GLASNIK INSTITUTA ZA BOTANIKU I BOTANIČKE BAŠTE UNIVERZITETA U BEOGRADU
BULLETIN DE L'INSTITUT ET DU JARDIN BOTANIQUES DE L'UNIVERSITE DE BEOGRAD
Tom XXIV-XXV, 1990-1991 (1993), Beograd

UDC: 581.522.5 : 582.683.2
Original scientific paper

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MORPHO-ANATOMICAL ADAPTATIONS OF ENDEMIC SPECIES FIBIGIA TRIQUETRA (DC.) BOISS. (BRASSICACEAE)

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Damjanović, O. and Stevanović, B. (1990-1991): *Morpho – anatomical adaptations of endemic species Fibigia triquetra (DC.) Boiss. (Brassicaceae).* – Glasnik Instituta za botaniku i botaničke bašte Univerziteta u Beogradu, Tom XXIV – XXV, 9 – 19, 1990-1991.

Fibigia triquetra is steno-endemic relic plant distributed in the area of Mid-Dalmatia, Mediterranean region. The morpho-anatomical features of leaves and whole-plant growth form were analysed in order to elucidate the structural characteristics of its adaptive mechanism. These investigations provided more data on the relic plant performance thus allowing the adequate approach to its protection under presently prevailing disturbed environmental conditions.

Key words: endemite, relic plant, morpho-anatomical adaptations, *Fibigia triquetra,* Mediterranean area.
Ključne reči: endemična vrsta, reliktna biljka, morfoanatomske adaptacije, *Fibigia triquetra,* Mediteranska oblast.

INTRODUCTION

The Balkan Peninsula is distinguished by the large number of endemic plants (1754 species according to T u r r i l, W.B. 1929). In this respect Mediterranean region

of the Balkans is of particular interest. Here, the presence of the great number of endemic plants results from the existence of isolated topographic entities such as islands and coastal high mountains. Paleoendemic species such as *Degenia velebitica* (Deg.) Hayek, *Pancicia serbica* Vis. (Lakušić, R. & Grbelja, J. 1969), *Amphoricarpus neumayeri* Vis. (Blečić, V. & Mayer, E. 1967), *Fibigia triquetra* (DC.) Boiss, *Satureja horvatii* Šilić (Šilić, Č. 1974), *Edraianthus pumilio* (Portenschl.) DC., (Lakušić, R. 1973) and others have been persisting in this region from the Tertiary Age thus confirming, by their chorological characteristics and conservative ecomorphism, the ecological constraints of the Balkan endemism.

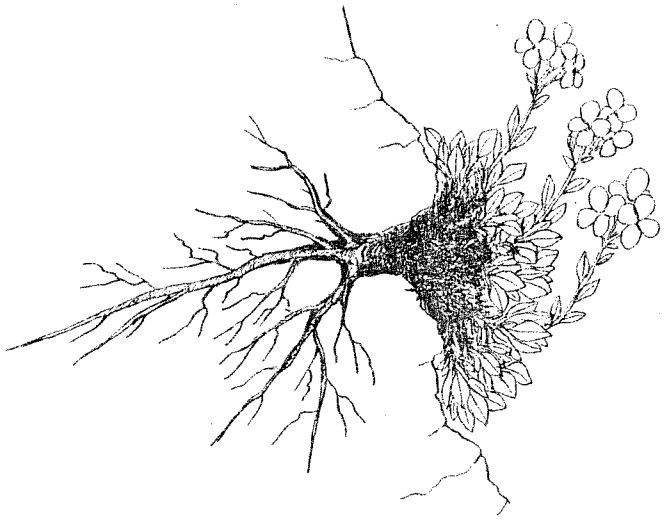

Fig. 1. – *Fibigia triquetra* on limestone crevicies.

Semi-shruby *chamaephyta suffruticosa Fibigia triquetra* is stenoendemic species of Mid-Dalmatian region (Fig. 1). It is distributed in 12 spatially close localities, 7 of which are situated along the massifs of Mt. Biokovo, at the Adriatic coast, whereas the other are on the Peninsula of Pelješac and on the isles of Hvar and Brač (Fig. 2). The greatest part of its microdisjunctive range extends narrowly along the Mediterranean montane fragment of Mid-Dalmatia, where Adriatic-Mediterranen climate prevails. The plant is obligate calciphyte, inhabits steep limestone, along the slope gradient of 200-1100 m above the see level. It is very rare on screes i.e. it is found only on the locality of Vrulje at the foot of Mt. Biokovo (Mayer, E. 1981). Its microhabitats are limestones characterized by very low soil water content, great temperature fluctuations and intense radiation regime.

