

## MORPHO-ANATOMICAL DIFFERENTIATION OF THE BALKAN ENDEMIC SPECIES *TEUCRIUM ARDUINI* L. (LAMIACEAE)

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**Abstract** — *Teucrium arduini* L. is an endemic of the Mediterranean to sub-Mediterranean part of the Western Balkans. The ecological plasticity, i.e., inter-population differentiation, of the species *Teucrium arduini* was analyzed on the basis of morpho-anatomical variability of six populations from different types of vegetation, i.e., of rocky crevices, rocky ground, and a thermophilous forest in the eu-Mediterranean, sub-Mediterranean, and transitional sub-Mediterranean-Central-European climate zones. Univariate statistical analysis included 22 quantitative characters related to leaf and stem anatomy and morphology. In order to establish the variability and significance of morpho-anatomical differentiation, principal component analyses (PCA), multivariate analyses of variances (MANOVA), and discriminant components analysis (DCA) were done. The analyses of plants from these spatially separated populations confirmed that the species *T. arduini* belongs to the category of xerophytes with malacophyllous leaves.

**Key words:** Lamiaceae, *Teucrium arduini*, endemic species, leaf anatomy, stem anatomy, Balkan Peninsula

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### INTRODUCTION

*Teucrium arduini* L. is a Mediterranean endemic plant with restricted range in the Western Balkans, distributed along the Adriatic Coast from the Istra Peninsula in Croatia in the north to Albania in the south (Fig. 1). It belongs to the category of regional endemic species of the Mediterranean flora, more than 50% of which consist of Circum-Mediterranean vascular flora with more than 25000 species and subspecies in total (Quezel, 1985; Greuter, 1991). The floristic richness of the Mediterranean Basin is primarily due to its unique climatic diversity and habitat heterogeneity, historical factors, and different origins of the flora itself (Quezel, 1995). Thus, populations of *T. arduini* mainly grow in localities with Mediterranean (Adriatic Mediterranean) and sub-Mediterranean. However, some isolated populations inhabit limestone canyons and gorges in the transitional sub-Mediterranean-Central-European climatic zone with strong Mediterranean influence.

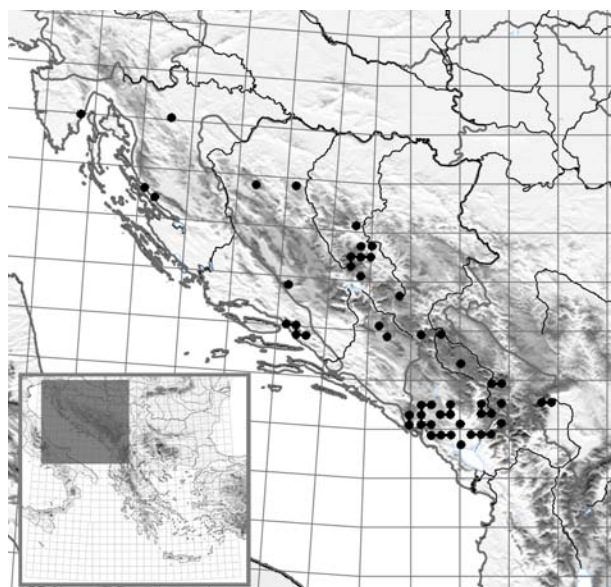


Fig. 1. Map of distribution of *Teucrium arduini* L.

*T. arduini* is a branchy, semi-woody deciduous dwarf shrub 10 to 30 cm (and sometimes up to 60 cm) high whose life form is that of a suffruticose

**Table 1.** Ecological characteristics of habitats of the analyzed populations.

Localities	Biogeography	Vegetation	Substratum	Altitude	Average annual temperature (°C)	Average January temperature (°C)	Annual precipitation (mm)
Risan (Montenegro)	Adriatic province of eu-Mediterranean region	Rocky crevices ( <i>Asplenietea rupestris</i> )	limestone	10 m	15-16	7-8	1300-2300
Mt. Lovćen, near Njeguši (Montenegro)	Adriatic province of eu-Mediterranean region	Rocky ground ( <i>Festuco-Brometea</i> )	limestone	800 m	10-16	1-5	1500-3100
Canyon of the Cijevna, (Montenegro)	Adriatic province of sub-Mediterranean region	Rocky ground ( <i>Festuco-Brometea</i> )	limestone	80 m	10-16	1-5	1500-3100
Canyon of the Morača (Montenegro)	Adriatic province of sub-Mediterranean region	Rocky crevices ( <i>Asplenietea rupestris</i> )	limestone	200 m	10-16	1-5	1500-3100
Canyon of the Komarnica (Montenegro)	Illyrian province of Central-Europaeen	Termophyllous forest ( <i>Seslerio autumnalis-Ostryetum</i> )	limestone	1100 m	9-12	-1.3-0	800-1000
Rugovo Gorge (Serbia)	Illyrian province of Central-Europaeen	Rocky crevices ( <i>Asplenietea rupestris</i> )	limestone	700 m	9-12	-1.3-0	800-1000

chamaephyte. The species belongs to the subfamily *Ajugoideae* Kostel (Harley et al., 2004), and section *Stachyobotrys* Benth (Tutin and Wood, 1972; Kästner, 1978), and in Europe it has a single relative *T. lamiifolium* D'Urv (including *T. cordifolium* Čelak), which is distributed in Asia Minor and the eastern part of the Balkans.

The species grows only on calcareous rocks, on rocky outcrops, and in ravines, at altitudes between 0 m and 1400 m. The majority of populations are recorded in zones between 10 and 200 m, and between 600 and 1000 m. Generally, the species follows the distribution of sub-Mediterranean forest and shrub vegetation of the alliance *Ostryo-Carpinion* Ht. 1954. Moreover, *T. arduini* is a characteristic species of the endemic Adriatic order *Moltkeoetalia petraeae* Lakušić 1967, (*Asplenietea*

*trichomanes* Br.-Bl. 1934) (Lakušić, 2000).

