Structure features of assimilative organs of the species *Salsola leptoclada* Gand. in the desert region of Uzbekistan

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Abstract: The article presents the results of the morpho-anatomical structure of the assimilation organs of the species Salsola leptoclada Gand, which is widespread in the Kyzylkum desert region of Uzbekistan, and reveals the structural, diagnostic and adaptive features. It was found that the leaf of species *Salsola leptoclada* has long multicellular nodular trichomes from the base to the tip and the absence of trichomes in the cotyledons. It was established that in the cotyledon and leaf the epidermal cells have a straight multifaceted protrusion, the presence of paracytic and hemiparacytic stomata in the epidermis in the cotyledon, and in the leaf - anomacytic and hemiparacytic type. A dorsiventral (*Aksiroid*) type of cotyledon mesophyll was found, and in the leaf there was a kranz-centric (*Salsoloid*) and a kranz-ventrodorsal type. The microscopic analysis of biometric indicators and anatomical characteristics of the cotyledons and leaves of the studied species *Salsola leptoclada* established the relationship between halomorphic and xeromorphic characteristics of assimilating organs, which prevail in arid conditions. These identified anatomical characters are explained by the predominance of halomorphic characters in the cotyledon mesophyll of xeromorphic characters in the leaf mesophyll.

1 Introduction

Genus of the *Salsola* L. is included in the cadastre of the flora of Uzbekistan of the Amaranthaceae family and information on the life form, ecology, distribution, and economic importance of each plant species is provided [1]. *Salsola leptocla* species M.M. Il'in [2] by *Aleuranthus* Iljin section in Flora of the USSR,. Section *Cardiantra* Aellin by V.P. Bochantsev [3], *Forcipitatae* Botch. included in subsection H. Akhani, G. Edwards, E.H. The species of *S. leptoclada* belonging to the genus *Salsola* by Roalson [4] *Caroxylon* Thunb. of the genus *Caroxylon turkestanicum* (Litw.) Akhani & E. H. Roalson listed as type. *S. leptoclada* Gand. The species is distributed in saline and sandy soils of Kyzylkum, Karakum, Amudarya, and Syrdarya regions of Iran, Leningrad, Central Asia [2], it is distributed in sandy and clay deserts, mountainous plains, saline lands, Kyzilkum, Lower Zaravshan,

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Karshi-Karnab deserts of the territory of Uzbekistan [1]. In halophytic and xerophytic plants belonging to the family Chenopodiaceae, 4 different structural-ecological groups are distinguished according to the characteristics of the adaptation of the anatomical features of the leaf mesophyll to thermo-helio-xeric conditions, the modification of the leaf mesophyll in the scleromorphic and succulent type [5, 6]. From our side, the species *Salsola paulsenii (Kali paulsenii)* belonging to the genus *Salsola* has kranz-centric (*Salsoloid*) mesophyll of seed cotyledon, kranz-centric (*Salsoloid*) and kranz-ventro-dorsal types of leaf mesophyll and according to the morpho-anatomical structure of the seed cotyledon of species *S. leptoclada* the of the seed cotyledon mesophyll dorsiventral (*Aksiroid*) type was determined [7]. Anatomical structure of the assimilative organs *S. leptoclada* was partially studied based on the information from the literature sources listed above. Identification of structural, diagnostic and adaptive features based on a comparative analysis of cotyledons and leaf mesophyll shows the relevance and scientific novelty of our research.

2 Materials and Methods

The object of research is *S. leptoclada* Gand, an annual herbaceous plant belonging to the genus *Salsola* L. of the Amaranthaceae family is a type. *S. leptoclada* is an annual, forage herb, branching from the base in a bushy form. The height is 10-35 cm, yellow-green, often the stem is reddish in color. The leaves are linear, short, widened at the base, arranged in a row on the stem. When the plant enters the generative stage, the leaves dry up and fall off. Petals are pinkish-black or reddish in color. Blossoms and bears fruit in July-August. The research was conducted in 2022-2024 in South-Western Kyzylkum region of Bukhara region. The species *S. leptoclada* was collected from salty sandy and sand-gravel soils, and herbarium specimens and fixation materials were prepared. For anatomical studies, cotyledons and leaves were fixed in 70% ethanol. The epidermis was studied using paradermal and transverse sections. Cross sections of the cotyledon and leaf are made through the middle. Descriptions of the main tissues and cells are given in accordance with classical methods [5, 8]. The measurements were carried out in 30-fold repetition with an eyepiece micrometer and converted to micrometers. Preparations prepared manually were stained with methylene blue and then sealed in glycerin-gelatin [9]. Descriptions of the main tissues and cells are given according to R.F. Evert [10]. Photomicrographs were made using a Bioblue S/N - EC 2209876 trinocular microscope. Statistical processing of the obtained data was performed in the OriginPro 7.5 program.