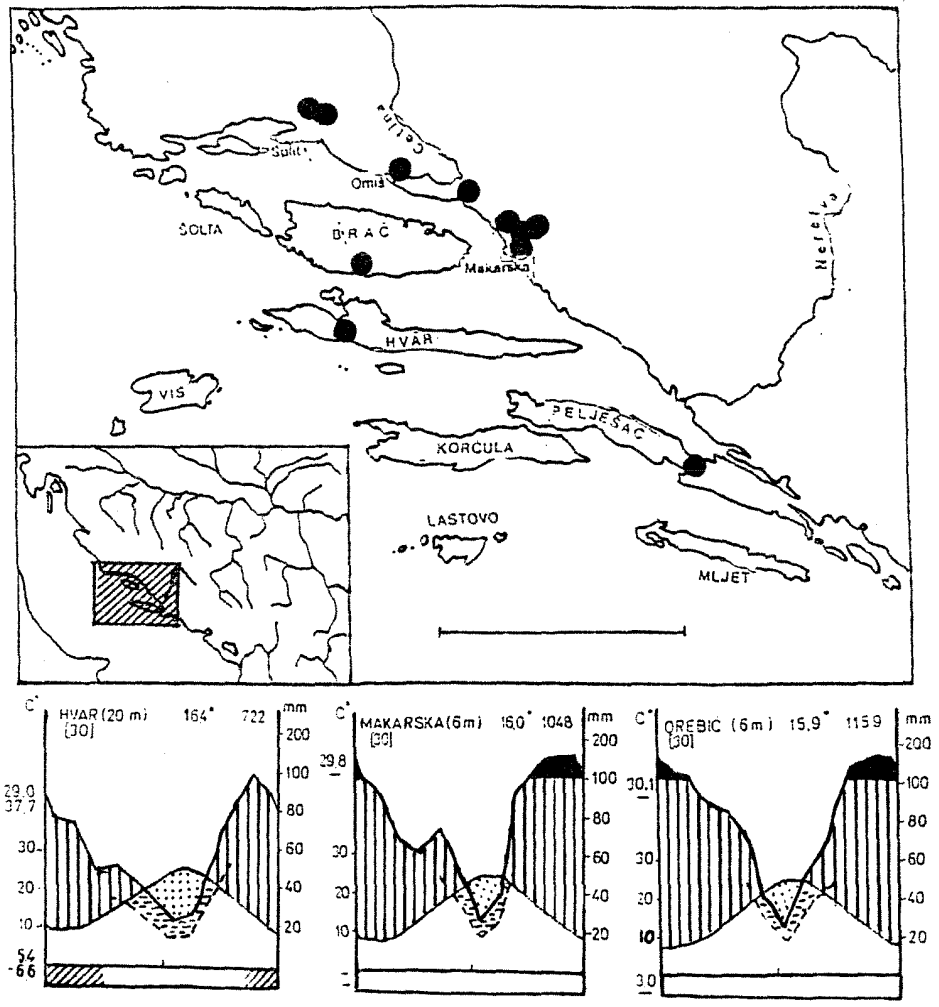

Fig. 2. – Distribution of the species *F. triqetra* including the climatic diagrams of some of its localities.

Extreme ecological conditions of the habitat influenced the pattern of morpho-anatomical adaptations, both at the level of organism, and at the level of some organs, tissues and cells.

Bearing this in mind the objective of our work was to analyse morpho-anatomical characteristics of leaves and to establish basic eco-morphological adaptive strategies of this species.

MATERIAL AND METHODS

Morpho-anatomical adaptations of the species *F. triquetra* were studied on fresh, fixed in FAA (formalin-acetic alcohol) material as well as on herbarium specimens (The Herbarium of Botanical Garden in Belgrade). The plants were collected on the locality of Klis, near Split, at the altitude of 130 m.

The hairs, epidermal cells and stomata were analysed both by light microscopy (on hand cut slides) and by SEM.

