin-Dias, 2009).

When correlate the internal structures of the plant with the aquatic environment, some adaptations are interesting to note: the type of root system, for holding the plant or to allow it to move; gaseous exchange system, to aid flotation of leaves and stems; formation of aerenchyma for carrying oxygen down to the root zone; waxines of leaves, in order to protect against transpiration and saturation (http://www.penritlake-e.schools.nsw.edu; http://ag.arizona.edu/azaqua/aquaplants/).

Ceratophyllum submersum L. (*Ceratophyllales*, *Ceratophyllaceae*) is a cosmopolitan aquatic plant that lives entirely submerged (Rutishauser, 1999). The leaves and stems are delicate, with a green or reddish coloration (Kasselmann, 2003).

Another vascular aquatic plant is *Lemna trisulca* L. (*Alismatales*, *Lemnoideae*), a small species with a rapid grow, which lives submerged except when flowering (Daubs, 1965; Kara & Kara, 2005). The ivy-leaved duckweed plants are connected by short stalks, so they form a dense mat across the water surface (Hiscock, 2003).

An annual herb often found on small water bodies, marshes and pastures is *Ranunculus sceleratus* L. (*Ranunculales*, *Ranunculaceae*) (Hrivnak & Csiky, 2009; Mei et al., 2012).

As regarding the free-floating fern *Salvinia natans* L. (All.) (*Pteridophyta*, *Salviniaceae*), this annual plant can grow in large populations at the surface of lakes, ditches or canals, being protected in the Danube Delta where occupies significant areas in the shallow waters (RIZA rapport, 2002.049; http://www.iucnredlist.org; Bercu, 2006).

Although all four of the above-mentioned plant species are native to Romanian vascular flora, data about their morpho-anatomical features and life adaptations are almost lacking in scientific literature, with few exceptions (Bercu, 2006). The hydrophytic features of those plants, highlighted by cross sections made through different part of their organs are in accordance to the aquatic habitat.

MATERIALS AND METHODS

We used vegetal material of the following species: soft hornwort (*Ceratophyllum submersum*), ivy-leaf duckweed (*Lemna trisulca*), celery-leaved butter cup (*Ranunculus sceleratus*) and floating fern (*Salvina natans*) (Figure 1). After being sampled from their natural habitat (Comana Natural Park, respectively Danube Delta, in the case of the last mentioned species), those aquatic plants were preserved in jars with 70% ethyl alcohol for further investigations.
Microscopic characterization of the morpho-anatomic structures was made by analysing several cross-sections through different levels of the studied plants, with the aid of a ML-4M IOR microscope (Andrei, 2003).

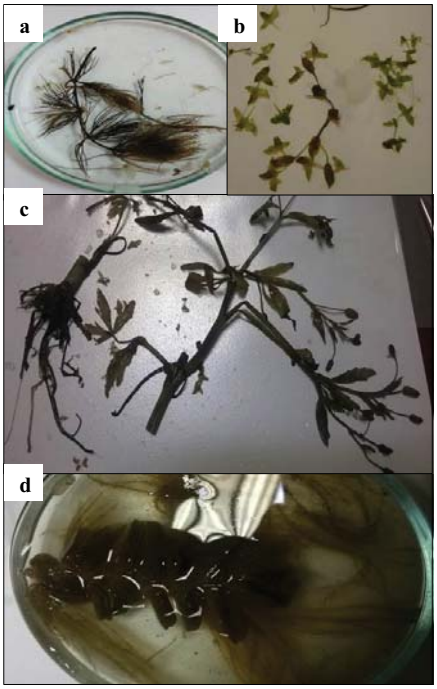

Figure 1. Alcohol-preserved plant species for morpho-anatomic study: a. *Ceratophyllum submersum*; b. *Lemna trisulca*; c. *Ranunculus sceleratus*; c. *Salvinia natans*

RESULTS AND DISCUSSIONS

Results regarding morpho-anatomical features of *Ceratophyllum submersum* (soft hornwort)

This submerged, free-floating perennial plant has a submersible branched stem that bears whorls of soft leaves, bifurcated 2-3 times in 4-8 filiform lacinia (Figure 1a).
The cylindrical stems are slender.
In cross section, the stem of soft hornwort presents epidermis, cortex and the central cylinder, while the pith is lacking (Figure 2).