On the territory involved in the present study (Montenegro and Serbia), six distinctly separate populations of *T. arduini* developing under different bioclimatic and commonly occurring environmental conditions were analysed in order to establish the relation between habitat particularities and inter-population differentiation of this endemic plant. One of the six populations studied inhabits a perhumid region with Adriatic Mediterranean climate on the Bay of Kotor near Risan (Montenegro) at an altitude of 10 m. Two populations inhabit the sub-Mediterranean hinterland, in the canyons of the Cijevna and Morača Rivers (Montenegro) at 80 and 200 m, respectively. The supra-Mediterranean population near Njeguši on Mt. Lovćen (Montenegro) grows at 800 m under conditions of a perhumid

sub-Mediterranean Adriatic climate. The last two populations exist in the Komarnica (Montenegro) and Rugovo (Serbia) inland canyons at 1100 and 700 m, respectively, markedly distant from the main range of this species in the Adriatic Mediterranean region. These localities are situated in the transitional sub-Mediterranean-Central-European climate zone (Table 1).

## MATERIAL AND METHODS

### *Plant material*

Morpho-anatomical analysis was done on plant samples from six spatially separated populations of the species *T. arduini* growing in Montenegro and Serbia (Metohia). The collected plant material was fixed in 50% alcohol and deposited in the herbarium of the Institute of Botany and Jevremovac Botanical Garden, Faculty of Biology, University of Belgrade (BEOU) and that of the Institute of Botany, Faculty of Pharmacy, University of Belgrade (HFF).

### *Voucher specimens*

1. Montenegro: Bay of Kotor, Risan, limestone, 10 m a.s.l. (Stevanović V., 2145/96, BEOU, 16-Aug-1996)
2. Montenegro: Canyon of the Cijevna, village of Dinoša, limestone, 80 m a.s.l. (Lakušić, B., Jančić, R., Slavkowska, V., 2520, HFF, 09-Jul-1997);
3. Montenegro: Canyon of the Morača, Dromir, limestone, 200 m a.s.l. (Lakušić, B., Jančić, R., Slavkowska, V., 2522, HFF, 12-Jul-1997); Platije: *Asplenietea*, limestone, 200 m (Lakušić, D., Conti, F., 511/96, BEOU, 03-Jul-1996);
4. Montenegro: Mt. Lovćen near Njeguši, limestone, 800 m a.s.l. (Lakušić, B., Slavkowska, V., Jančić, R., 2521, HFF, 11-Jul-1997);
5. Montenegro: Mt. Durmitor, Canyon of the Komarnica, *Seslerio-Ostryetum*, limestone, 1100 m a.s.l. (Lakušić, D., 1149/95, BEOU, 31-Jul-1995);
6. Serbia (Metohia): Rugovo gorge, limestone, 700 m a.s.l. (Stevanović, V., Lakušić, D., Niketić, M. 2231/91, BEOU, 01-Oct-1991).

### *Morpho-anatomical analysis*

Anatomical analyses of the leaves and stem were done on permanent slides prepared by the standard method for light microscopy. Cross-sections of the leaves (180 samples) and stem (60 samples) were cut on a Reichert sliding microtome a thickness of up to 10 µm. The sections were cleared in Parazone and thoroughly washed before staining in safranin (1% w/v in 50% ethanol) and alcian blue (1% w/v, aqueous).

Epidermal peels (180 samples) for analyses of surface structures and stomata, were prepared using Jeffrey's solution (10% nitric acid and 10% chromic acid, 1 : 1) and stained in safranin and alcian blue. All slides were mounted in Canada balsam after dehydration.

Density and the type of leaf and stem hairs, as well as the paradermal aspect of epidermal cells, were also studied with a JOEL JSM-6460 scanning electron microscope (SEM) for which the samples were sputtered with gold.

All morpho-anatomical measurements were done with the Ozaria 2001 Image Analyzer System and data were processed using the Statistica 4.5 for Windows statistical package. For each of the quantitative characters, 30 leaf samples and 10 stem samples were obtained from different individuals belonging to each of the six populations analyzed.

The total of 22 quantitative characters subjected to statistical analysis were grouped in three categories: I. Leaf anatomy characters (13); II. Leaf shape characters (4); and III. Stem anatomy characters (5).

### *Leaf anatomy characters*

1. Height of adaxial epidermal cells; 2. Thickness of palisade tissue; 3. Thickness of spongy tissue; 4. Height of abaxial epidermal cells; 5. Number of palisade layers; 6. Surface area of adaxial epidermal cells; 7. Surface area of abaxial epidermal cells; 8. Surface area of abaxial stomata; 9. Number of abaxial stomata; 10. Number of adaxial glandular hairs; 11. Number of abaxial glandular hairs; 12. Number of

adaxial non-glandular hairs; 13. Number of abaxial non-glandular hairs.

#### Leaf shape characters

14. Leaf length; 15. Distance between the point of largest leaf width and the leaf top; 16. Largest width of the leaf; 17. Leaf surface area.

#### Stem anatomy characters

18. Stem diameter; 19. Stem diagonal; 20. Stem cortex thickness; 21. Stem vascular cylinder thickness; 22. Stem pith diameter.

#### Statistical analysis

For each of the quantitative characters, a univariate statistical analysis was done on the basis of the following parameters: average value, minimum, maximum, standard deviation, and standard error. The significance of differences between the populations studied was established by multivariate analyses of variances (MANOVA). General structure of the sample variability was established by principal component analysis (PCA). To check the hypothesis that the analyzed sample was composed of discrete groups morphologically differentiated from each other, a discriminant component analysis (DCA) was done. Overall differences between the compared groups are represented in terms of Mahalanobis' distances, which are used for clustering according to the UPGMA method.

## RESULTS

*T. arduini* is a deciduous semi-shrub whose height and general habitus slightly vary within the studied populations. Except for the plants from Rugovo Gorge and Morača Canyon (which have a compact habitus, 18 to 23 cm high), the plants of all the other populations have a more or less diffuse habitus, 34 to 55 cm high. In all the populations studied, the lower woody part is less expressed, up to 5 cm long.

#### Leaf shape and anatomy

*T. arduini* has elliptical oval leaves, slightly narrowed towards the top in the upper third part. The lamina is more or less sphenoidously narrowed,

becoming an expressed leaf blade. The leaf margin is obtusely dentate. The leaves of all the studied plants are 19 to 45 mm long, 9 to 24 mm wide, with a surface of 90 to 640 mm<sup>2</sup>. The lowest leaf surface values were from 90 to 270 mm<sup>2</sup> (Rugovo). The highest ones (from 350 to 640 mm<sup>2</sup>) were in plants from the sub-Mediterranean region (Cijevna), while in those of other populations leaf surface values range between 230 and 620 mm<sup>2</sup>.