Herbarium leaves were silver coated and hairs and stomata from the upper and lower leaf surface were observed by SEM (JOEL JSM-35).

The permanent slides were made by the standard method (Chamberlain, C. 1931; Prozina, M.N. 1956; Jensen, V.N. 1962). The plant material was fixed in the Navashin fixative. Sections (15 μm thick) were cut on sliding microtome, deparaffined and stained with safranin-fast green combination. The thickness of lamina, mesophyll, palisade and spongy tissues were determined. Besides, the width and lenght of cells in the upper and lower leaf epidermis were measured.

Quantitative data obtained were also statistically computed according to Statgraph 4.2.

RESULTS AND DISCUSSION

Genus *Fibigia* Medicus belongs to the family of *Brassicaceae* trib. *Alysseae* subtrib. *Alyssinea* (Janchen, E. 1942). In European flora the four following species of the genus *Fibigia Medicus* were reported: *Fibigia clypeata* (L.) Medicus, *Fibigia eriocarpa* (DC) Boiss., *Fibigia lunarioides* (Willd.) Sibth & Sm and *Fibigia triquetra* (Dc.) Boiss. (Ball, W.P., 1964).

The species *Fibigia triquetra* is a semi-shrub which may be 5-20 cm high. Young stems are herbaceous, circular in cross section. Older stems, when lignified, are triangle like. These characteristics of the stem were reported as early as in 1829 by Visiani.

F. triquetra is common on massive, vertical limestones and cliffs, mostly on northern slopes. Its microhabitats are deep or shallow crevices of the northwest facing outcrops. In these habitats the radiation regime is intense even when due to difuse light the conditions of so called „blue" shade prevail, given that the light is reflected from the surrounding, radiant limestone. This plant is fixed to the rocky ground, through extensive tap root, which provides water transport even under the most unfavourable environmental conditions.

The ability of this plant to adapt to stressful conditions of the habitats, i.e. to extreme microclimatic conditions, at places with undeveloped soil, are reflected in its growth form (*chamaephyta suffruticosa*). Namely, this semi-woody plant has shortened internodes, ever-green, tough tiny leaves, which are linear, lancet-like and slightly

inwardly folded. The upper and lower leaf surfaces are covered with dense, silvery-grey indumentum, composed of dendritic stellate-like, dichotomously brached hairs. This indumentum represents a significantly efficient heliomorphic and xeromorphic protection since it covers not only the leaves but also the shoots, flower stems and silicles.

Tab. 1. – Anatomical features of the species F. triqetra on cross section in μm.

	Mean	Min.-max.	Variance	Std.deviation
Leaf Thickness	388.5 ± 10.07	284 – 437	1826.7	42.74
Mesophyll Thickness	366.6 ± 10.4	260 – 400	1964.5	44.32
upper Pallisade Tissue	133.5 ± 3.4	116 – 166	213.9	14.62
lower Spongy Tissue	113.4 ± 4.8	70 – 147	428.9	20.71
lengh Upper Epidermis	100.6 ± 7.86	69 – 156	1113.0	33.36
width	21 ± 0.94	13.65 – 30.45	15.95	3.99
lengh Lower Epidermis	29.4 ± 1.39	16.8 – 44.1	35.15	5.92
width	18 ± 0.66	13.65 – 23.1	8.07	2.84
	26 ± 1.04	15.75 – 33.6	19.78	4.44

The leaves are 18-62 mm long, 5-11 mm wide and 284-437 μm thick. Such microphyllous leaves, whose leaf area/thickness ratio is decreased, reduce transpiration rate and represent an important evolutive-adaptive response of the plant to the conditions of environmental water deficit.

The upper and lower epidermis are single layered, and the cells are equal in size (Tab. 1). The inner tangential and lateral walls of epidermal cells are thickened, whereas their cuticle is moderately developed.

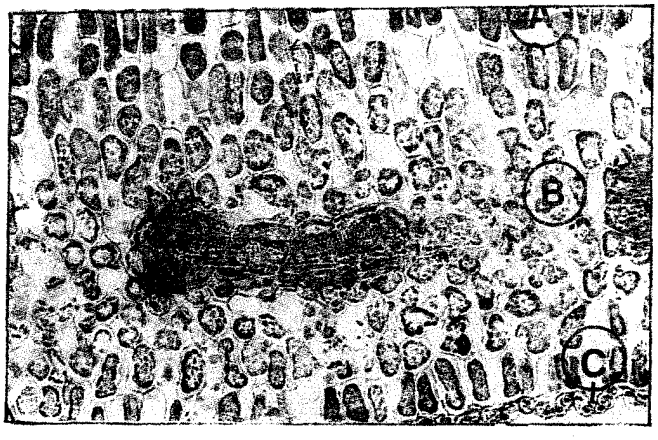

Fig. 3. – Cross section of leaf of *F. triqetra:* A – pallisade tissue, B – spongy tissue, C – stomata.