3 Results and Discussion

The cotyledon of *S. leptoclada* is lanceolate, 6-8 mm long, 0.5-1 mm wide. The outlines of epidermal cells on a paradermal section are rectilinear, the projection of epidermal cells is polygonal. The number of epidermal cells per surface unit (1 mm^2) is 561.9±1.59. Epidermal cells are a series of round-oval shaped cells with a height of 16.19±0.21 μm and consist of a thin-walled cuticle (3.77±0.06 μm) compared to the leaf. Cotyledons have an amphistomatic structure, stomata are found in the upper and lower epidermis. The stomata in the epidermis of the seed pod are round in shape, its length is 24.21±0.23 μm, its width is 24.22±0.24 μm, the number of 1 mm^2 is 162.39±1.08, and the connective cells in them are almost one found to have different lengths the stomata in the cotyledon are deep (7.45±0.079 μm) compared to the leaf. 2 different types of stomata were identified in the epiderma of the seed pod, of which the parasite type stomata predominated and were more numerous (77-80%), the hemiparasite type stomata were less numerous (20-23%) (Fig. 1, a). The type of *S. leptoclada* was determined to be dorsiventral (*Aksiroid*) type with cotyledon mesophyll [8]. Dorsiventral

(Axiroid) type cotyledon consists of 2 types of palisade and porous cells with mesophyll. In the upper epidermis of the cotyledon, there are palisade cells with 2-3 rows of chlorophyll, their length is 40.6±0.39 µm, width is 9.06±0.11 µm, index palisade is 4.48 µm. In the lower epidermis of the cotyledon there are 6-7 rows of pore cells with chlorophyll. Porous cells are thin-walled, round, oval, isodermic in shape, their diameter is 19.52±0.18 µm, thickness is 132.66±0.55 µm, and they make up 49.9% of cotyledosis mesophyll. It was found that C_3-type photosynthesis takes place in columnar and porous cells. The vascular bundles are closed collateral type and are located in the palisade and spongy cells in the central part of the cotyledon mesophyll. The xylem in the vascular bundle is small in size and larger in diameter compared to the leaf. The number of xylem vascular bundles is 8-9, its diameter is 6.26±0.06 µm (Fig. 1 b-e). The leaves of species *S. leptoclada* are sclerophyte, unbanded, annular, semicircular, 0.8-1 cm long, 1-1.5 mm wide, 0.5-1 mm thick, widened from the base to 2/3 of the leaf length, long covered with multicellular nodular hairs and arranged alternately on the stem. During the generative period, the leaves on the main stem dry out and fall off. Epidermal cells in the paradermal sections of S. leptoclada leaves are straight, the projection is multi-faceted, and its height is 14.28±0.26 µm. There are many long multicellular nodular trichomes in epidermal cells, the length of trichomes is 2151.45±17.16 µm, and these trichomes absorb water less in plant leaves in dry conditions performs the function of evaporation and protection (Fig. 2, b). The leaves of S. leptoclada have an amphistomatic structure, the stomata are round in shape and their length is 17.55±0.19 µm, width is 18.3±0.19 µm, and also slightly deep (3.3±0.08 µm).

