

**Predrag VASIĆ, Zoran KRIVOŠEJ,  
Marina TOPUZOVIĆ, Darko DUBAK and Danijela PRODANOVIĆ<sup>1</sup>**

**MORPHOLOGICAL – ANATOMICAL CHARACTERISTICS OF TWO  
COMMON JUNIPERS (*Juniperus communis* and *Juniperus oxycedrus*)  
FROM THE AREA OF MOUNTAIN KOPAONIK IN SERBIA**

**SUMMARY**

This paper aims to explore the variety of anatomical and morphological characteristics of two different juniper species (*Juniperus communis*, *Juniperus oxycedrus*) from the area of Kopaonik Mountain. Analysis specimens for the species *Juniperus communis* and *Juniperus oxycedrus* were collected from the altitude of 420 m and 1,420 m. This paper presents analysis of three morphological and sixteen anatomical characteristics of the mentioned species.

**Key words:** *Juniperus communis*, *Juniperus oxycedrus*, morpho-anatomical characteristic, altitude

**INTRODUCTION**

The genus *Juniperus* L. belongs to the family of Cupressaceae. Within flora in Serbia (Jovanović, 1992), this genus has nine species, six local and three park species (introduced). The genus *Juniperus communis* and *Juniperus oxycedrus* belong to the group of phanerophyta (a bush or a short tree). The researches on this genus are mainly related to study of essential oils in leaves (Adams *et al.*, 2011, Adams 1998; Matovic *et al.*, 1996). Since the anatomy and morphology of *Juniperus communis* and *Juniperus oxycedrus* are not so familiar and were seldom analysed in the past, it was only recently that the study of morpho-anatomical features of juniper has become significant (Zanoni & Adams, 1975; Franjić, 1994; Gomez & Segura, 1996, Vasić *et al.*, 2008; Vasić *et al.*, 2008; Vasić & Dubak 2012; Lakušić & Lakušić 2011; Chiou-Rong Sheue *et al.*, 2003).

Taking into consideration that the literature data related to this subject are scarce, the results obtained in this paper may help researches better understand the impact of the ecological factor on morphological and anatomical structure of juniper. We analysed those characters from the aspect of their variability with the increase of altitude.

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<sup>1</sup> Predrag VASIĆ (corresponding author: zor\_z\_strasni@yahoo.com), Zoran KRIVOŠEJ, Institute of Biology, Faculty of Science, University of Pristina, Lole Ribara 29, 38220 Kosovska Mitrovica; Marina TOPUZOVIĆ, Institute of Biology and Ecology, Faculty of Science, University of Kragujevac, Radoja Domanovica 12, 34000 Kragujevac; Darko DUBAK, Biotechnical Faculty, University of Montenegro, Mihaila Lalica 1, 81000 Podgorica; Danijela PRODANOVIĆ Faculty of Agriculture, University of Pristina, Kosovska Mitrovica, Zubin Potok.

## MATERIAL AND METHODS

The collected material was fixed in a formalin-alcohol (50:50) solution. Next, it was conducted through a series of alcohols of increasing concentrations due to dehydration. Unused conserved plant materials, as well as microscopic preparations, are located in the herbarium of the University of Pristina's Department of Biology at the Faculty of Science (head office temporarily located in Kosovska Mitrovica). Anatomical analyses of the needles were prepared by the standard method for light microscopy. Cross-sections of the needles were cut (up to 15  $\mu\text{m}$  thick) on a manual microtome. Anatomical characteristics leaf types *Juniperus oxycedrus* and *Juniperus communis* were investigated on leaf samples collected in the time interval from 2001 to 2004th.

