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ANATOMICAL INDICATORS OF THE LEAF STRUCTURE OF *FERULA ILIENSIS*, GROWING IN THE EASTERN PART OF ZAILIYSKIY ALATAU (BIG BOGUTY MOUNTAINS)

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Abstract

Anatomical characteristics of *Ferula iliensis* leaf blades of different age from three different populations; growing in the eastern part of Zaliliyskiy Alatay (Big Boguty Mountains, Kazakhstan); were analyzed. In all the plants from investigated populations a single type of blade formation and xero-mesomorphic structure was determined. The planar polarity of the blade showed multilayer of palisade mesophyll, a characteristic for all plants. Most of the covering hairs on the pubescent leaves are located on the lower side of the blades. The leaf type in general is xero-mesomorphic. The differences are mainly of quantitative character and are related to the environmental conditions of the plants. The leaf structure reflects the result of plant adaptation to various environmental factors, so the information on the leaf structure complements the environmental characteristics of the plants and improves the idea of its range of plasticity.

Key words: Umbelliferae, *Ferula iliensis*, Narrow endemics, Xeromesomaphic leaf type.

Introduction

Ferula genus occupies a noticeable place in the rich and diverse flora of Central Asia and Kazakhstan among the extensive Umbelliferae. There is a high endemism among the representatives of this genus (40 species), with a significant number of narrow endemics which are known only from the local type. Of particular concern is a narrow endemic from Dzungarian Alatau foothills (the southern slope of Mount Ulken Kalkan, Chulak) and the Zailiyskiy Alatau (northern slope, Small Boguty and Syugaty Mountains), *Ferula iliensis* Krasn. ex Korov,– a plant widely used medicinally by the local population and in need of protection (Buras *et al*., 2012; Mukhitdinov *et al*., 1996; Ydyrys *et al*., 2013; Begenov *et al*., 2014).

A complex approach is required in the study of the ecological-cenotical features of such endemic and rare plants which need protection (Ozturk *et al*., 2004, 2008; Uysal *et al*., 2011). The effective use of environmental resources and the normal plant development are provided by their morphological and anatomical structures.

The dependence of the morphological and anatomical structures of the vegetative organs of plants on their living environment is well known and fully stressed in many studies (Vardar & Ozturk, 1973; Ozturk & Szaniawiski, 1981; Uysal & Ozturk, 1991; Schönenberger *et al*., 2012; Isnard *et al*., 2012).

Particularly clear correlations with ecological factors are typical for anatomical leaf characteristics (Goryshina *et al*. 1992; David, 1985; Sagaram *et al*., 2007). Many researchers cite the leaf as a primary indicator in the study of the degree of stability and adaptability of plants, due to its main functions - photosynthesis and transpiration (Vardar & Ozturk, 1972, 1975; Nicholaevsky, 1979; Ozturk *et al*., 1983; Neverova, 2009; Kurbatova *et al*., 2003).

The leaf structure reflects the result of plant adaptation to various environmental factors, and therefore information on the leaf structure complements the environmental characteristics of plants and improves the idea of its range of plasticity (Ozturk & Vardar, 1973; Ergasheva, 2011; Lana *et al*., 2002).

Materials and Methods

During the expedition, three populations of *Ferula iliensis* Krasn. Ex Korovin were found in the Big Boguty Mountains (the eastern part of Zailiyskiy Alatau). The study of the cenotic population and the measurement age of the population was done using traditional method (Rabotnov, 1978; Uranov 1973).

The anatomical structure of plants was studied using standard methods (Barykina, 2004). A comparative analysis of the internal structure of the blades from the plants of three different populations differing in ages was given. Common terminology was used when describing the leaf structure (Lotova *et al*., 2007; Evert *et al*., 2006; Dickison, 2000; Cutler *et al*., 2009; Beck, 2005; Mauseth, 2008).

The first population occupied a hollow wide gorge. The terrain was a gently sloping plain covered with light brown soil, slightly gravelly and humidity was normal. Vegetation was represented by a saltwort-ferrule-sagebrush aggregation. The cover was 60-65 percent. It mainly comprised of *Ferula iliensis*, *Salsola orientalis* S.G. Gmel., *Kochia prostrata* (L.) Schrad., *Comphorosma lessingii* Litv., *Krascheninnikovia ceratoides* (L.) Gueldenst.

