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STRUCTURAL PECULIARITIES OF VEGETATIVE ORGANS OF *SEMPERVIVUM TECTORUM L.* (CRASSULACEAE) AND *SALICORNIA EUROPAEA* L. (CHENOPODIACEAE) – RESIDENTS OF EXTREME HABITATS

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Anatomical-morphological characteristics of leaves and stems of plants of succulent type Sempervivum tectorum L. and Salicornia europaea L. from extreme habitats were studied. Basic quantitative parameters of anatomical indices were presented. The comparative analysis of the structure of vegetative organs of succulents was carried out. A number of common features, which result from adaptation to such conditions of growth (characteristic peculiarities of the external structure, weak differentiation of mesophyll, considerable development of the water-bearing tissue CAM – type of photosynthesis) and features, which distinguish the studied species (the type of leaf mesophyll, presence of trichomes, type of the stomata apparatus, the degree of the conductive system development) were registered.

Key words: anatomy, stem, leaf, plants of succulent type, extreme habitats.

СТРУКТУРНІ ОСОБЛИВОСТІ ВЕГЕТАТИВНИХ ОРГАНІВ *SEMPERVIVUM TECTORUM L.* (CRASSULACEAE) ТА *SALICORNIA EUROPAEA* L. (CHENOPODIACEAE) – МЕШКАНЦІВ ЕКСТРЕМАЛЬНИХ МІСЦЕЗРОСТАНЬ

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Вивчено анатомо - морфологічні характеристики листків та стебел рослин сукулентного типу Sempervivum tectorum L. та Salicornia europaea L. з екстремальних місцезростань. Представлено основні кількісні параметри анатомічних показників. Проведено порівняльний аналіз будови вегетативних органів сукулентів. Відмічено низку спільних ознак, які є результатом пристосування до подібних умов зростання (характерні особливості зовнішньої будови, слабка диференціація мезофілу, значний розвиток водоносної тканини, САМ – тип фотосинтезу) та ознаки, які відрізняють досліджувані види (тип мезофілу листка, наявність трихом, тип продихового апарату, ступінь розвитку провідної системи). Виявлено взаємозв'язок анатомічної будови з функціональною активністю рослин та умовами середовища існування.

Ключові слова: анатомія, стебло, листок, рослини сукулентного типу, екстремальні місцезростання.

СТРУКТУРНЫЕ ОСОБЕННОСТИ ВЕГЕТАТИВНЫХ ОРГАНОВ *SEMPERVIVUM TECTORUM* L. (CRASSULACEAE) И *SALICORNIA EUROPAEA* L. (CHENOPODIACEAE) – ЖИТЕЛЕЙ ЭКСТРЕМАЛЬНЫХ МЕСТООБИТАНИЙ

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Изучены анатомо – морфологические характеристики листьев и стеблей растений суккулентного типа, произрастающих в экстремальных условиях. Указаны основные количественные параметры исследованных показателей. Проведен сравнительный анализ строения вегетативных органов исследуемых видов и выявлена взаимосвязь анатомического строения с функциональной активностью растений и условиями среды обитания.

Ключевые слова: анатомия, стебель, лист, растения сукулентного типа, экстремальные местообитания.

Plants depend on the action of external ecological factors of the environment, including biotic ones. Conditions of the environment influence the habitus, structure and functional activity of plants. Among factors of the environment there are a lot of stressful ones, for instance, water deficiency and soil salinization [7].

Studying anatomical-morphological structure of plants of extreme habitats reveals the essence of adaptive mechanisms, which resistance of plant organism to the environmental conditions is based on.

Adaptation of plants occurs at different levels of their organisation due to complication of the internal structure. It is the structure of vegetative organs, in particular leaves, which is the feature that is widely used to evaluate interrelationship of plants and the environment [5].

Comparative anatomy of vegetative organs is an important source of cognition of regularities of the structural organisation of plants, its formation in onto- and phylogenesis, as well as represents essential addition to morphological-biological characteristics of species. This determines the relevance of such study, especially of representatives of those groups, which have not been studied completely enough, or differ in the internal structure of their organs from the majority of related taxa [1].

Quantitative characteristics of anatomical features of plants of extreme habitats, which are almost absent in literature, can be used in the solution of problems of evolution, impact of external conditions on different species and sorts, as well as in the solution of a variety of tasks not only in biology and agronomy but also in criminalistics and a number of branches of industry – food industry, pharmaceutical industry, etc. [9].

The aim of the work was to compare peculiarities of the anatomical-morphological structure of vegetative organs of plants of succulent type *Sempervivum tectorum* L. and *Salicornia europaea* L., which grew in extreme conditions.