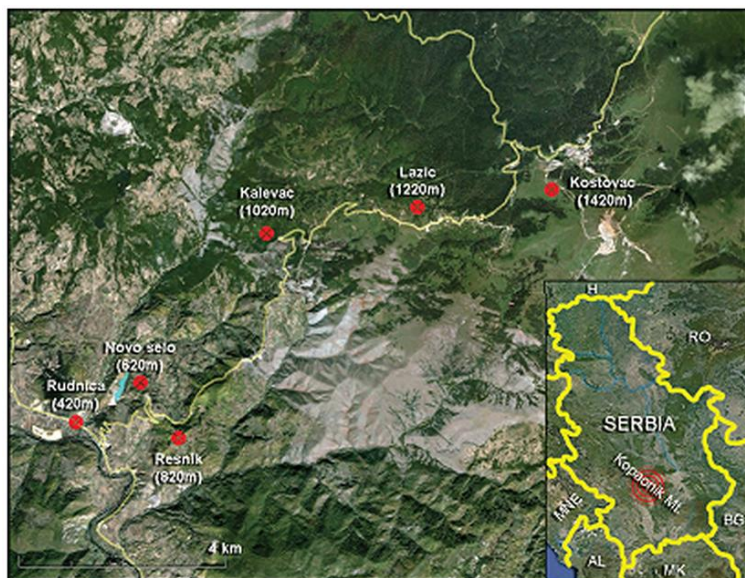


Figure 1. Geographical location of the studied species.

The plant material used for comparative anatomical and morphological analysis was collected in the south-western part of Kopaonik Mountain (Serbia) and came from altitudes of 420, 620, 820, 1020, 1220, and 1420 m (Figure 1).

For each anatomic character, 100 preparations were analysed. In total, 16 anatomic and 3 morphological characters were analysed.

The measured anatomic characters are: leaf width (SL), leaf thickness (DL), front cuticle thickness (DKL), back side cuticle thickness (DKN), thickness of outer wall of front epidermis (DSZEL), thickness of inner wall of front epidermis (DUZEL), front epidermis width (SEL), back side epidermis width (SEN), front epidermis height (VEL), back side epidermis height (VEN), conductive vessel length (DPS), conductive vessel width (SPS), thickness of inner wall of back side epidermis (DUZEN), thickness of outer wall of back side epidermis (DSZEN), resin canal width (UDSK) and resin canal length (SDSK).

Morphological characters are: leaf length (MDL), leaf width (MSL) and leaf thickness (MD, BL).

The measurements of morphological and anatomical characters of the leaf were statistically processed with a software package Statistics 6.0 (Statcoft 2001). Descriptive statistical analyses were made for all morphological and anatomic characters of the leaf.

## RESULTS AND DISCUSSION

Morphological Juniper Leaf Properties, Descriptive Statistics of Morphological Characters of a Juniper Leaf.

Descriptive statistical analysis was made to calculate the mean value and range for all morphological characters of leaves (its length, width and thickness) of *Juniperus communis* and *Juniperus oxycedrus* species. The results of this statistical analysis are presented in Table 1. From Table 1, can be seen that species of *Juniperus communis* has high mean value of the length of a leaves plant at an altitude of 420 m (15.1mm). As altitude increased, the mean value leaf length gradually became smaller, so the plants at the highest altitude 1,420m showed (11.1mm) leaf length.

The maximum measured length one specimen juniper leaf (19.30mm) was measured at 420 meters, while the minimum leaf length was measured at an altitude of 1,420 m (only 8.03mm). When other two morphological characters of a leaf were considered (width and thickness), a reverse trend related to the leaf length was observed. Namely, as altitude increased, the values of two *Juniper communis* leaf characters also increased. The smallest average leaf width was measured at 1,420 m (1.0 mm), whereas the highest value was found at 420 m (1.4 mm). The maximum leaf width of 1.74 mm was also measured at this altitude. The smallest and largest average leaf thicknesses were measured at 1,420 m (0.4 mm) and at 420 m (0.6 mm).

The measurement results obtained for *Juniperus oxycedrus* (Table 1) demonstrated that the average leaf length of this type of juniper was largest at 420 m (14 mm) while the average leaf length decreased with the altitude increase, so the smallest mean value of leaf length was found at the altitude of 1,420 (12.9mm).