#### Leaf indumentum

The leaf indumentum in plants of all the studied populations is composed of glandular and non-glandular trichomes. The glandular trichomes are peltate and capitate. Peltate trichomes consist of an unicellular stalk and a multicellular secretory head with a large subcuticular space. There are two structural types of capitate trichomes: "type I" consists of an unicellular stalk and a rather large secretory head of four cells with a small subcuticular space, while "type II" consists of a unicellular stalk and a secretory head of one or two cells. The non-glandular trichomes are unicellular or multicellular, mostly having two to five cells, which are uniseriate and branchless, the top cell having a sharp edge, always straight. More or less wart-like cuticular structures are observed on the surface of the non-glandular hairs (Fig. 2b).

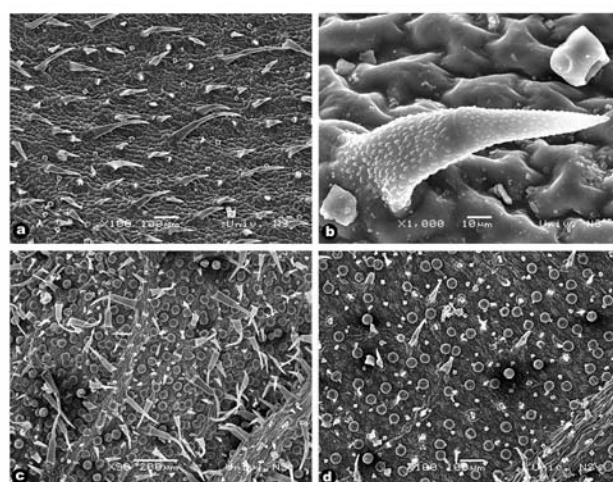


Fig. 2. *Teucrium arduini* – Indumentum (SEM): a - upper leaf side; b - non-glandular hair with more or less wart-like cuticular structure; c - lower leaf side (Rugovo); d - lower leaf side (Cijevna).

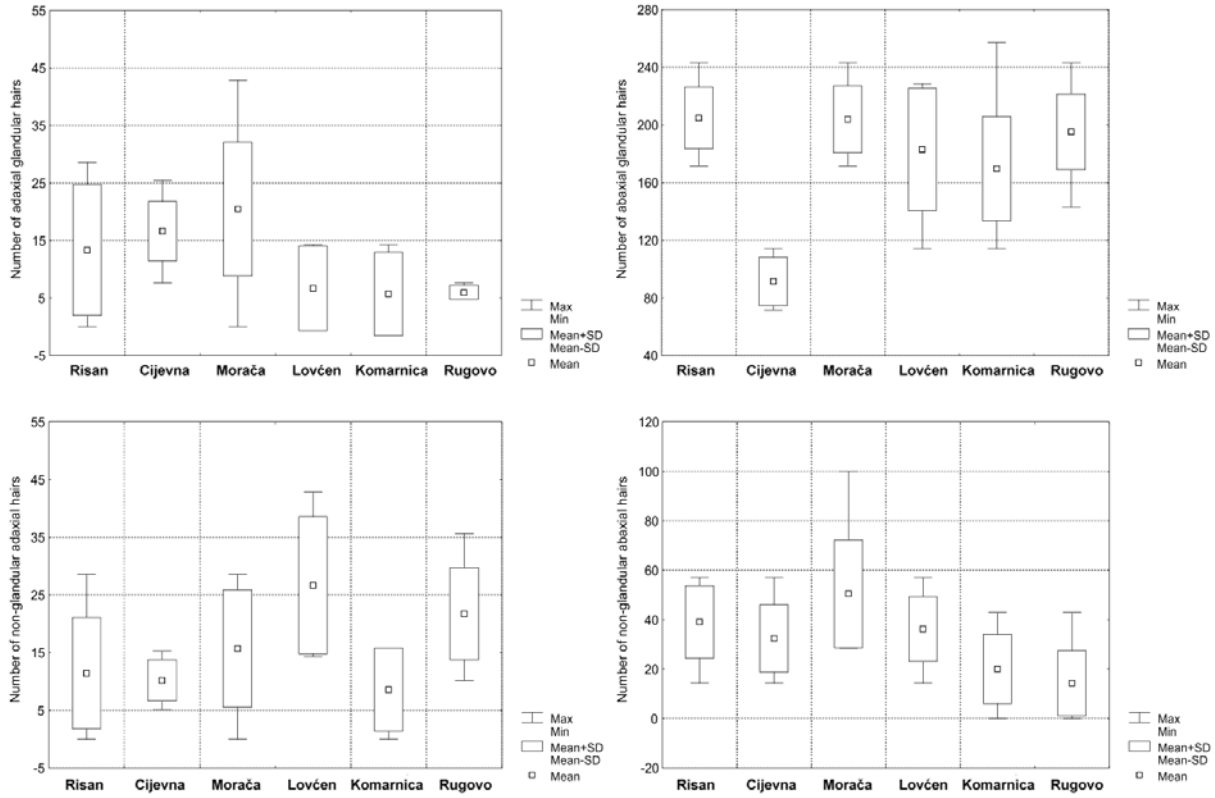


Fig. 3. Box and whisker plots of basic statistical parameters of indumentum.