Materials and research methods

In order to compare anatomical features of different as to their geographical origin plants, two species were studied: *S. tectorum* L. (Crassulaceae) and *S. europaea* L. (Chenopodiaceae), which belong to original ecological group – succulents. The first species is cultivated in botanical gardens and is grown as a decorative plant under conditions of water deficiency. The other dominates in flora complexes of the coastal zone of the Kuyalnik estuary and has adapted to drought and the high level of soil salinization quite successfully.

The coastal zone of the Kuyalnik estuary is characterised by chloride type of soil salinization. The content of easily soluble salts (NaCI, KCI, $MgCI_2$, $CaCI_2$) in the surface soil horizon in the summer-autumn period reaches 2.7% [11], which makes it possible to refer these soils to highly salinized and very highly salinized (salt marshes) in accordance with N.I.Bazylevych classification [2]. In addition, the Kuyalnik estuary belongs to medicinal water bodies with chloride-sodium mineral table water.

The material was collected during the vegetation season in 2014-2015. The research was carried out on fixed and live samples.

Temporary and permanent preparations were prepared in accordance with conventional methodology with application of different tissue dies [3].

The microscopic study of vegetative organs of *S. europaea* L. and *S. tectorum* L. was carried out by means of light microscopes "Biolam – 70, XSP – 104 (Russia) with ocular magnification x10 and objectives x4, x10 and x40. To carry out the quantitative analysis measurements of morphological-metric indices were performed by means of ocular-micrometer MOV-1-15. The results were processed by variation-statistical methods [10]. Microphotographs were made by means of photocamera Nikon.

Research results and their discussion

Peculiarities of the anatomical structure of *S. europaea* L. In accordance with the results of the research of some authors [6, 12], the cell sap of *S. europaea* includes a great number of chloride anions and sodium cations, which is the main ecological-physiological peculiarity of this species. This makes it possible for the plant to balance high osmotic pressure of soil solution and absorb water from the soil even under conditions of high salinization. Gradual accumulation of ions of easily soluble salts (Cl^- and Na^+) in organs of *S. europaea* L. during the vegetation period is balanced with the intensive growth and active accumulation of soil moisture by cells (development of the water-bearing parenchyma as succulence feature). Thus, great salt capacity and high ability to bear and use internal salinity were developed in *S. europaea* L. That is why this plant has characteristic peculiarities of external structure: leaves grew together with each other and with the stem into cylindrical succulent segments, which makes it possible to reduce the surface for the same volume.

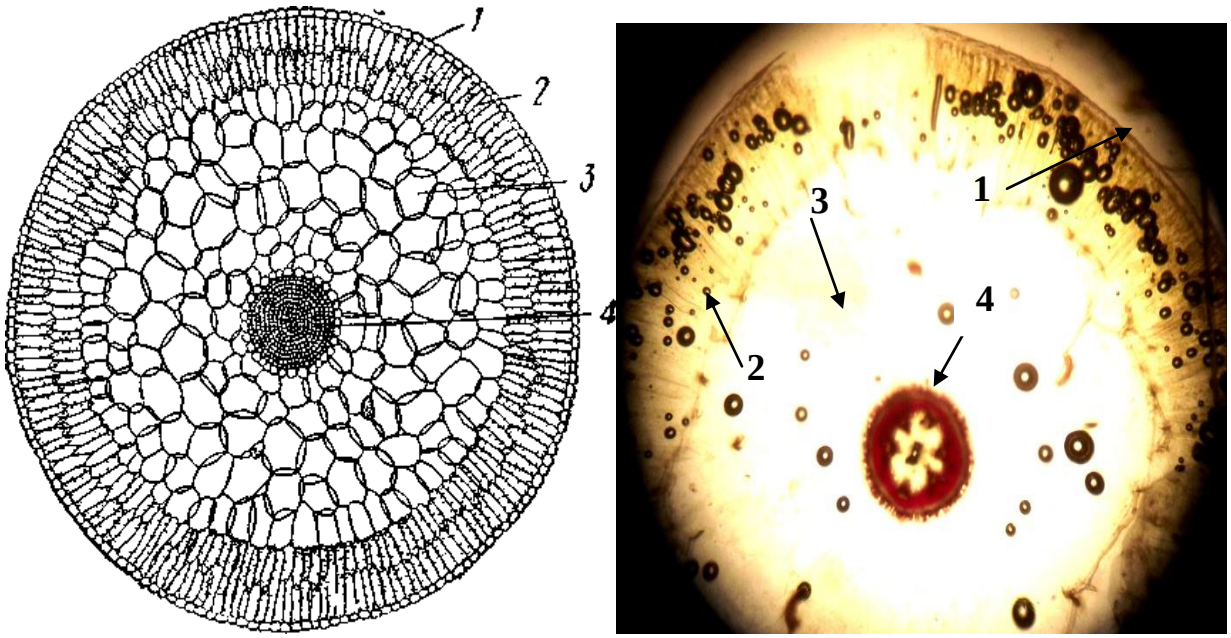
This also affected peculiarities of the internal structure of *S. europaea* L. Leaves and stems have similarity of the anatomical structure. The stem covering tissue does not have trichomes. The epidermis is single-layered (from 0.7±0.2 to 1.5±0.5 mcm) with the thin external wall and stomata apparatus which is not embedded into the epidermis. The type of stomata apparatus is anomocytic. The number of stomata varies from 25.2 ± 1.4 to 28.9 ± 0.6 per mm^2 (table 1.) and they are located randomly.