The second population occupied the largest area. In the centre was dry river bed with a water flow only in the spring. The terrain was a gently sloping plain, the soil was light-brown and slightly gravelly and humidity was normal. Vegetation was represented by a bush-ferrule-sagebrush aggregation. The cover was 65-75 percent with the predominant plants as *Kochia prostrata* (L.) Schrad., *Artemisia sublessingiana* Krasch. ex Poljak., *Krascheninnikovia ceratoides* (L.) Gueldenst., *Stipa* sp. and others.

The third population was on a plateau-like hill. The terrain was slightly sloping plain and humidity was normal. The soil was light-brown and slightly gravelly. Vegetation was represented by a saltwort-ferrule-sagebrush aggregation. The cover was 55-60 percent. The predominant plants included *Artemisia sublessingiana* Krasch. ex Poljak., *Stipa* sp., *Nanophyton erinaceum* (Pall.) Bge., *Ceratocarpus utriculocus* Bluk., *Ferula iliensis*.

Results and Discussion

Anatomical structure of the *F. iliensis* blade (juvenile plants): The outer blade of the *F. iliensis* is covered with an epidermis with a small amount of a cover of hairs. Epidermal cells are elongated in tangential direction: their width is much greater than their height.

Mesophyll has thin-walled cells of chlorenchyma, located between the upper and lower epidermis. Mesophyll consists of two or three layers of palisade (columnar) cells elongated perpendicularly to the upper and lower epidermis.

Conducting bundles are collateral, closed, located in a row across the thickness of the blade. In the centre is a large vascular bundle and there are small vascular bundles on each side to the thickness of palisade mesophyll. The whole system of vascular bundles has a sclerenchyma covering. The mechanical tissue is most pronounced at the base of a large midrib near the lower epidermis (Fig. 1).

While studying the morphometric parameters of the internal structure of *F. iliensis* blades of different populations it was found that plants from population 1 have the thickest blade and the thickness of the upper epidermal cells far exceeds the size of the epidermal cells of plants of other populations. In juvenile plants from population 2 palisade mesophyll cells are the most elongated, and the thickness is much greater than the corresponding figures for plants from plant populations 1 and 3. This population has also well developed mechanical and conductive tissue in comparison with the other two studied populations (Table 1).

Anatomical structure of the *F. iliensis* blade (immature plants): Epidermal cells of the *F. iliensis* blades are arranged in a tight row with no intercellular space. The outer walls of the epidermis are covered with a thin layer of cuticle. There are unicellular covering hairs.

The entire thickness of the blade is filled with parenchymatous cells of assimilating tissue. The mesophyll - palisade consists of several layers of cells, elongated perpendicularly to the top and bottom of the blade.

Small vascular bundles are more or less completely immersed in the mesophyll, and a large vascular bundle is accompanied by a spine on the bottom of leaf. The vascular bundles are surrounded by a single layer of tightly packed cells, forming a mechanical cover of conductive tissues (Fig. 2).

The plants from population 1 have the thickest blade in comparison with the other two populations. The increase in the average thickness of epidermal cells of the blade top and bottom, the size of the palisade parenchyma, the sclerenchyma thickness and the diameter of the conducting tissues contribute to an overall increase in the blade's thickness. The two other studied populations have no significant difference in the relevant indicators of their leaf structure (Table 2).

Anatomical structure of the *F. iliensis* blade (juvenile generative plants): Most of the epidermal cells of the *F. iliensis* blade are packed in tightly and covered with a thin layer of cuticle which reduces water loss. There is a cover of trichomes.

The blade is filled with palisade mesophyll cells - the basic leaf tissue with numerous chloroplasts. In the palisade parenchyma the cells have a columnar shape with long axies at right angles to both the upper and lower epidermis.

The mesophyll of the leaf is thick with numerous vascular bundles or veins directly connected to the culm conducting system. The largest (central) vascular bundle runs along the axis of the leaf in the place where surrounding basic and mechanical tissues overhang the bottom surface like a crest. The vascular bundle contains xylem and phloem. Xylem is on the top of the leaf, the phloem is on the bottom (Fig. 3).

While studying the morphometric parameters of the internal blade structure of *F. iliensis* of three different populations it was found that the average thickness of the upper and lower epidermis cells do not significantly differ. The epidermal cells of the upper and lower sides of the epidermis are of almost the same thickness.