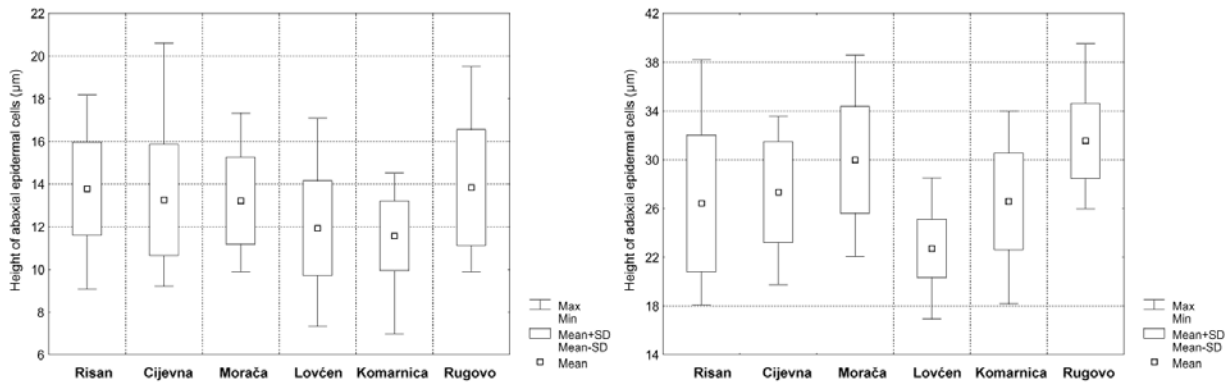
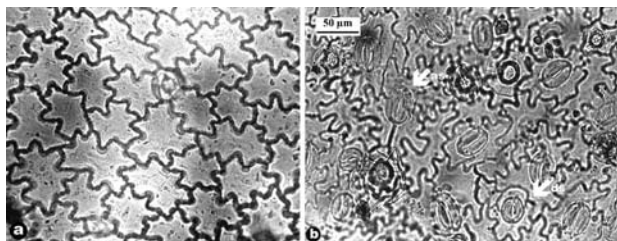


Fig. 4. Box and whisker plots of basic statistical parameters of epidermis.

The indumentum of the upper leaf side is sparse; there are 30-71 trichomes per 1 mm<sup>2</sup> (Fig. 2a). The ratio of glandular to non-glandular hairs per 1 mm<sup>2</sup> is 1:1 (Risan, Komarnica), 1.5:1 (Cijevna), 1:3 (Mt. Lovćen), 1:4 (Rugovo), or 2:1 (Morača) (Fig. 3).

The indumentum of lower leaf side is dense, with 177 to 341 hairs per mm<sup>2</sup>. The ratio of glandular to non-glandular hairs is 2:1 (Cijevna, Morača) (Fig. 2d), 4:1 (Risan, Mt. Lovćen), or 6:1 (Komarnica, Rugovo) (Fig. 2c). Due to the dominance of glandular hairs



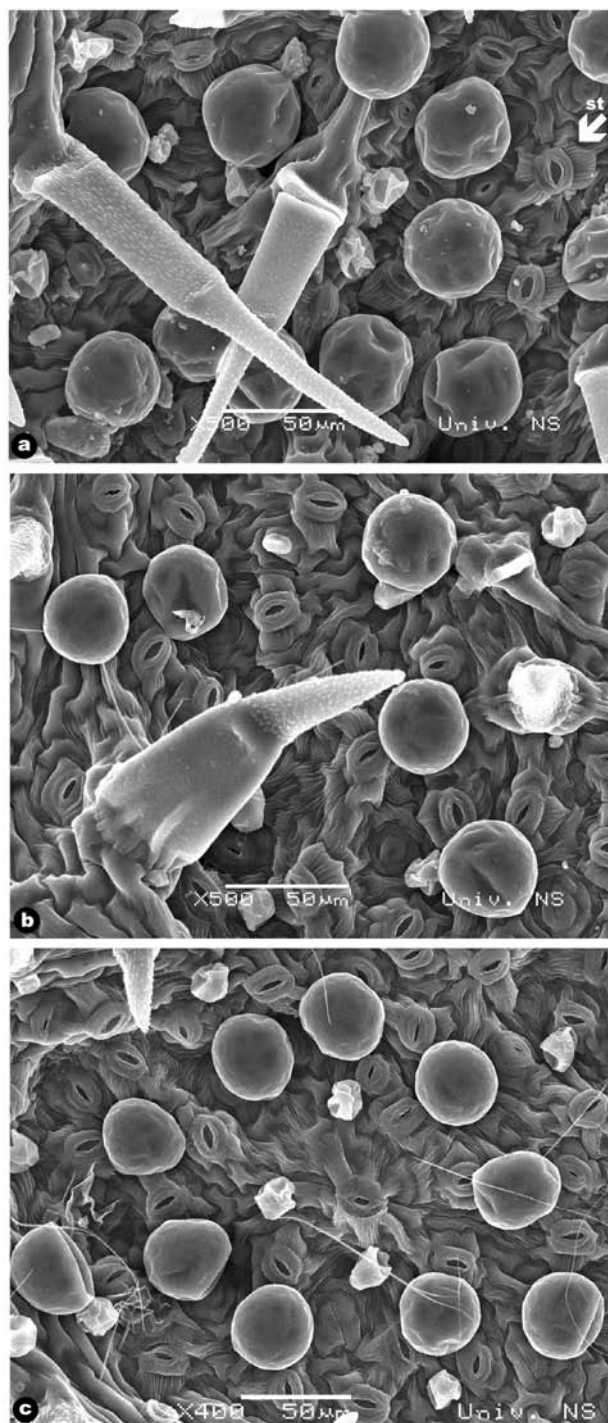
**Fig. 5.** *Teucrium arduinii* – Paradermal view: a - undulate anticlinal walls of the adaxial epidermal cells; b - undulate anticlinal walls of the abaxial epidermal cells with anomocytic (as) and diacytic (ds) stomata.

(69 to 260 per mm<sup>2</sup>) over non-glandular ones (41 to 100 per mm<sup>2</sup>) the indumentum is of the glandular type (Fig. 3). In the glandular layer, towards the very margin of the epidermal surface, which is dominated by peltate hairs that with their wide secretory heads cover the greater part of the epidermis (Fig. 2c,d) capitate hairs of “type I” are more frequent, while capitate hairs of “type II” are scarce and concentrated around the main nerve and along the leaf margin. Non-glandular hairs are curved and bent above the glandular layer.

The cuticle on the leaf adaxial epidermis is thicker than 2 µm, while that on the abaxial epidermis is thicker than 0.5 µm in plants of all the six populations studied (Fig. 8). Both the adaxial epidermis and the abaxial epidermis of the leaf are simple, and adaxial epidermal cells are two to three times larger than abaxial ones (Fig. 4). The epidermal cell walls are thickened and mostly external, particularly in plants from the Rugovo Gorge (Fig. 8d), Morača Canyon, and Mt. Lovćen (Fig. 8c).