Table 1.

Quantitative-anatomical characteristics of the stem of *S. europaea* L.

Part of stem	Stem diameter, mcm	Thickness of epidermis, mcm	Number of stomata per 1 mm^2	Height of palisade tissue, mcm	Radius of water-storage tissue, mcm	Dimensions of idioblasts, mcm	Diameter of central cylinder, mcm
M ± m	M ± m	M ± m	M ± m	M ± m	M ± m	M ± m	M ± m
upper	2881.0 ± 10.5	0.7 ± 0.2	25.2 ± 1.4	400.2 ± 1.2	780.7 ± 6.8	21.6 ± 0.4	520.0 ± 8.5
middle	3234.3 ± 8.0	1.0 ± 0.4	27.3 ± 0.5	486.5 ± 4.6	860.0 ± 9.6	22.2 ± 0.1	540.3 ± 1.3
lower	3403.2 ± 9.3	1.5 ± 0.5	28.9 ± 0.6	520.0 ± 2.2	900.0 ± 12.3	23.0 ± 0.2	560.1 ± 4.6

The mesophyll is of radial type. The primary bark is composed of large thin-walled water-accumulating cells (fig. 1), the dimensions of which are mainly determined by the level of ecotope salinization. Thus, the radius of water-bearing tissue varies from 780.7 ± 6.8 to 900.0 ± 12.3 mcm. In water-bearing parenchyma around the central core schlerenchymal specialised reinforcing elements – idioblasts (21.6 ± 0.4 – 23.0 ± 0.2 mcm) are found.



А **Б**

Fig. 1. Transverse section of the stem of *S. europaea* L.: A – scheme of construction (in accordance with N. A. Ivanova, L. M. Muzychko, 2013); B – photograph. 1 – epidermis, 2 – palisade tissue, 3 – water-bearing tissue, 4 – central part with conductive bundle (magnification 10 x 4).

The internal parenchymal layer of the primary bark in the stem is undifferentiated. The stem has bundle structure. The perimedullary zone of the core is represented by parenchymal cells with an evenly thickened envelope. The central part includes a closed collateral vascular-fibrous bundle, which is characterised by presence of a chlorenchymal sheath. This probably reduces the level of transpiration intensity.

Thus, *S. europaea* L. has a succulence feature – 18-23% increase of the area of water-bearing parenchyma in comparison with the area of the palisade tissue.

Peculiarities of the anatomical structure of *S. tectorum* L. Leaf. Transverse section of leaf is crescent-shaped with concave upper and convex lower surfaces (fig.2).

Fig. 2. Transverse section of the leaf of *S. tectorum* L. (magnification 10 x 4): 1 – upper epidermis, 2 – lower epidermis; 3 – water-storing tissue.

The cuticle layer is rather thin. Leaves are covered with glandular hairs. The epidermis is single-layered, somewhat thickened from the lower side (to 30.0 ± 1.4 mcm) (table 2).

Leaves carry few randomly located stomata on both surfaces of leaves. However, the latter occur in greater quantity from the lower side (to 21.8 ± 0.5 per 1 mm^2). *S. tectorum* L. like the majority of Crassulaceae is characterised by anisocytic stomata apparatus with three subsidiary cells of different sizes (fig. 3). Leaf morphogenesis is typical of xerophytes.

Table 2.

Quantitative-anatomical characteristics of leaves of *S. tectorum* L.