The arrangement, size and number of stomata on the leaves are typical of xerophyte. Namely, they are very tiny and densly distributed whereby the upper leaf surface is covered with 172 stomata/mm^2, and the lower with about 214 stomata/mm^2 of leaf area.

Dense hairs form a thick protective boundary layer (still air), which enables that stomata either level with the epidermal cells or are even raised. Besides, this layer reduces the movement of water i.e. minimizes transpiration rate.

The leaves of *F. triquetra* are isobilateral, which is striking characteristic of xeromorphic structure. Palisade tissue is multilayered both on the upper and lower leaf surface (Fig. 3). It is composed of relatively tiny, typically elongated, markedly compact cells between which are very small intercellular spaces. Such a structure increases the toughness of the leaves, provides a considerably more efficient water transport and photosythetical light utilization (G i v n i s h, T.J. 1986). The thickness of palisade tissue on the upper leaf surface (116-166 μm) is slightly greater than that of the lower surface(70-147 μm) (Tab. 1). A considerable number of chloroplasts are primarily on transversal cellular walls of palisade cells.

Spongy tissue is weakly developed and is situated in the midmesophyll i.e. between palisade tissue of the upper and that of the lower leaf epidermis. The cells of spongy tissue are tiny, round, and arranged in several irregular rows the total thickness of which is 69-156 mm.

The ratio between mesophyll tissues, palisade to spongy parenchyma, is 3:1, which indicates a markedly xeromorphic structure of the leaves (Fig. 4 and Fig. 5).

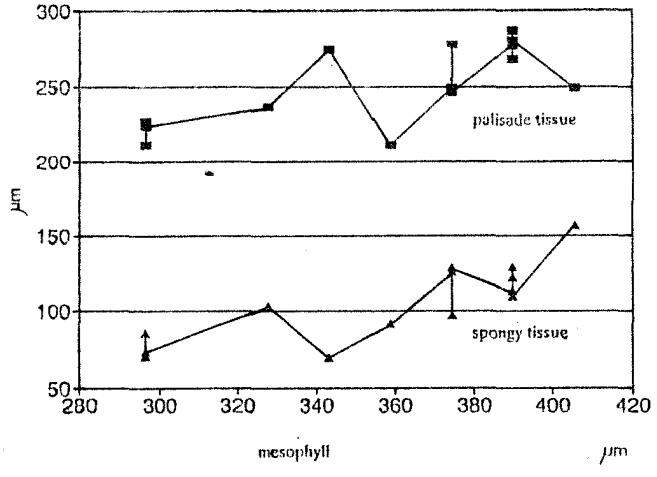

Fig. 4. – Thickness of pallisade and spongy tissue in relation to overall mesophyll.

The most clearly expressed and the most efficient adaptive feature of the species *F. triquetra* is silvery-grey, dense indumentum composed of dendritic stellate, large, tough, dichotomously branched hairs which cover all above ground parts of the plant.

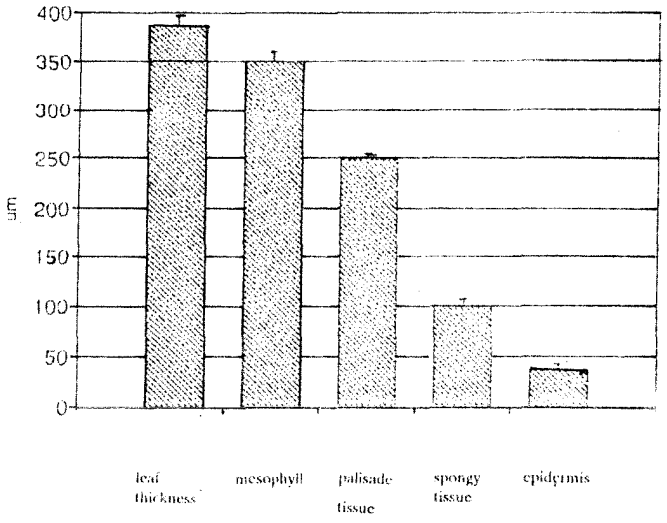

Fig. 5. – Thickness of leaf tissues (bars represent means).