However, it should be noted that juvenile generative plants of population 2 have the thickest blade, and thus thicker layers of palisade parenchyma. In these plants the thickness and multilayers of the blade are the greatest. The diameter of the vascular bundles is also much greater than the corresponding figure for plants from population 1. *F. iliensis* juvenile generative plants of population 1 have a thin blade, the size of which depends on the location and plant growth conditions (Table 3).

Table 1. Morphometric parameters of *Ferula iliensis* blade (juvenile plants).

Population	The blade thickness, micron	Epidermis thickness, micron		Palisade mesophyll thickness, micron	Sclerenchyma thickness, micron	Conducting bundle diameter, micron
		Upper	Lower			
1	143, 55 ± 4, 30	12, 10 ± 1, 33	11, 95 ± 1, 03	58, 23 ± 3, 52	44, 40 ± 3, 23	45, 68 ± 3, 22
2	133, 65 ± 4, 73	10, 14 ± 2, 73	12, 73 ± 1, 56	71, 53 ± 4, 53	57, 81 ± 2, 03	53, 23 ± 3, 87
3	100, 64 ± 5, 73	10, 12 ± 1, 21	10, 04 ± 1, 16	58,77 ± 2, 45	49, 95 ± 2, 43	45, 33 ± 2, 34

Table 2. Morphometric parameters of *Ferula iliensis* blade (immature plants).

Population	The blade thickness, micron	Epidermis thickness, micron		Palisade mesophyll thickness, micron	Sclerenchyma thickness, micron	Conducting bundle diameter, micron
		Upper	Lower			
1	172, 83 ± 4, 83	13, 35 ± 2, 98	14, 34 ± 2, 43	88, 22 ± 5, 92	76, 39 ± 3, 14	66, 07 ± 3, 01
2	169, 01 ± 3, 12	12, 22 ± 2, 29	13, 55 ± 2, 77	73, 92 ± 4, 74	66, 75 ± 3, 61	63, 15 ± 2, 38
3	146, 62 ± 3, 28	11, 85 ± 1, 64	13, 85 ± 2, 73	67, 96 ± 2, 53	74, 83 ± 4, 56	56, 49 ± 2, 93

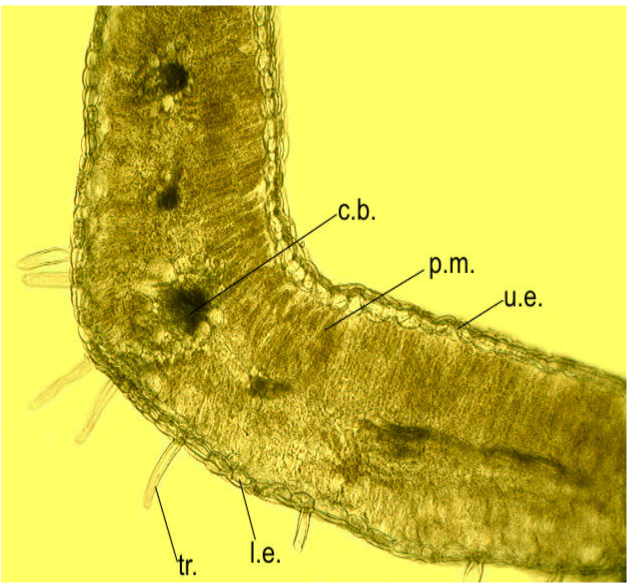

Fig. 1. Anatomical structure of the *F.iliensis* blade (juvenile plants).
u.e. – upper epidermis, l.e. – lower epidermis, tr. – trichomes, p.m. – palisade mesophyll, scl. – sclerenchyma, c.b. - conducting bundle