Storeys of leaves	Thickness of lamina, mcm	Thickness of epidermis, mcm		Number of stomata per 1 mm^2		Thickness of mesophyll, mcm
		upper	lower	upper epidermis	lower epidermis	
M ± m	M ± m	M ± m	M ± m	M ± m	M ± m	M ± m
upper	2813.0 ± 1.9	23.2 ± 0.5	31.6 ± 0.4	18.3 ± 0.1	21.8 ± 0.5	2980.4 ± 10.4
middle	2739.2 ± 3.7	21.4 ± 2.1	31.0 ± 1.2	17.2 ± 1.7	20.6 ± 0.7	2890.1 ± 16.3
нижній	3700.0 ± 2.4	20.0 ± 0.6	30.0 ± 1.4	16.7 ± 0.2	18.9 ± 0.9	2800.0 ± 8.0

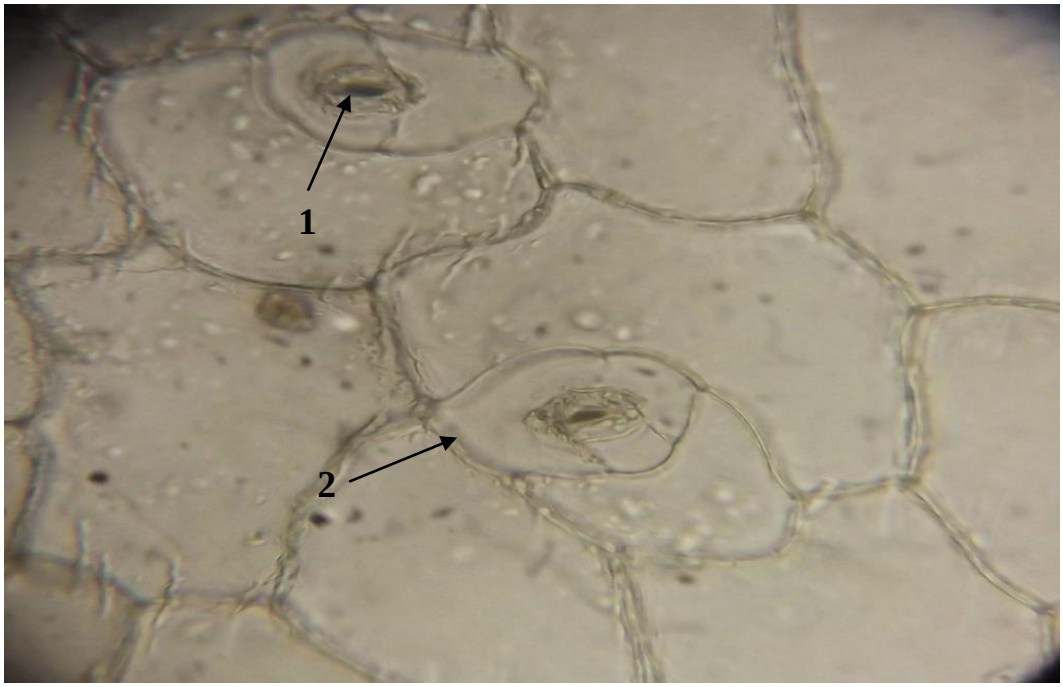


Fig. 3. Cells of epidermis of *S. tectorum* L. with stomata of anisocytic type (magnification 10 x 4): 1 –stomatal slit; 2 –subsidiary cells.

Isolateral mesophyll. Weak differentiation of mesophyll into columnar and spongy is a characteristic difference of the anatomical structure of leaves, which is also characteristic of the majority of Crassulaceae which have expressed succulent appearance. In the studied species mesophyll is represented by cells of palisade type (5-7 layers) (table 2). Intercellular spaces are rather big. Mesophyll density is not high, with mesophyll cells being located randomly in the central part of leaf. Specialised water-bearing tissues, as a rule, are absent, and the entire

parenchyma has a water-storing function. Mucilage-containing cells can be found in epidermis and mesophyll.

Conductive bundles are rather small, with parenchymal sheath around.

The stem is covered with single-layered epidermis with thickened cutinised external cells and is highly tomentous (fig. 4).