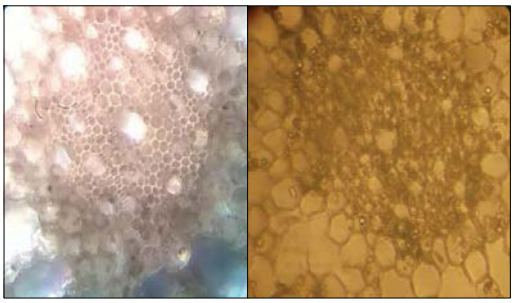

Figure 2. *Ceratophyllum submersum*: stem cross section

The unistratified epidermis is covered by a thin cuticle (Figure 3).

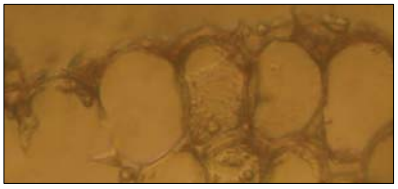

Figure 3. Soft hornwort: stem epidermis

The cortical parenchyma is well developed Aerenchyma surrounds the central cylinder, poorly developed. In the cells of aeriferi parenchyma, raphides are present – acicular crystals of calcium oxalate (Figure 4).

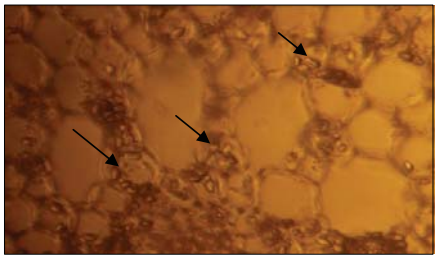

Figure 4. Raphides in aeriferi parenchyma of *C. submersum* stem (see arrows)

The cross section through the leaf shows a single-nerved structure, oval-shaped (Figure 5).

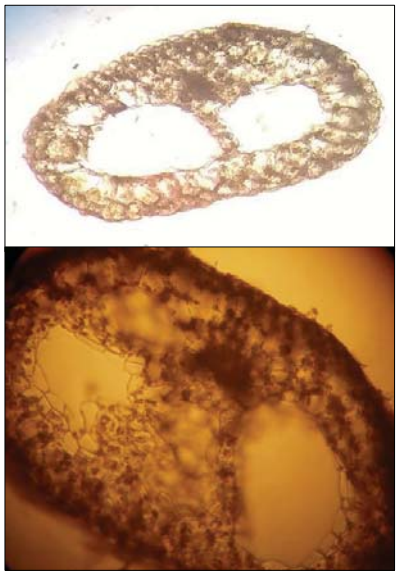

Figure 5. *Ceratophyllum submersum*: leaf cross section

The leaves of soft hornwort have a unistratified epidermis, covered by a developed cuticle. In the homogeneous mesophyll, the aeriferi parenchyma is well developed, consisting of many aeriferous canals by different sizes, around the conducting tissue (Figure 6).
The ribs are underdeveloped.

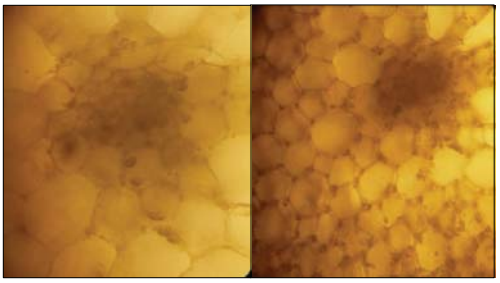

Figure 6. Aeriferi parenchyma of *C. submersum* leaf

Results regarding morpho-anatomical features of *Lemna trisulca* (ivy-leaf duckweed)
The cosmopolit duckweed presents floating oval fronds, with elongated stalks providing plant clustering (Figure 1b).
In cross section through stalk, numerous air spaces can be noticed (aerenchyma) (Figure 7).

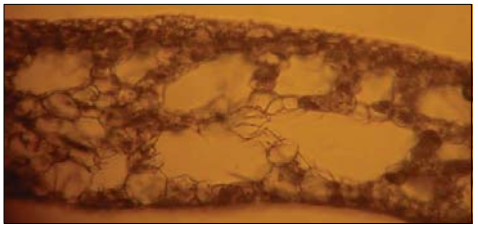

Figure 7. *Lemna trisulca*: stalk cross section

The filiform root of this aquatic plant presents a root cap (Figure 8). Central position of the conducting tissue helps to increase the tensile strength of the organs.