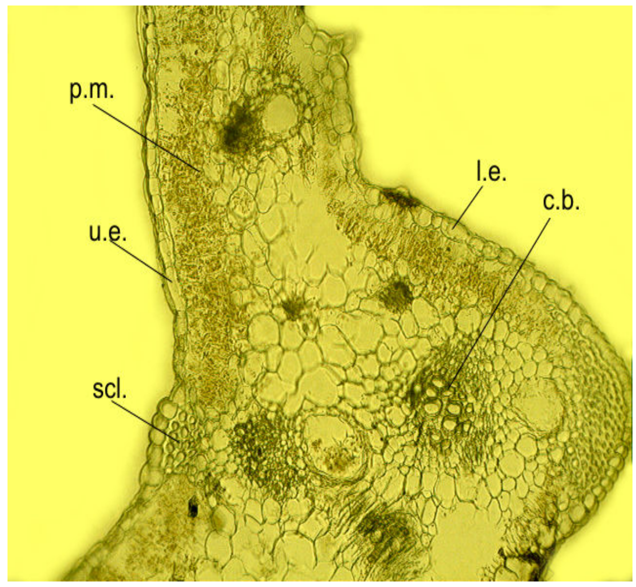

Fig. 3. Anatomical structure of the *F. iliensis* blade (juvenile generative plants).
u.e. – upper epidermis, l.e. – lower epidermis, tr. – trichomes, p.m. – palisade mesophyll, scl. – sclerenchyma, c.b. - conducting bundle

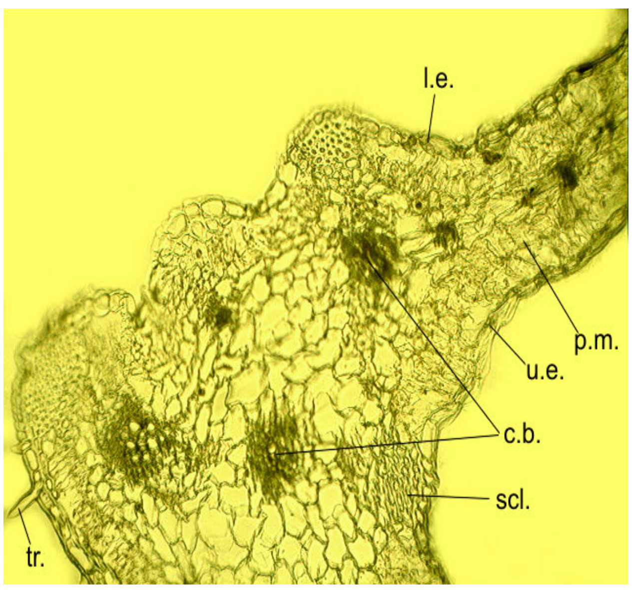

Fig. 2. Anatomical structure of the *F. iliensis* blade (immature plants).
u.e. – upper epidermis, l.e. – lower epidermis, tr. – trichomes, p.m. – palisade mesophyll, scl. – sclerenchyma, c.b. - conducting bundle

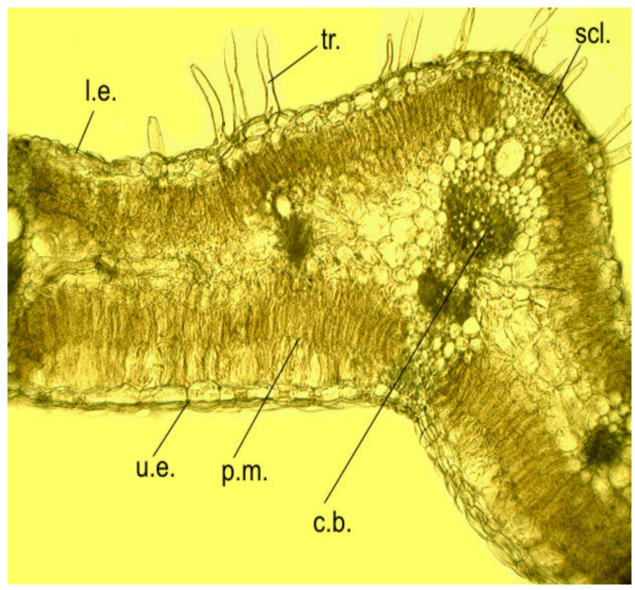

Fig. 4. Anatomical structure of the *F. iliensis* blade (mature generative plants).
u.e. – upper epidermis, l.e. – lower epidermis, tr. – trichomes, p.m. – palisade mesophyll, scl. – sclerenchyma, c.b. - conducting bundle

Anatomical structure of the *F. iliensis* blade (mature generative plants): The *F. iliensis* leaves are covered with epidermis outside, the outer walls of which are covered with a thin layer of cuticle. There is a cover of trichomes. The mesophyll occupies all the space between the upper and lower epidermis. Palisade mesophyll cells are fairly uniform in shape - slightly elongated perpendicularly to the epidermis and forming several layers. The palisade tissue thickness varies in plants of different populations depending on the location of their growth. In the mature generative plants of population 2 the mesophyll is more developed compared to the tissue of two other populations. Xylem and phloem are combined in closed (without cambium) collateral vascular bundles. Xylem is turned towards the top, and the phloem to the bottom of the leaf (Fig. 4).