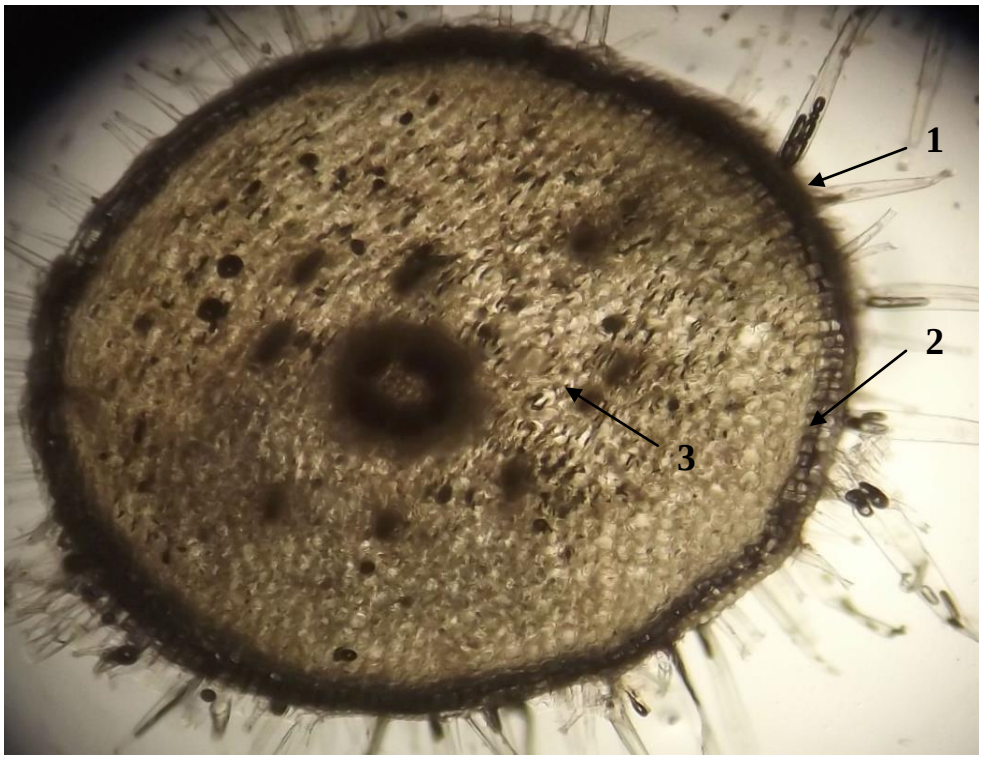


Fig. 4. Transverse section of the stem of *S. tectorum* L. (magnification 10 x 4): 1 – epidermis; 2 – cholenchyma; 3 – core parenchyma.

Well-developed bark, which almost completely consists of big parenchymal cells, which is typical of succulents, is a characteristic feature. In the peripheral part of the primary bark there are 1-2 layers of cells of cholenchyma which forms continuous cylinder. The number of cells of bark parenchyma varies from 17 to 22 (table 3). Numerous conductive bundles are located in main bark parenchyma. Each of them is surrounded by a layer of endodermis. Size of bundles varies in one and the same section. Weak development of phloem and xylem is one of characteristic features of the anatomical structure of stems of succulents [4, 8]. Primary conductive system has bundle structure. The secondary one belongs to circular type. The core is well-developed with its cells forming a cavity in the central part. So, both big-celled core parenchyma and bark stem parenchyma have water-storing function in *S. tectorum* L. Xymem, which preserved features of primary structure, favours the most effective redistribution and use of water.

Table 3.

Quantitative-anatomical characteristics of the stem of *S. tectorum* L.

Part of stem	Stem diameter, mcm	Thickness of epidermis, mcm	Collenchyma		Bark parenchyma	
			thickness, mcm	number of rows	thickness, mcm	number of rows
M ± m	M ± m	M ± m	M ± m		M ± m	
upper	1830.3 ± 16.9	28.7 ± 0.5	49.4 ± 0.9	1	721.3 ± 9.6	17
middle	1878.1 ± 8.0	29.0 ± 0.4	50.1 ± 0.7	2	740.0 ± 6.8	18
lower	1988.0 ± 14.8	30.3 ± 1.6	53.2 ± 2.3	2	780.2 ± 1.3	22

The species which we studied is mainly spread in arid regions with warm climate and is capable of special CAM – type of photosynthesis, which enables it to survive under conditions of water deficiency and high temperature stress. In addition, arrangement of leaves in rosette makes it possible for the latter to shadow the other ones and condense moisture near the stem base. However, it can be seen from our research that under conditions of temperate climate *S. tectorum* L. preserved the anatomical structure, typical of tropical representatives from xeric habitats.

CONCLUSIONS

Thus, comparison of peculiarities of the anatomical structure of stems and leaves of representatives of families Crassulaceae and Chenopodiaceae made it possible to identify in their structure both common features (characteristic peculiarities of the external structure, weak differentiation of mesophyll, considerable development of water-bearing tissue, CFV – type of photosynthesis) and features which differ the studied species (type of leaf mesophyll, presence of trichomes, type of stomata apparatus, degree of conductive system development), which obviously are an evolutionally fixed adaptation to extreme habitats. Plants *S. tectorum* L. and *S. europaea* L., studied by us, which respectively grow under conditions of drought and salinization, have similar survival strategy, which is manifested at all levels of organisation: morphological, anatomical and physiological.

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