Functional value of this indumentum is multiple. It reflects light from the leaf surface (light filter); decreases warming of the leaf tissues (thermal insulator); prevents excessive transpiration (adaptation to drought conditions of the habitat). General morphology of the hairs on the upper and lower leaf surface is more or less identical. From the large, slightly raised basic epidermal cell, radiate stellate hair arms (Fig. 6). These arms branch dichotomously once, twice and rarely three times. The ripe base cell has lignified walls.

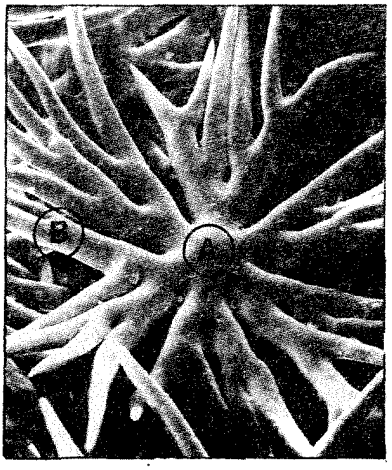

Fig. 6. – Leaf hairs (SEM): A – basic epidermal cell, B – stellate hair arms, x 400.

Hair arms bear parallel elliptic, warty cuticular micropapillae. Our experiments did not support the assumption that these micropapillae are calcium carbonate deposits originating from the adjacent rocks. On the hairs of the upper leaf surface these micropapillae are faint, sparse, and distanced from each other (Fig. 7). They are much more numerous and dense on the lower leaf surface (Fig. 7).

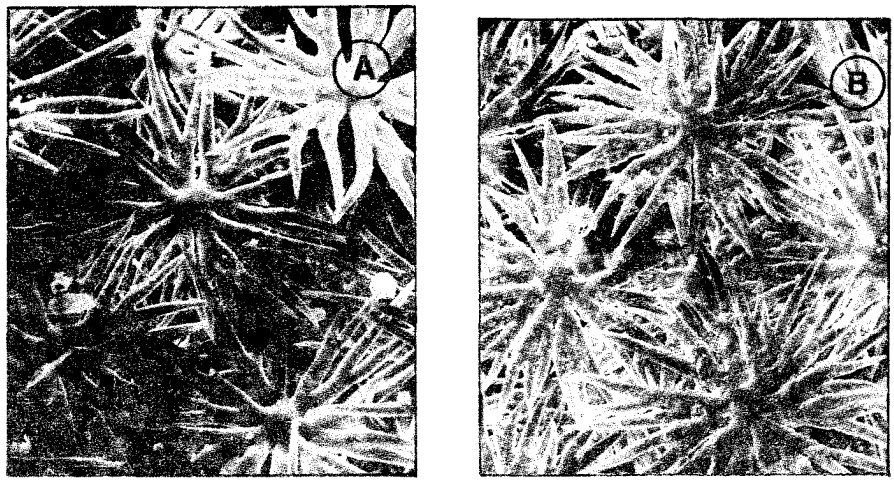

Fig. 7. – Leaf hairs (SEM): A – on the upper leaf surface, B – on the lower leaf surface, x 200.

In addition to differences in general morphology between hairs of the upper and lower epidermis, there are also differences in the appearance of the basic cell as well as in the length and width of the arm. Namely, on the upper leaf surface the basic cell has the elongated „neck" whereas on the lower surface this „neck" is thick, short and faint. Dichotomously branched arms of the hair on the upper epidermis are elongated and clearly separated from each other. However, more compact, thicker and shorter hair arms on the lower epidermis, clinging to each other with their internal sides, are almost fused.

Indumentum on the upper and lower leaf surface is distinguished by dichotomously branched hairs, which vary in size. They are distributed in several longitudinal rows and overlap with their arms. In this away the complex spatial structure of indumentum is formed.

The leaf pubescence affects the distribution of stomata in the way that they are most numerous close to the base cell of the hair. Actually, stomata are surrounded and protected by „umbrellas" composed of the hair arms and by cuticular micropapillae (Fig. 8).