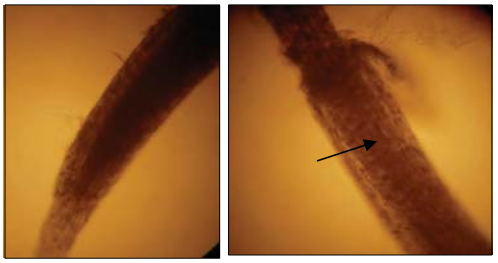

Figure 8. Root of *Lemna trisulca* (arrow indicates the root cap)

Results regarding morpho-anatomical features of *Ranunculus sceleratus* (celery-leaved buttercup)
The fibrous root of buttercup has a very well developed aerenchyma, with big aeriferous canals, arranged in one or two rows (Figure 9).
The central cylinder possesess four wooden fascicles and four liberian fascicles.
The endodermis has Caspary thickening.

Figure 9. *Ranunculus sceleratus*: root cross section with aerenchyma

The epidermis of the stem is unistratified (Figure 10). The cortical parenchyma contains larger air spaces arranged towards the outside and smaller air spaces arranged towards the central cylinder.

Figure 10. *Ranunculus sceleratus*: stem cross section

The stele is represented by numerous liberian and wood fascicles, bounded by well developed sclerenchyma (Figure 11).

Figure 11. Central cylinder of *Ranunculus sceleratus*

The leaves has unistratified epidermis with stomata (Figure 12).

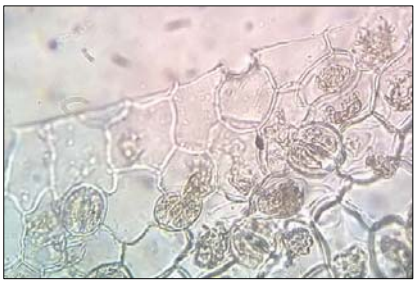

Figure 12. *Ranunculus sceleratus*: leaf stomata

The mesophyll is differentiated in palisadic tissue (Figure 13) formed by one-row cells and lacunar tissue.
The ribs are underdeveloped (Figure 14).

Figure 13. *Ranunculus sceleratus*: palisadic tissue

Figure 14. *Ranunculus sceleratus*: leaf cross section

Results regarding morpho-anatomical features of *Salvinia natans* (floating fern)
The oval-elliptical petiolate leaves are arranged opposite at each node of the short stem (Figure 15).
The petiole has epidermis, cortex and stele (Figure 15). Epidermis contains one single row of cells with thin cellular walls, being covered by a soft cuticle and elongated, sharp tectorial sharp hairs (trichomes).

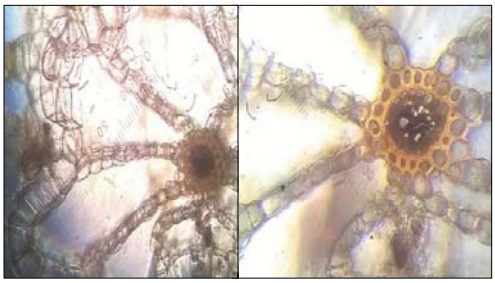

Figure 15. *Salvinia natans*: cross section of the petiole

The cortex is well developed, represented by aerenchyma with 8-9 air chambers disposed around the stele. The air chambers are separated by a row of cells, forming so-called trabecullae. The endodermis has large thick-walled cells.
The stele has a single xylem-phloem conducting fascicle, underdeveloped, situated

in the centre of the section, with one-layered pericycle (Figure 16). Thus, like any fern, the floating fern is characterised by a hadrocentric stele (xylem lying in the centre and liberian vessels facing the pericycle).

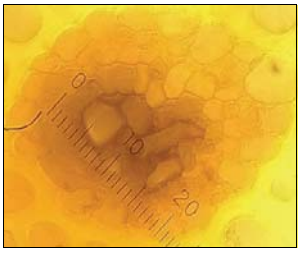

Figure 16. *Salvinia natans*: hadrocentric stele

In cross section, the submerged leaves of the floating fern have unistratified epidermis (Figure 17), with many trichomes, formed by elongated cells, very similar to those disposed on the petiole (Figure 18).

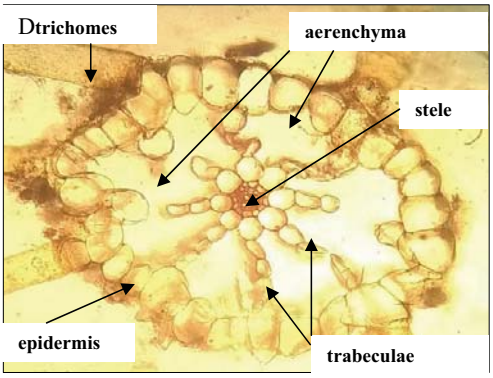

Figure 17. *Salvinia natans*: cross section of the submerged leaf

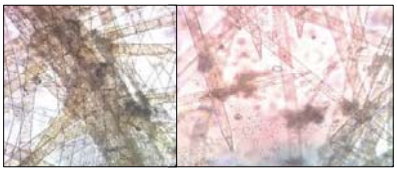

Figure 18. *Salvinia natans*: epidermal sharp hairs of the submerged leaves

According to some authors (Bercu, 2006), the third submerged leaf of the floating fern serves as a root. Actually, the modified leaves of *S. natans* are root-like structures and do not represent a real root; we have not identified any absorbent root hairs or secondary roots.