The altitude rise impacted the leaf width. At 420 m the average leaf width was 1.4 mm, the mean value of leaf width slightly increased with the altitude increase; at 1,420 m the average width was 1.57 mm.

The data obtained by measuring the leaf thickness of *Juniperus oxycedrus* also showed that the altitude increase influenced the increase of the average leaf thickness. So, at 420 m the leaf thickness was 0.60 mm and at 1,420 m the leaf was 0.64 mm thick.

Anatomical Characters of Juniper Leaf, Descriptive statistics of anatomical characters of the leaves of two types of juniper, *Juniperus communis* and *Juniperus oxycedrus*.

Table 1. Descriptive statistics of morphological characters of the leaves of two types of juniper *Juniperus communis*, *Juniperus oxycedrus*.

Altitude (m)	The leaf length		The leaf width		The leaf thickness	
	Mean value (mm)	Standard deviation	Mean value (mm)	Standard deviation	Mean value (mm)	Standard deviation
	<i>Juniperus communis</i>					
420	15.1	1.77	1.4	0.13	0.6	0.07
620	14.7	1.44	1.3	0.08	0.5	0.05
820	14.2	1.30	1.2	0.15	0.5	0.05
1020	13.3	1.23	1.3	0.14	0.5	0.04
1220	13.1	1.21	1.1	0.08	0.5	0.04
1420	11.1	1.49	1.0	0.14	0.4	0.06
	<i>Juniperus oxycedrus</i>					
420	14.0	1.32	1.5	0.16	0.6	0.05
620	13.7	1.56	1.4	0.18	0.6	0.07
820	14.6	1.25	1.3	0.11	0.6	0.04
1020	13.1	1.36	1.2	0.08	0.5	0.05
1220	12.9	0.98	1.4	0.09	0.6	0.05
1420	12.9	1.67	1.4	0.13	0.6	0.04

The results of descriptive statistical analysis of anatomical leaf properties of *Juniperus communis* and *Juniperus oxycedrus* species are presented in Tables 2, 3, 4 and 5 and in Figures 2, 3, 4, 5, 6 and 7. The obtained values are given in  $\mu\text{m}$ .

While studying anatomical leaf structure of these two juniper species, the observations were made on a leaf cross section. For this purpose, the cross-sections were made in the middle of the leaf at the level of the main vessel.

Three basic layers were observed in the cross sections of *Juniperus communis* (Figure 2A, 2B and 2C) and *Juniperus oxycedrus* leaf (Figure 3A, 3B and 3C): adaxial epidermis, mesophyll, and abaxial epidermis. The adaxial epidermis was well developed and covered with cuticle. Layers of mesophyll were also well developed the basic species and were made of palisade and spongy tissue. Palisade parenchyma cells were of rectangular shape. Spongy parenchyma was made of ball-shaped cells with intercellular between them.

The resin canal was located on the leaf abaxial side and was well developed. On leaf edges, the collenchyma cells, which were distributed in several layers, was observed. Inside the epidermis were stomata that were retracted in comparison with the surface of the epidermis. The main vessel consisted of one conductive vessel of collateral type.

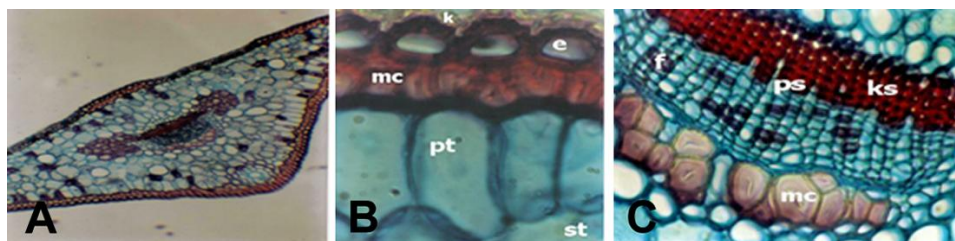


Figure 2: Cross section of Common leaf *Juniperus communis*, k-cuticle; e-epidermis; mc-mechanical cells; pt-palisade tissue; ps-conductive vessel; ks-xylem; f-phloem.