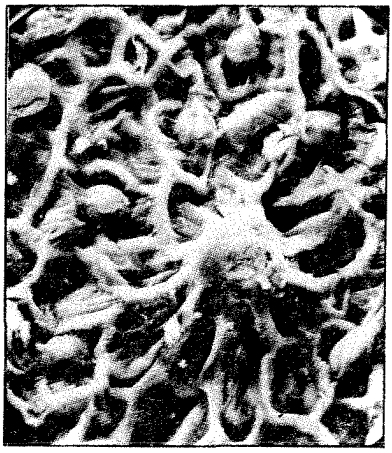

Fig. 8. – Stomata surrounded and protected by "umbrellas" composed of hairs and arms and by cuticular micropapilae (SEM), x 600.

The general growth form and individual anatomical features of the species *F. triquetra* show the adaptive response of the plant to multiple environmental stress. The plant responds to high temperature, long spans of seasonal drought, stony ground, with poorly developed soil, thanks to short shruby habit, tap root and tiny xeromorphic leaves. Due to the preserved structural characteristics and physiological adaptations, this plant secured longevity, over geological time, and survival on the particular type of mediterranean habitat.

CONCLUSION

The species *Fibigia triquetra* (DC) Boiss. is paleo and stenoendemic plant of the Tertiary Age, occupying a narrow area of Mid Dalmatia, Mediterranean region.

It is characterized by an array of heliomorphic and xeromorphic adaptations: tap root, low shruby growth form, stem with the shortened internodes, tiny tough leaves. Stem and leaves are covered with dense silvery – grey indumentum. Tiny leaves are of isobilateral structure, with multiple palisade tissue, both on the upper and lower leaf surface. The dominance of the palisade to spongy parenchyma, and the dense hairy covering are the most significant xeromorphic features of this plant.

Owing to these morpho-anatomical features and its life from (*chamaephyta suffruticosa*) it is capable to utilize economically and efficiently scarce resources of the mediterranean environment: insufficient water supply, especially during summer hot spans, on limestone habitat with poorly developed soil. In this way this old, tertiary plant has been adapted to presently prevailing conditions of its habitat, which is nowadays endangered by human impact.

ACKNOWLEDGEMENTS

This work is supported by the Serbian Fund of Science; Grant No. 0321.

The authors thank Mr.M. Bokorov for SEM micrographs, Mrs Ljiljana Jovanović for technical assistance, and Mr. Ognjen Glišić for statistical analysis. We also extend our thanks to Mrs Danka Filipović for translating the paper.

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Rezime

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MORFO-ANATOMSKE ADAPTACIJE ENDEMIČNE VRSTE FIBIGIA TRIQUETRA (DC.) BOISS. (BRASSICACEAE)

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Endemične biljke su uvek izazov, ali su od posebnog interesa u ekološkim istraživanjima, bilo zbog jedinstvenog rešenja načina života, bilo zbog, često urgentne, potrebe njihove zaštite u savremenim uslovima sredine. Vrsta *Fibigia triquetra* (DC) Boiss. je paleo i stenoendemit, biljka tercijerne starosti i uskog areala na srednjedalmatinskom području u Mediteranu.

Vrsta *Fibigia triquetra* odlikuje se nizom heliomorfno-kseromorfnih karakteristika: snažnim i dubokim korenom, niskom žbunastom formom nadzemnog dela biljke, stablom sa skraćenim internodijama, sitnim listovima. Stablo i listovi prekriveni su gustim srebrnastim dlakavim indumentumom. Sitni listovi su izobilateralne građe, sa višeslojnim palisadnim tkivom i na licu i na naličju lista. Odnos osnovnih tkiva mezofila je 3:1, što je značajna kseromorfna odlika biljke.

Heliomorfno-kseromorfne adaptacije i životna forma *chamaephyta suff.* vrste *F. triquetra* obezbeđuju opstanak ovoj paleoendemičnoj biljci. Na osnovu njih ona je u mogućnosti da štedljivo i efikasno iskorišćava oskudne resurse spoljašnje sredine: nedovoljnu količinu vode, naročito u toplom periodu godine, na kamenitom staništu sa slabo razvijenim zemljištem. Na taj način ova stara tercijerna biljka prilagođena je savremenim uslovima staništa.