The cortex is composed of well developed aerenchyma, with eight air chambers separated by trabeculae.

The stele (Figure 19), centrally disposed, is surrounded by eight parenchyma cells. The conspicuous pericycle contains cells by different sizes. The conducting vessels are represented by central xylem and peripheral phloem.

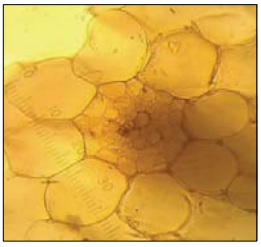

Figure 19. *Salvinia natans*: cross section of the leaf, showing the stele

The floating leaf has unistratified upper epidermis bearing groups of papillae and covered by a thin cuticle (Figure 20).

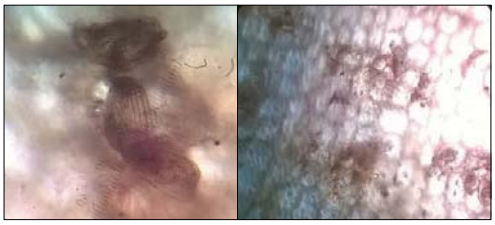

Figure 20. *Salvinia natans*: groups of papillae in the floating leaf

The cells of lower epidermis have corrugated cell walls and many-celled hairs (trichomes) with elongated cells, last of their cell being very sharp (Figures 21-22).

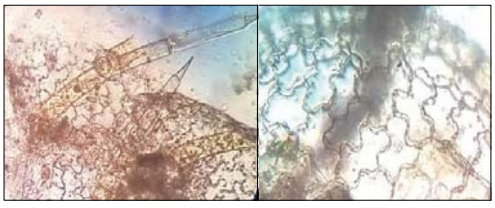

Figure 21. *Salvinia natans*: lower epidermis of the floating leaves showing the trichomes

The mesophyll presents intracellular large, hexagonal spaces, delimited by one row of cells (Figures 23). The conducted vessels are reduced, being surrounded by 11 cells of the mesophyll (Figure 24).

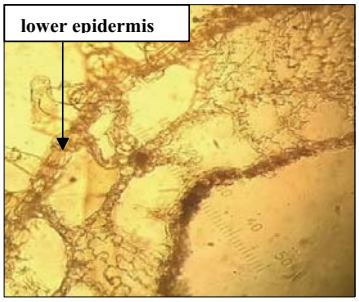

Figure 22. *Salvinia natans*: cross section of the floating leaf

Figure 23. *Salvinia natans*: intracellular spaces of the mesophyll

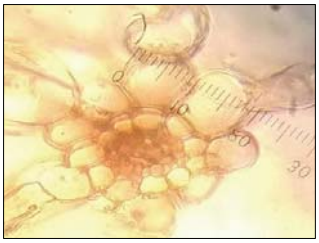

Figure 24. *Salvinia natans*: conducting vessels of the floating leaf

Cross sections made throughout all levels of the studied plants revealed some important adaptations for life in water. Thus, the submerged species like soft hornwort show a very thin cuticle, lack of roots and stomata, reduced xylem and large air-filled cavities. The numerous hairs of the floating fern leaf allow the plant to remain floating. On the other hand, marsh plants like celery-leaved buttercup have a tough xylem which enables resistance to winds and fluctuations in water levels.

CONCLUSIONS

As far as we know, the morpho-anatomical structures of *Ceratophyllum submersum*, *Lemna trisulca* and *Ranunculus sceleratus* were described for the first time in the Romanian scientific literature, highlighting the plant adaptation at aquatic environment.

In terms of *Salvinia natans*, we contributed to the knowledge of morpho-anatomical structure of this species, by analysing the cross sections of its leaves. The many-celled sharp hairs from the surface of the submerged leaves are very similar to those described in the petiole and lower epidermis of the floating leaves. No absorbent hairs or secondary roots were noticed; thus, the submerged leaves of the floating fern can not substitute a real root.

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