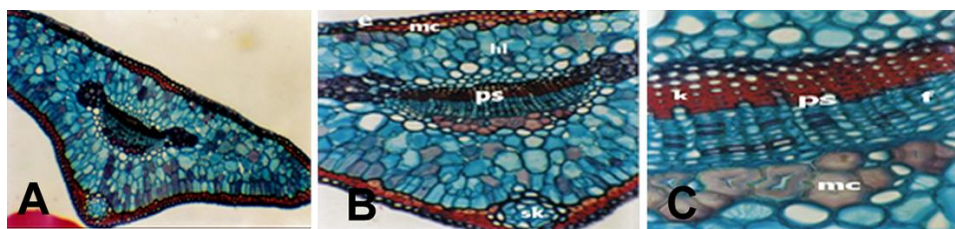


Figure 3: Cross section of Common leaf *Juniperus oxycedrus*, k-cuticle; e-epidermis; mc-mechanical cells; ps-conductive vessel; ks-xylem; f-phloem.

The leaf thickness of *Juniperus communis* at 420 m was 131.75  $\mu\text{m}$ . At the increasing altitude (1420m) it reached 187.9  $\mu\text{m}$  (Table 2). The epidermis and cuticle thickness showed the lowest mean value of 79  $\mu\text{m}$  at 420 m, the thickness of the cuticle increased with the increasing altitude, so at 1420 m it reached 1.26  $\mu\text{m}$ , which proved that the thickness increased with the increasing altitude. Mean values of the back side cuticle thickness of *Juniperus communis* leaf demonstrated a great variability with increasing altitude; so at 420 m it reached 0.80  $\mu\text{m}$  and then slowly rose to 1020 m to reach 1.57  $\mu\text{m}$ , then started to fall at altitude of 1420 m to reach thickness of 1.18  $\mu\text{m}$ , which indicated that the cuticle thickness changed with a change in altitude.

Table 2 presents the results of measuring of thickness of the outer wall of the epidermis. *Juniperus communis* showed the lowest values at 420 m (1.19  $\mu\text{m}$ ), so the thickness increased with the increasing altitude; the thickness at 1220 m and 1420 m was 2.3 $\mu\text{m}$  and 2.02  $\mu\text{m}$ . At 420 m, the thickness of the inner wall of the epidermis was 0.41  $\mu\text{m}$ , but the value changed with the change in altitude, so at 1220 m and 1420 m they reached 0.7  $\mu\text{m}$  and 0.6  $\mu\text{m}$ .

The mean values of epidermis width showed that the lowest values were at 420 m reaching 3.6  $\mu\text{m}$ . The epidermis width increased with the increasing altitude, with the highest value at 1220 m reaching 4.55  $\mu\text{m}$ , and at 1420 m slightly decreasing to 4.45  $\mu\text{m}$ . The values of the back epidermis width were lowest at 420 m (3.57  $\mu\text{m}$ ), but reached its highest value at 1420 m (4.73  $\mu\text{m}$ ).

Table 2. Descriptive statistics of some anatomic characters of Common Juniper (*Juniperus communis*).