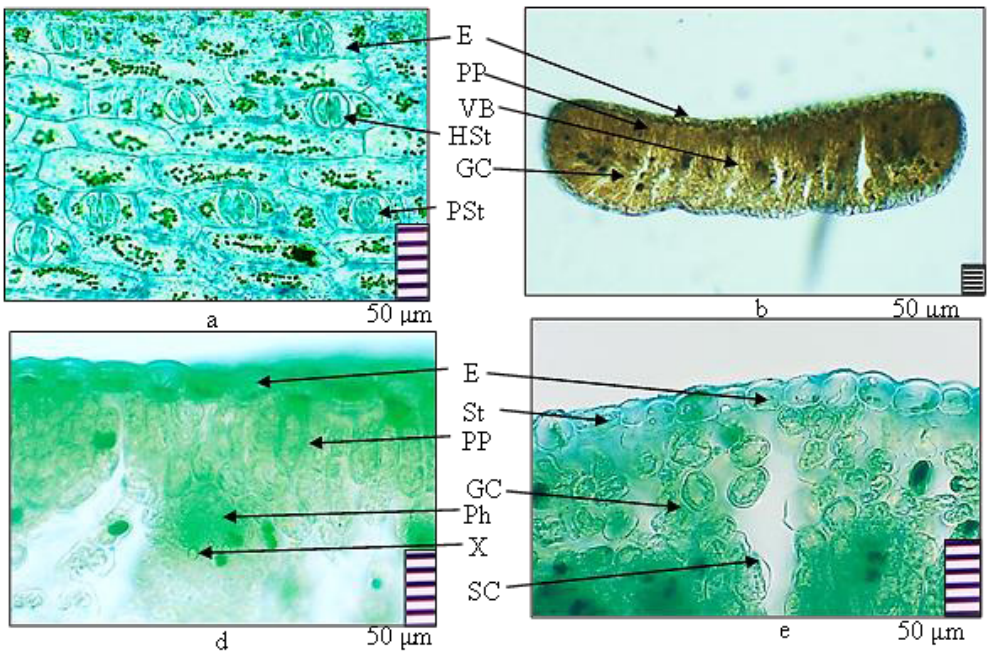

Fig. 1. Anatomical structure of cotyledon epidermis and mesophyll in *S. leptoclada*:a-epidermis, cotyledon stomata: hemiparasite and parasitic leaf stomata; b-e - epidermis, cotyledon stomata, palisade parenchyma, grieving cells and vascular bundles. **Conditional symbols:** ASt – anomocytic stoma, E – epidermis, GC – grieving cell, HSt – hemiparacytic leaf stoma, PSt – paracytic leaf stomata, Ph – phloem, PP – palisade parenchyma, St– stoma, X– xylem, VB– vascular bundles. SC– space between cells.

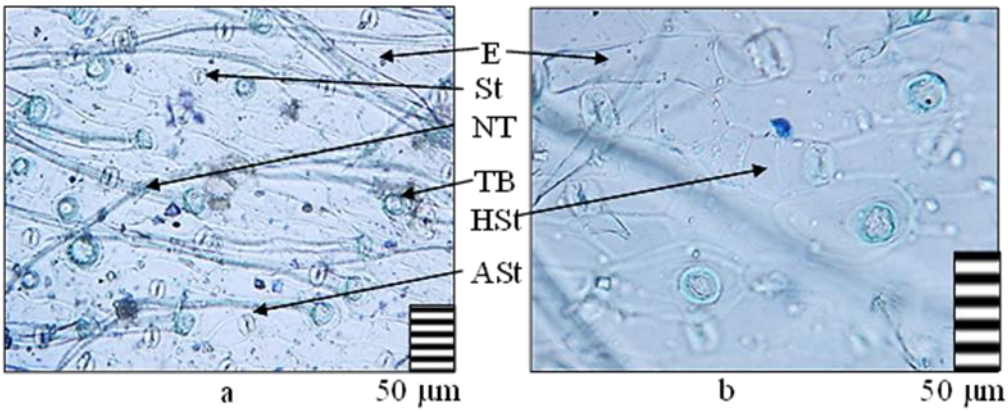

Fig. 2. Anatomical structure of *Salsola leptoclada* leaf epidermis in paradermal section: a - epidermis, leaf mouths, base of trichomes and nodular trichomes; b - hemiparasite-type leaf stomata in the epidermis. Conventional signs: ASt - anomacytic stomata, St - hemiparacytic stomata, E - epidermis, NT - nodular trichomes, TB - trichome base.