The anticlinal adaxial and abaxial epidermal cell walls are undulating with shallow and deep amplitudes (Fig. 5). The periclinal adaxial epidermal walls are smooth; on the abaxial epidermis there are cuticular thickenings in the form of long parallel striae, which are particularly pronounced around stomatal cells (Fig. 6a).

The leaves are always hypostomatic: the stomata are more or less elevated above the epidermal cells (Fig. 6) and are of the diacytic and anomocytic type (Fig. 5b). Their frequency varies from 130 to 420 per mm<sup>2</sup>. The highest number of stomata is present in



**Fig. 6.** *Teucrium arduinii* – Stomata (SEM): a - abaxial epidermis with cuticular thickenings in form of long parallel striae (st); b - stomata with non-glandular and glandular hairs and cuticular striae on abaxial epidermis; c - stomata encircled by the glandular hairs.

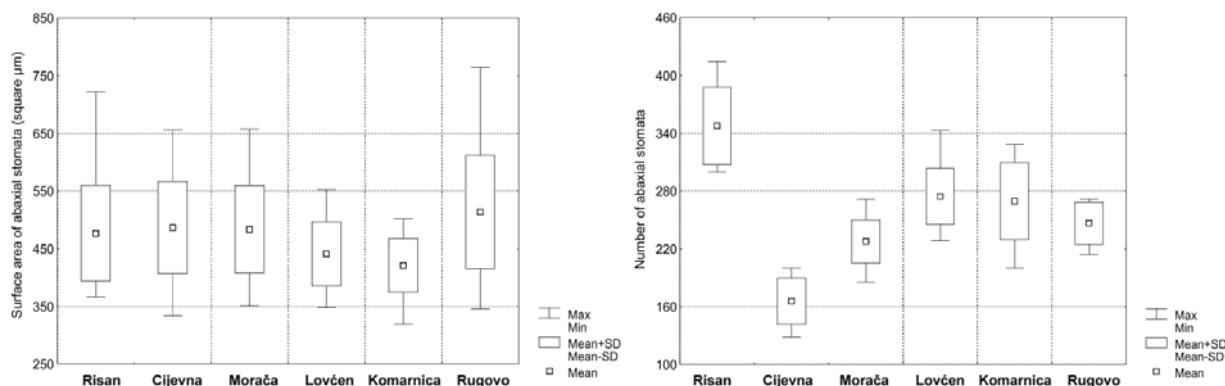


Fig. 7. Box and whisker plots of basic statistical parameters of stomata.

the plants from Risan (300–420 per  $\text{mm}^2$ ), the lowest in those from the Cijevna Canyon (130–200 per  $\text{mm}^2$ ). The stomal size is uniform in all the analyzed populations (Fig. 7).

All the analyzed populations have leaves of dorsiventral structure (Fig. 8).

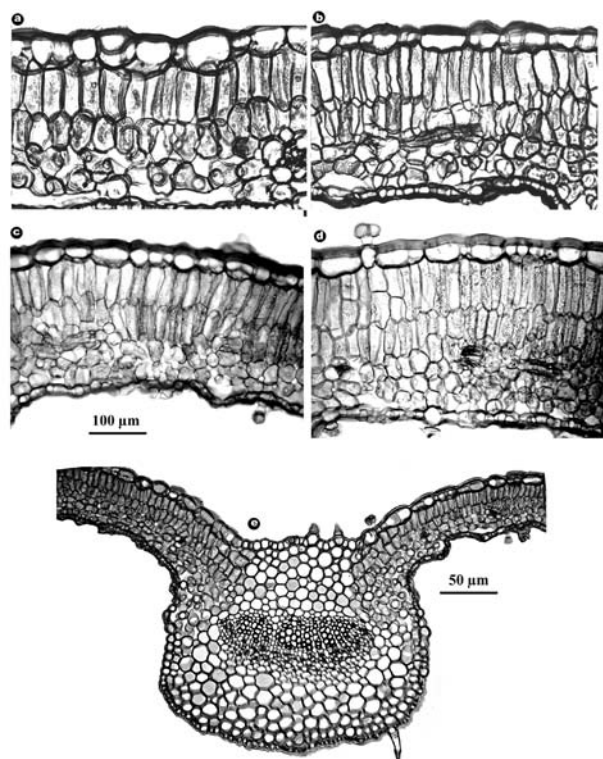


Fig. 8. *Teucrium arduini* – Cross section of leaves from: a - Cijevna; b - Risan; c - Mt. Lovćen; d - Rugovo; e - Cijevna.

Leaf thickness in all the plants studied ranged between from 148  $\mu\text{m}$  to 372  $\mu\text{m}$ , the thinnest leaves being in the plants from Cijevna (148–252  $\mu\text{m}$ ) and thickest in those from the Rugovo Gorge (230–372  $\mu\text{m}$ ).

The mesophyll is compact and clearly differentiated into palisade and spongy parenchyma (Fig. 8); the ratio of these two photosynthetically functional mesophyll tissues is 1.5:1 (Komarnica and Rugovo Gorge); 1.7:1 (Morača, Cijevna); and 2:1 (Risan, Mt. Lovćen). The palisade parenchyma consists of one to three layers of densely compacted, elongated cells. In the plants from Komarnica, the Rugovo Gorge and Mt. Lovćen (Fig. 8 b,c), the anticlinal walls of palisade cells are slightly inter-twisted. The spongy parenchyma consists of two to three layers of globular cells with small intercellular spaces (Fig. 9). The leaf cross section is dominated by the central nerve surrounded by the multi-layered collenchyma, which spreads up to the adaxial and abaxial epidermis (Fig. 8 e). In the lateral parts of the leaf there are two to three relatively large conducting bundles together with numerous small ones, all of them being surrounded by the pronounced conducting parenchyma made of large cells.

#### Stem shape and anatomy

The herbaceous stem in *T. arduini* in its cross section has a square form, with more (Morača, Rugovo Gorge - Fig. 10c) or less (Risan, Mt. Lovćen, Cijevna, Komarnica - Fig. 10 e) pronounced angles.