Anatomic characters of leaf ( $\mu\text{m}$ )		Altitude (m)					
		420	620	820	1020	1220	1420
DL	$\bar{X}$	388.7	695	401.6	505.9	490.8	481.9
	min	270	630	280	350	420	400
	max	430	780	540	670	630	660
SL	$\bar{X}$	131.75	264.1	154.05	193.7	189.1	187.9
	min	120	200	120	140	150	170
	max	160	350	200	270	220	210
DKL	$\bar{X}$	0.79	1.71	1.04	1.27	1.06	1.26
	min	0.41	0.83	0.41	0.41	0.83	0.83
	max	0.83	3.32	1.66	2.49	2.49	2.90
DKN	$\bar{X}$	0.80	1.45	1.32	1.57	0.97	1.18
	min	0.41	0.83	0.41	0.41	0.83	0.41
	max	1.66	3.32	2.075	2.49	1.245	2.49
DSZEL	$\bar{X}$	1.19	3.06	1.70	1.95	2.30	2.02
	min	0.83	1.24	0.83	0.83	1.24	0.83
	max	2.07	4.98	2.07	3.32	4.15	2.90
DUZEL	$\bar{X}$	0.41	0.52	0.415	0.45	0.70	0.60
	min	0.41	0.41	0.41	0.41	0.41	0.41
	max	0.41	0.83	0.415	0.83	1.245	0.83
SEL	$\bar{X}$	3.6	7.38	3.68	3.97	4.55	4.45
	min	2.49	4.15	2.49	2.49	2.07	2.49
	max	4.98	9.13	4.98	5.81	7.47	6.22
SEN	$\bar{X}$	3.57	7.35	3.51	4.46	4.41	4.73
	min	2.49	4.98	2.07	2.49	2.49	2.07
	max	4.98	9.13	5.81	6.22	5.81	6.64

The epidermis heights front (VEL) of *Juniperus communis* at 1220 m and 420 m were lowest and they are 2.27 $\mu\text{m}$  and 2.74  $\mu\text{m}$ . *Juniperus communis* demonstrated the highest epidermis front (VEL) value at 1420 m, (3.12  $\mu\text{m}$ ). Both the front and back epidermis heights varied. They were lowest at 420 (2.45  $\mu\text{m}$ ), reaching 3.05  $\mu\text{m}$  at 1020 m, while at a 1420 m the value was somewhat lower - 2.94  $\mu\text{m}$  (Table 3). The given indicators showed that the front and back side epidermis height values were similar at almost all altitudes and were rather stable in both properties of the species.

*Juniperus communis* showed the lowest thickness value of the outer wall of the back epidermis at 420 m (1.35  $\mu\text{m}$ ), while the highest measured value was at 1420 m (2.1  $\mu\text{m}$ ). The thickness of the inner wall on the back side showed differentiated values at all altitudes investigated. (Table 3).

The thinner diameter of the conductive vessel of *Juniperus communis* had the lowest and highest values at 420 m (42.76  $\mu\text{m}$ ) and at 1020 m (68.21  $\mu\text{m}$ )

proportionally and slowly decreased with an increased value in altitude, at 1220 and 1420 m they reached 66.44 $\mu$ m and 58.38 $\mu$ m.

The measured values obtained for the wider diameter of the conductive vessel showed that *Juniperus communis* had the lowest value at 420 m (20.7  $\mu$ m), and rose to 29.23  $\mu$ m at 1020 m, then with the increased altitude of 1220 m it decreased (27.36  $\mu$ m), reaching 27.94  $\mu$ m at 1420 m.

*Juniperus communis* had the lowest value of the thinner diameter of the resin canal at 420 m (39.6  $\mu$ m), and the highest value at the altitude of 1220 m (53.48  $\mu$ m). *Juniperus communis* showed the lowest value of the wider diameter of the resin canal at 420 m (40.63  $\mu$ m), and the highest at 820 m, 1020 m and 1220 m (44.35, 48.8 и 56.14  $\mu$ m (Table 3).

Table 3 . Descriptive statistics of some anatomic characters of Common Juniper (*Juniperus communis*).