Two different types of stomata were found in the leaf epidermis, the predominance and large number of stomata of the anomicytic type - 79% and the small number of stomata of the hemiparacytic type - 21% were found (Figure 2, Table 1). The anatomical structure of the leaf mesophyll of *S. leptoclada* was carried out by making transverse serial sections of the leaf and 2 different types of leaf mesophyll were identified. Kranz-ventro-dorsal type leaf mesophylls were found in the base of the leaf mesophyll, and kranz-centric (*Salsoloid*) type leaf mesophylls were found from the tip to 2/3 of the leaf. It was found that C_4-type photosynthesis is carried out in columnar and kranz cells in the identified leaf mesophylls. The anatomical structure of the base of the leaf mesophyll is marked by the Kranz-ventro-dorsal type of leaf mesophyll (Fig. 3 a: 1-3). The height of the epidermal cell is 14.28±0.26 µm, and the thin-walled cuticle is 2.87±0.06 µm. Between the upper and lower epidermal cells are palisade parenchyma, kranz, water-retaining cells and vascular bundles. Palisade parenchyma cells of 1 row of oblong cells with chlorophyll grains were 32.05±0.48 µm long, 3.24±0.05 µm wide, index palisade - 9.89 µm (Fig. 3, Table 1).

Base of leaf mesophyll Kranz cells are the smallest with a diameter of 13.72±0.16 µm and have a cubic shape, vascular bundles of a closed collateral type and small xylem diameter 3.12±0.07 µm, and also direct vessels 10-11 with comparison from the mesophyll of cotyledons. The vascular bundles are sclerified due to the formation of multirow sclerenchymal cells and are associated with the scleromorphic kranz-ventro-dorsal and kranz-centric mesophyll of the leaf. Also in the mesophyll leaf there are numerous (23-26) peripheral vascular bundles that are adjacent to the kranz cell, the connection with this is the kranz-centric mesophyll leaf of the *Salsaloid* type (Fig. 3, 1-3).

The leaf of this species is succulent due to the most developed thin-walled, multirow and small-celled aquifer parenchyma with a diameter of 35.92±0.26 µm. There are 5-6 rows of water- bearing cells in the leaf mesophyll, their thickness is 900.1±12.48 µm, which makes up 71.8% and occupies the main part of leaf mesophyll. The presence of numerous monohedral crystals of calcium oxalate in the water-bearing cells of the leaf mesophyll was also discovered in the leaf mesophyll, with a comparison of the cotyledons that this species is a euhalophytic plant (Fig. 3, Table 1).