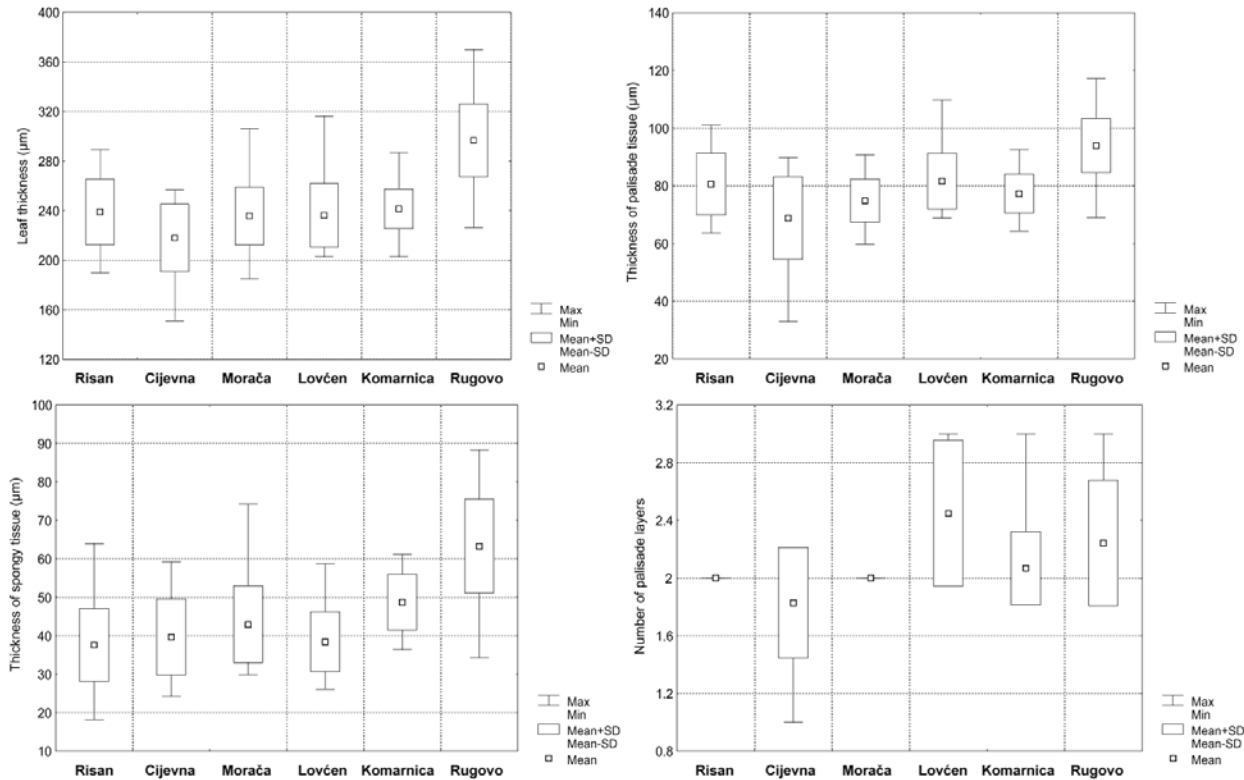


Fig. 9. Box and whisker plots of basic statistical parameters of mesophyll.

The stem is covered by a thick layer of cuticle, and the dense indumentum is built of glandular and non-glandular hairs of the same type and distribution as in the leaf (Fig. 10 a,b). The epidermis is one-layered, made of cells whose external walls are thickened. The stomata are scarce, and the guard cells are slightly elevated above the epidermis. In the angles of the cortex and in one to two layers along the straight sides of the stem, there is a sub-epidermal multi-layered collenchyma. The rest of the cortex is built of the compact parenchyma. Cortex width is almost the same in all populations.

The pericycle is in a cylinder made of sclerenchyma elements, interrupted in a few places by several parenchyma cells (Fig. 10 d,f). Conducting tissues form four (Risan, Cijevna, Morača) or six (Rugovo, Mt. Lovćen, Komarnica) bundles, making almost a cylinder, which is most pronounced in the angles (Fig. 10 c,e). A considerable part of the stem

is filled with large parenchyma medullar cells. The coefficient of the correlation between cortex and the whole stem ranges from 0.208 (Risan) to 0.352 (Rugovo Gorge).

#### Multivariate analysis of morpho-anatomical characters

Principal component analysis (PCA) showed that the structure of variability of the populations studied is complex, since the first two axes comprise only 66.86% of total variability. By multivariate analyses of variances (MANOVA), it was established that there are statistically significant differences between the examined populations. The most important characters in structural differentiation are those related to stem anatomy, indumentum, leaf shape, and leaf anatomy, in that order of significance (Table 2).

Discriminant component analysis (DCA) of the studied populations of *T. arduini* revealed three



**Table 2.** Analysis of variances on the level of individual characters.

Depend variable	Mean sqr Effect	Mean sqr Error	F(df1,2) 4,45	p-level
Height of adaxial epidermal cells	151.64	10.61	14.29	0.00000
Thickness of palisade tissue	927.85	107.66	8.62	0.00001
Thickness of spongy tissue	324.34	72.41	4.48	0.00177
Height of abaxial epidermal cells	7.63	4.68	1.63	0.16797
Number of palisade layers	0.50	0.12	4.07	0.00334
Surface area of adaxial epidermal cells	1694068.25	200624.38	8.44	0.00001
Surface area of abaxial epidermal cells	116727.09	34565.64	3.38	0.01012
Surface area of abaxial stomata	23659.78	5577.09	4.24	0.00256
Number of abaxial stomata	31240.53	999.32	31.26	0.00000
Number of adaxial glandular hairs	805.42	55.40	14.54	0.00000
Number of abaxial glandular hairs	19656.86	744.41	26.41	0.00000
Number of non-glandular adaxial hairs	773.19	63.20	12.23	0.00000
Number of non-glandular abaxial hairs	801.11	192.53	4.16	0.00291
Leaf length	215.50	15.33	14.06	0.00000
Distance between point of largest leaf width and leaf top	70.56	9.62	7.33	0.00003
Largest width of leaf	104.16	4.94	21.09	0.00000
Leaf surface area	145930.67	6937.80	21.03	0.00000
Stem diameter	3996971.25	49448.28	80.83	0.00000
Stem diagonal	5398255.50	21570.06	250.27	0.00000
Stem cortex thickness	32274.18	4963.37	6.50	0.00009
Stem vascular cylinder thickness	1025664.13	11845.08	86.59	0.00000
Stem pith diameter	667366.31	7448.00	89.60	0.00000

morphologically separate groups. On the first two axes, the populations from the sub-Mediterranean canyons (Morača and Cijevna) stand completely apart from the populations from the continental gorge (Rugovo). The populations from Risan, Mt. Lovćen, and Komarnica have a transitional position (Fig. 11). Morpho-anatomical separation between these three groups of populations is also clearly observed on the basis of overall Mahalanobius' distances (Fig. 12).