An analysis of the morphometric parameters of the internal structure of the *F. iliensis* blades of the studied populations showed that plants of population 2 have the most xeromorphous characteristics (maximum thickness and multilayers of the blade, the elongated form of palisade parenchyma cells, a strong epidermis cutinization), which is related to the environmental conditions of populations. Also, there is a strong development of mechanical tissue and vascular bundles in comparison with the plants of the population 1 and 3 (Table 4).

Table 3. Morphometric parameters of the *F. iliensis* blade (juvenile generative plants).

Population	The blade thickness, micron	Epidermis thickness, micron		Palisade mesophyll thickness, micron	Sclerenchyma thickness, micron	Conducting bundle diameter, micron
		Upper	Lower			
1	196, 95 ± 3, 87	11, 54 ± 2, 42	12, 56 ± 2, 36	78, 23 ± 5, 63	73, 81 ± 4, 35	45, 93 ± 3, 82
2	216, 94 ± 5, 24	12, 15 ± 2, 33	13, 43 ± 3, 39	88, 46 ± 3, 74	74, 57 ± 5, 04	68, 65 ± 4, 52
3	200, 13 ± 5, 82	12, 66 ± 1, 67	12, 11 ± 2, 48	83, 56 ± 5, 98	82, 76 ± 6, 63	63, 74 ± 4, 95

Table 4. Anatomical structure of the *F. iliensis* blade (ephebic generative plants).

Population	The blade thickness, micron	Epidermis thickness, micron		Palisade mesophyll thickness, micron	Sclerenchyma thickness, micron	Conducting bundle diameter, micron
		Upper	Lower			
1	204, 65 ± 5, 48	12, 34 ± 2, 24	11, 54 ± 1, 68	89, 16± 4, 82	77, 75 ± 4, 16	58, 93 ± 4, 94
2	219, 35 ± 6, 19	13, 26 ± 2, 78	12, 93 ± 2, 13	102, 86 ± 5, 40	104, 14 ± 6, 52	88, 95 ± 5, 59
3	193, 95 ± 5, 32	12, 97 ± 2, 82	11, 7 3± 1, 78	96, 82 ± 5, 12	89, 74 ± 5, 69	68, 63 ± 4, 42

On the basis of studies conducted by us on the anatomical structure of the *F. iliensis* blades of different ages, taken from different populations, and the analysis of morphometric data, the following conclusions can be drawn:

1. A comparison of the anatomical structure of the *F. iliensis* blades of different ages and of different populations showed they had a strong resemblance. The planar polarity of the blade multilayer of palisade mesophyll is characteristic for all plants. Most of the covering hairs of the leaves are located on the lower side of the blades, which can be attributed to the environmental conditions of the plants.
2. Plants of *F. iliensis* of different ages growing in different populations are generally characterised by a xeromesomorphic leaf type.
3. In the blades of juvenile plants of the population 3 well-developed closed collateral vascular bundles are found, formed by the best opened xylem vessels providing the best conduction of water and dissolved substances, as xylem provides an ascending stream of substances from the underground section of the plant to the surface section.
4. The increase in the average thickness of epidermal cells of the upper and lower side of the blade, the size of the palisade parenchyma, the sclerenchyma thickness and the diameter of the conducting tissues, all facilitate an overall increase in the thickness of the blade in immature plants of population 1.
5. The most xeromorphic features (maximum thickness and multilayers of the blade, the elongated form of the palisade parenchyma cells, a strong epidermis cutinization) are seen in the juvenile generative plants of population 2.
6. The blades of mature generative plants of population 2 are distinguished by a strong epidermis cutinization, maximum thickness of the blade, the multilayer palisade parenchyma, and the strong development of mechanical tissue - sclerenchyma, as well as maximum vascular bundle size.

The characteristics of the full life cycle of *F. iliensis* relate it to the monocarps, i.e., plants flowering once at the very end of their life cycle and die after fruiting. *F. iliensis* is in flower and fruit in the 7-9th year of life (Safina, 2012). Because of the limitations and diffusivity of its distribution, its small population and its monocarp characteristics, this valuable species needs increased protection, and work needs to be carried out on its cultivation.

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