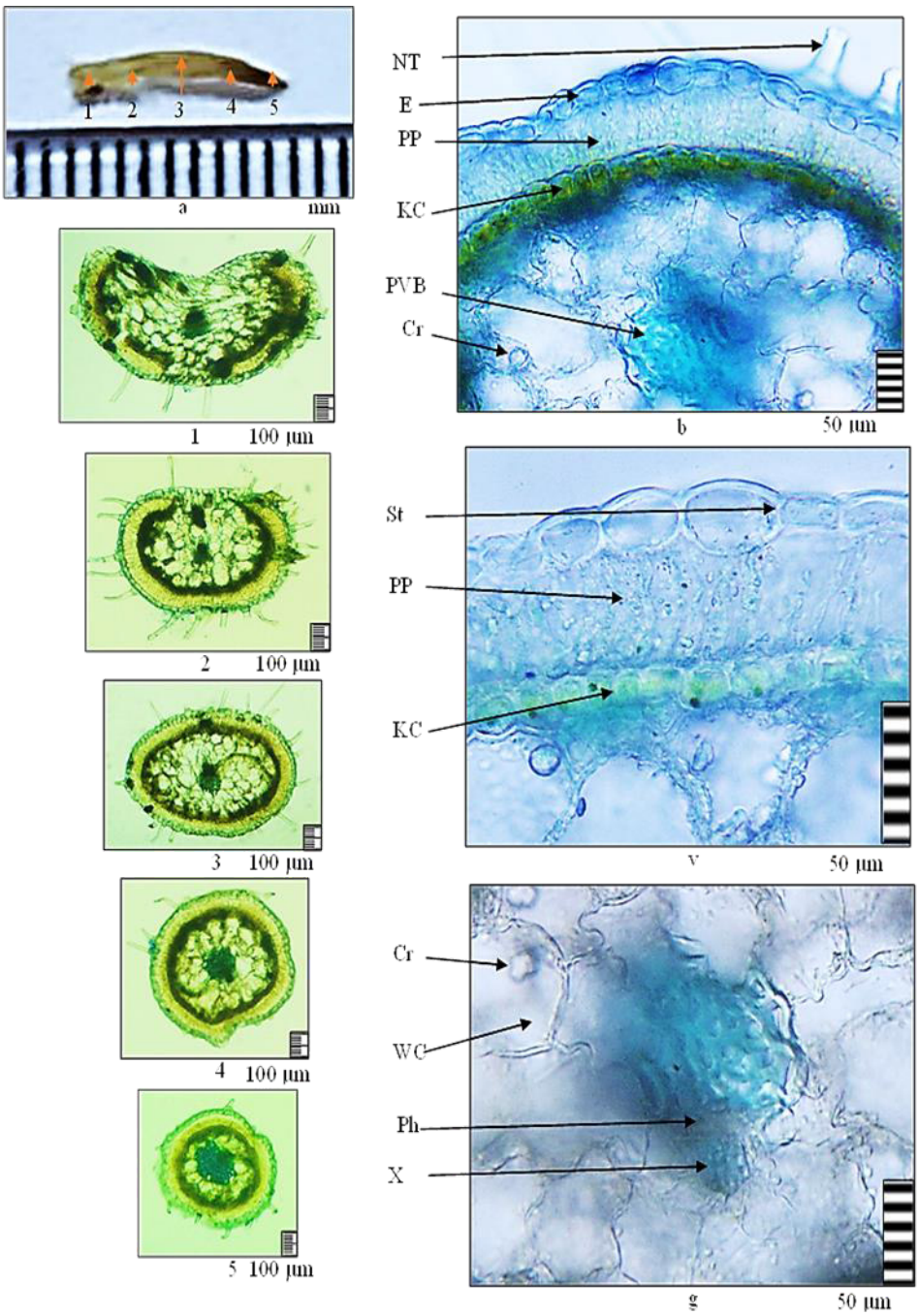

Figure 3. Anatomical structure of the mesophyll leaf of *Salsola leptoclada* in cross section:a - general view of a ring-shaped leaf; b – detail of leaf mesophyll; v - leaf stomata, palisade parenchyma and kranz cells in the rib-like part of the leaf; g - crustals, water storage cell and vascular bundles. Conditional signs: C - crustals, E - epidermis, KH - kranz cells, NT – nodular trichomes, PVB - peripheral vascular bundles, Ph – phloem, PP – palisade parenchyma, St - stomata, X – xylem, WC - water-bearing cell.

Table 1. Quantitative parameters of the assimilating organ of *Salsola leptoclada* species (n=30).

Indicator		Cotyledon	Leaf
Mesophyll thickness, µm		**265,7±1,12**	1253,5±9,53
Epidermis, µm**:** height		16,19±0,21	**14,28± 0,26**
thick. outside walls		**3,77±0,06**	2,87 ±0,06
number of epidermis 1 mm^2		561,9±1,59	**616,5±0,92**
Stomata, µm**:** length		24,21±0,23	**17,55±0,19**
width		24,22±0,24	**18,32±0,19**
number of stomata 1 mm2		**162,39±1,08**	143,51±0,96
stomatal density		**7,45±0,079**	3,3±0,078
anomocytic types		-	79 %
hemiparacytic types		20-23%	21 %
paracytic types		77-80%	-
Trichome length, µm		-	**2151,45±17,16**
Palisade parenchyma, µm:	height	40,6±0,39	**32,05±0,48**
	width	9,06±0,11	**3,24±0,048**
	palisade index	4,48	**9,89**
Water-bearing cell, µm:	thickness of layer	-	**900,1±12,47**
	diameter	**-**	**35,92± 0,26**
	row number	-	**6-7**
	% of d-list	-	**71,8**
Spongy cell, µm:	thickness of layer	132,66±0,55	-
	diameter	**19,52±0,18**	-
	row number	**6-7**	-
	% of d-cotyledon	49,9%	-
Diameter of the Kranz, µm		–	**13,72±0,16**
Number of peripheral vascular bundles on a cross section		8-9	**22-24**
Number of vessels in the main vascular bundles		8-9	**10-11**
Diameter of vessels		6,26±0,06	**3,12±0,070**

The microscopic analysis of biometric indicators and anatomical characteristics of the cotyledons and leaves of the studied species *Salsola leptoclada* established the relationship between halomorphic and xeromorphic characteristics of assimilating organs, which prevail in arid conditions. The following halomorphic features in the cotyledon mesophyll: epidermal cells are large and small; palisade parenchyma cells are large and index palisade is low; a small number of collateral-type vascular bundles was found. Xeromorphic features: thick-walled epidermal cells; numerous and submerged stomata of the paracytic type; small and numerous spongy cells; fine mesophyll thickness of cotyledons was determined.