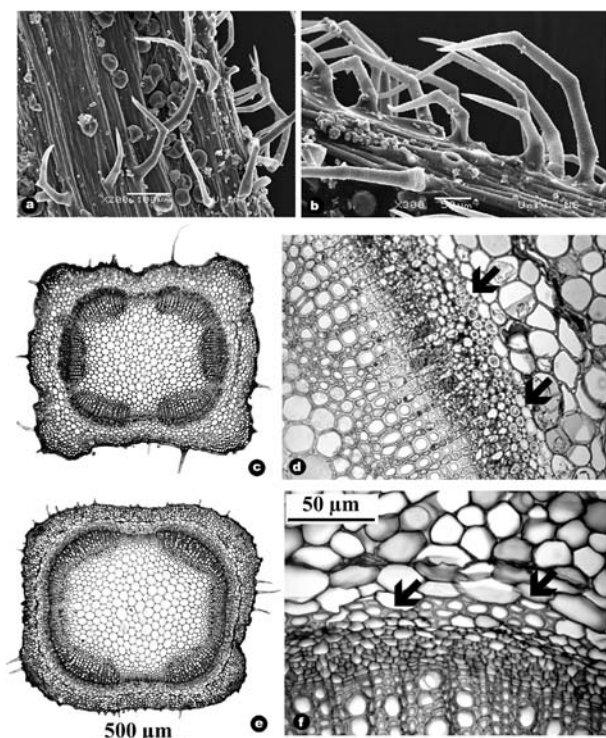
## DISCUSSION

*Teucrium arduini* is an endemic species of the western part of the Balkan Peninsula, with distribution in the eu-Mediterranean and sub-Mediterranean region. Isolated populations inhabit canyons and gorges in the transitional sub-Mediterranean-Central-European climate zone with strong Mediterranean influence. *T. arduini* grows

only on basic carbonate rocks at altitudes between 0 and 1400 m, the majority of populations being recorded in zones between 0 and 200 m (Lakušić, 2000).

Morpho-anatomical characteristics of leaves and stems in plants of the studied populations show numerous common features indicating that the species *T. arduini* belongs to the adaptive type of xerophytes with malacophyllous leaves (Walter, 1983) of relatively large surface (up to 640 mm<sup>2</sup>).

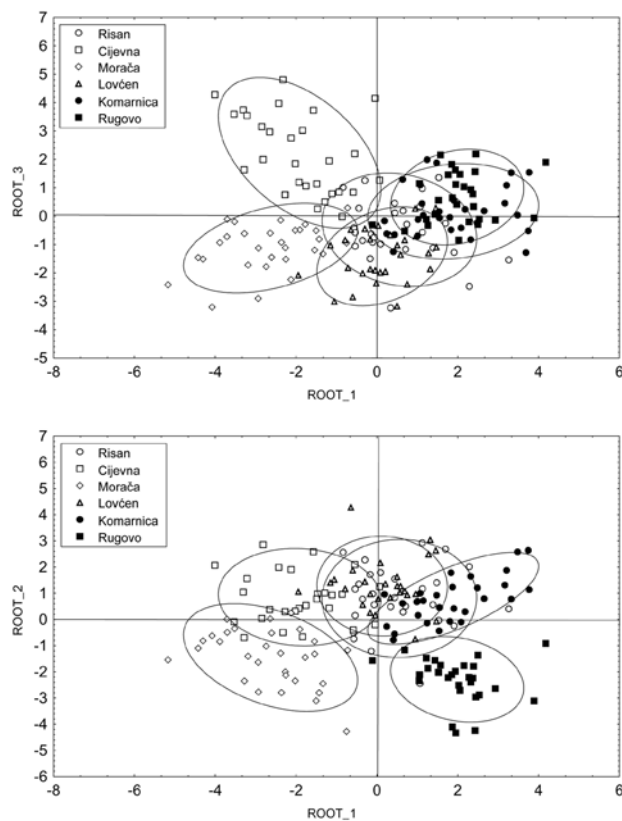
The xerophytic characteristics of this species are chiefly determined by the nature of its habitat. Regardless of whether the habitats of the analyzed populations are characterized by a humid or a perhumid climate, the distribution of precipitation in the course of the year is always such that almost two thirds of rainfall is concentrated in the winter-spring period, while the quantity precipitation in the course of the summer is extremely low. In addition



**Fig. 10.** *Teucrium arduini* – Stem: a & b – non-glandular and glandular hairs (SEM); c – square stem on the cross section from Rugovo; d – pericycle with sclerenchyma elements (arrow) from Rugovo; e – rounded stem on the cross section from Mt. Lovćen; f – pericycle with sclerenchyma elements (arrow) from Mt. Lovćen.

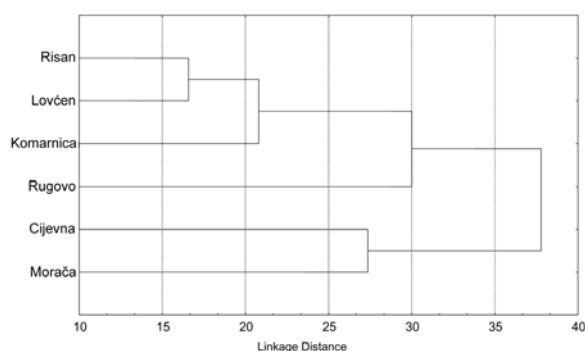
to high temperatures and porous limestone ground, this leads to the occurrence of pronounced droughts that in these habitats can last one or two and in extreme cases up to three months during the growing season. Xeromorphic adaptations of plants of the studied populations are manifested in the following characters: the nature of leaf and stem indumenta, number of stomata, structure of epidermal cells, characteristics of the mesophyll and structure of the stem.

The adaxial leaf indumentum is rarified, while the abaxial one is dense and glandular with 177 to 341 hairs per  $\text{mm}^2$ , considerably reducing absorbance, temperature, and transpiration of the leaf (Qualidi et al., 2002). As in other species of the genus *Teucrium* (Lakušić, 2000), in the species *T. arduini* an extremely high number of glandular hairs (from 118 to 260 per  $\text{mm}^2$ ) located on the abaxial



**Fig. 11.** Discriminant analysis of basic components (DCA).

side of the hypostomatic leaves is not in positive correlation with the quantity of extracted essential oil (from 0.06 to 0.1%). Since almost all plants of the studied populations inhabit more or less arid regions it can be assumed that the bulk of essential oil synthesized in the numerous glandular hairs constantly evaporates into the environment, thereby creating a



**Fig. 12.** Mahalanobis distances between analyzed populations of *Teucrium arduini*.

specific leaf nano-climate that influences regulation of transpiration (Ehleringer, 1984; Werker et al., 1985; Todorović and Stevanović, 1994; Lakušić et al., 2006). The resins extracted from leaf surfaces (1.78%), are dominated by free flavonoids, with 0.95% (Kovačević et al., 1998). Externally located flavonoids might have interesting ecological and physiological roles, including antimicrobial, antifungal, insecticidal or insect deterrent activity through provision of a chemical barrier against pathogens, as well as UV screening (Tomas-Barberan and Gil, 1992).

A high number of stomata, from 130 to 420 per mm<sup>2</sup>, distributed around glandular hairs or hidden under large secretory heads, is a feature of xeromorphic leaves (Fahn and Cutler, 1992). The plants from eu-Mediterranean conditions (Risan) have the greatest number of stomata, from 300 to 420 per mm<sup>2</sup>, while in ones from sub-Mediterranean and continental populations that number is even up to four times lower, from 130 to 341 per mm<sup>2</sup>. External cell walls of the adaxial leaf epidermis are very thickened, while those of stem and abaxial leaf epidermal cells are a bit less so. Periclinal walls of the abaxial leaf epidermis have cuticular thickenings in the form of long parallel stria. The anticlinal walls of both adaxial and abaxial epidermal cells of the leaves in all the studied populations are undulated, which has been described as a mesomorphic feature (Wilkinson, 1988; Fahn and Cutler, 1992; Lakušić et al., 1996).

The leaf mesophyll has a compact structure and is clearly differentiated into palisade and spongy tissues. The most developed palisade tissue present in a ratio of 2:1 in relation to spongy tissue, is characteristic of plants from the Mediterranean region (Risan, Mt. Lovćen), while in plants of the other populations palisade participation in the total mesophyll declines in the direction of the continental populations. Thus, in the leaves of the plants from Komarnica and Rugovo Gorge, the palisade to spongy parenchyma ratio is 1.5:1.

On the stem surface in plants from all the studied populations, there is a dense indumentum which covers sparse, elongated stomata. In the stem itself,

there is a well developed mechanical tissue: sub-epidermal collenchyma and a multi-layered pericycle of sclerenchyma elements, which is also noted in other species of the family Lamiaceae from arid habitats (Metcalf and Chalk, 1950; Kästner, 1979). The ratio of stem cortex to stem diameter ranges from 0.208 (Risan) to 0.352 (Rugovo), which is within the usual values found in xeromorphic stems (Fahn and Cutler, 1992; Yiotis et al., 2006; Lakušić et al., 2006)

The results of discriminant analysis indicate that in the given region slight morpho-anatomical differentiation has divided the studied populations into three groups of plants separated by very small distances, meaning that the species *T. arduini* has a stable conservative morpho-anatomical, xeromorphic structure, which is characteristic of other endemic species of the Balkan Peninsula as well (Damjanović and Stevanović, 1992; Todorović and Stevanović, 1994; Lakušić et al., 1999).

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**МОРФО-АНАТОМСКА ДИФЕРЕНЦИЈАЦИЈА БАЛКАНСКОГ ЕНДЕМИТА  
*TEUCRIUM ARDUINI* L. (LAMIACEAE)**

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*Teucrium arduini* L. је ендемична врста распрострањена у медитеранским и субмедитеранским подручјима западног дела Балканског полуострва, од Истре на северу до Албаније на југу. Врста припада секцији *Stachyobotrus* Bentham којој на простору Европе припада још само малоазијско-источнобалканска врста *T. laminifolium* D'Urv., у коју је укључен и таксон *T. cordifolium* Čelak.

Еколошка пластичност и интерпопулациона диференцијација врсте *T. arduini* је анализирана на основу морфо-анатомске варијабилности шест популација (Рисан, Његуши и кањони Цијевне, Мораче и Комарнице у Црној Гори и Руговска клисура у Србији) које се развијају у различитим типовима вегетације, и то у пукотинама карбонатних стена (*Asplenietea rupestris*), камењара (*Festuco-Brometea*) и термофилним шумама на кречњацима (*Ostryo-Carpinion orientalis*) у условима еумедитеранске, субмедитеранске и прелазне медитеранско-средњеевропске климе.

Статистичком анализом су обухваћена 22

квантитативна карактера везана за анатомију и морфологију листова и стабла. У циљу утврђивања природе варијабилности и степена статистичке значајности установљених разлика урађена је мултиваријациона анализа која је обухватила анализу варијанси (MANOVA), анализу основних компоненти (PCA) и дискриминантну анализу основних компоненти (DCA).

На основу урађених анализа биљака из шест популација које се развијају на различитим стаништима и у различитим еколошким условима, утврђено је да врста *T. arduini* припада групи ксерофита са малакофилном грађом листова. На основу резултата дискриминантне анализе установљено је да су анализиране популације морфо-анатомски веома незнатно издиференциране у три групе биљака између којих постоје веома мале разлике. На тај начин се показало да и врста *T. arduini* има веома стабилне, конзервативне морфо-анатомске, ксероморфне структуре, које су карактеристичне и за друге ендемичне биљке Балканског полуострва.