These identified anatomical characters are explained by the predominance of halomorphic characters in the cotyledon mesophyll. In *Salsola leptoclada*, the halomorphic characters are - thickened leaf mesophyll; a few anomacytic and hemiparacytic types of stomata; thin-walled epidermal cell was determined. Xeromorphic signs - small and large number of epidermal cells; succulentness of leaf mesophyll; small and large number of water-retaining cells; the smallness of the palisade parenxyma cells and the height of the index palisade; a large number of collateral-type peripheral vascular bundles and a small diameter of xylem cells were determined.These identified anatomical characters are explained by the predominance of xeromorphic characters in the leaf mesophyll.

4 Conclusion

In short, anatomical structure of the assimilative organs of plants *Salsola leptoclada* distributed in the arid region of Uzbekistan was determined based on the diagnostic structural adaptive signs. The species *Salsola leptoclada* has a dorsiventral (*Aksiroid*) type of mesophyll in the seed cotyledon, and the presence of kranz-centric (*Salsoloid*) and kranz-ventro-dorsal mesophylls in the leaf mesophyll, the epidermal cell wall is linear and multifaceted, and the leaf epidermis is simple , presence and abundance of multicellular nodular trichomes, amphistomatic type of seed cotyledon and leaf mesophyll, presence of hemiparacytic and paracytic type seed cotyledon stomata in the seed coat epidermis, and presence of anomacyte and hemiparacyte type leaf stomata in the leaf, the closed collateral type of the vascular bundles in the cotyledon and leaf mesophyll, the presence of a large number of crystals in the water-bearing cells of the leaf mesophyll was determined. The predominance of halomorphic features in the seed mesophyll of plant *Salsola leptoclada*, and the predominance of xeromorphic features in the leaf mesophyll indicates that this species is well adapted to the arid region.

Authors' contribution

G.M. Duschanova and G.A. Ibrokhimova prepared the manuscript, executed, and interpreted, contributed to the concept and study design.

References

1. K.Sh. Todjibaev, N.Yu. Beshko, Kh.F. Shomurodov. Flora cadastre of Uzbekistan: Bukhara region (Publishing and printing creative house: O‘qituvchi, Tashkent, 98-100, 2020)

2. M.M. Ilin Genus *Salsola*. Flora of the USSR (In the 30 vol. Publishing: USSR Academy of Sciences, Moscow–Leningrad, 1936, Vol. 6, 224-254

3. V.P. Botcszantsev. Genus *Salsola* L.-concise history of its development and dispersal (in Russian). Bot. Jurn., **54**(7), 989-1001 (1969)

4. H. Akhani, G. Edwards, E.H. Roalson. Diversification of the Old World Salsoleae s.l. (*Chenopodiaceae*): Molecular Phylogenetic Analysis of Nuclear and Chloroplast Data Sets and Revised Classification. Int. J. Plant Sci., **168**(6), 931-956 (2007). https://doi.org/10.1007/s00606-010-0310-5

5. A.A. Butnik Adaptation of the anatomical structure of species of the family Chenopodiaceae Vent. to arid conditions.: Author's abstract. dis. doc. biol. sci. Tashkent, 52, 1984

6. G.M. Duschanova. Structural adaptation of the leaf to xero- and halofactors in some species of the genus *Climacoptera* Botsch. Acta Botanica Hungarica, **57**(1–2), 29-39, (2015). https://doi.org/10.1556/abot.57.2015.1-2.6.

7. A. Butnik, O.A. Ashurmetov, R.N. Nigmatova, G.F. Begbaeva Ecological anatomy of desert plants of Central Asia, Eds.: “Fan” Academy of Science of Uzbekistan Republic, 155. 2009

8. R.F. Evert Esau’s plant anatomy, meristems, cells, and tissues of the plant body: their structure, function, and development, 3rd edition. New Jersey: John Wiley & Sons Inc., 601. 2006

9. R.P. Barykina, T.D. Veselova, A.G. Devyatov et al. Handbook of botanical microtechnology (fundamentals and methods). Publishing house: Moscow State University, Moscow, 2004, 6-68

10. Evert R.F. Plant anatomy of Esau. Meristems, cells and tissues of plants: structure, functions and development. Binnom. Knowledge Laboratory, Moscow, 600 (2006) https://doi.org/10.1007/10.1093/aob/mcm015