Anatomic characters of leaf ( $\mu$ m)		Altitude (m)					
		420	620	820	1020	1220	1420
VEL	$\bar{X}$	2.74	3.89	2.98	3.04	2.27	3.12
	min	1.66	2.49	2.07	1.66	0.83	1.66
	max	4.15	5.81	4.15	4.56	4.15	4.57
VEN	$\bar{X}$	2.45	3.44	2.56	3.05	2.66	2.94
	min	1.66	1.66	1.66	2.08	1.66	2.08
	max	3.73	4.98	3.73	4.56	4.57	4.15
DPS	$\bar{X}$	42.76	84.85	46.38	68.21	66.44	59.38
	min	34.86	55	29.88	36.52	49.8	48.14
	max	51.46	110.	74.70	106.24	86.32	76.36
SPS	$\bar{X}$	20.70	40.70	24.40	29.23	27.36	27.94
	min	16.6	30	16.6	24.90	21.58	21.58
	max	24.90	50.0	33.20	34.86	34.86	38.18
DUZEN	$\bar{X}$	0.415	0.87	0.44	0.49	0.87	0.65
	min	0.415	0.415	0.415	0.415	0.415	0.415
	max	0.41	2.07	0.83	0.83	1.66	1.24
DSZEN	$\bar{X}$	1.35	2.84	1.76	1.93	1.44	2.1
	min	0.83	0.83	0.83	1.24	0.83	0.83
	max	2.49	4.15	2.49	3.32	3.32	2.49
UDSK	$\bar{X}$	39.6	67.60	40.10	45.30	53.48	53.05
	min	28.22	49.50	66.40	21.58	33.20	39.84
	max	53.12	63.91	69.92	74.70	74.70	88.00
SDSK	$\bar{X}$	40.63	54.04	44.35	48.80	56.14	53.02
	min	26.56	33.00	16.60	23.24	36.52	33.20
	max	54.78	53.98	63.80	74.40	84.66	74.70

From the Table 4, we see that the thinner diameter value of the leaf of *Juniperus oxicedrus* was lowest at 820 m (502.8  $\mu\text{m}$ ) but with an increased altitude, the thinner diameter of the leaf also increased, so at 1420 m it had the highest value (753.6  $\mu\text{m}$ ).

The wider diameter of *Juniperus oxycedrus* leaf was lowest at 1020 m (173  $\mu\text{m}$ ) and highest (300.6 $\mu\text{m}$ ) at 1420 m (Table 4). As for the front cuticle, the thickness was lowest at 1020 m (1.18  $\mu\text{m}$ ), but at 820 and 420 m it had higher mean values (2.25  $\mu\text{m}$  and 1.75  $\mu\text{m}$ ). With an increase in altitude, the cuticle thickness increased so at 1220 and 1420 m its values were 1.75  $\mu\text{m}$  and 2.49  $\mu\text{m}$ , which prove that the front cuticle thickness increased with an increase in altitude.

Table 4. Descriptive statistics of anatomic characters of Common Juniper (*Juniperus oxycedrus*).

Anatomic characters of leaf ( $\mu\text{m}$ )		Altitude (m)					
		420	620	820	1020	1220	1420
UDL	$\bar{X}$	553.6	703	502.8	459.4	552.7	753.6
	min	470	670	420	330	450	420
	max	630	980	560	550	690	950
SDL	$\bar{X}$	221.5	280.6	208.4	173	203.1	300.6
	min	180	230	180	130	150	180
	max	240	380	240	210	270	390
DKL	$\bar{X}$	1.75	2.80	20.25	1.18	1.75	2.49
	min	0.41	1.66	1.24	0.41	0.83	1.66
	max	2.90	4.98	3.32	2.07	3.32	3.73
DKN	$\bar{X}$	1.79	2.66	2.29	1.24	2.26	2.88
	min	0.415	1.66	1.66	0.83	1.25	1.66
	max	3.32	3.32	3.32	2.49	2.91	4.15
DSZEL	$\bar{X}$	1.54	2.15	1.56	1.13	1.49	1.92
	min	0.415	0.83	0.83	0.83	0.83	0.83
	max	2.075	3.32	1.49	2.08	2.08	3.32
DUZEL	$\bar{X}$	1.54	0.83	0.415	0.415	0.415	0.415
	min	0.415	0.83	0.415	0.415	0.415	0.415
	max	2.075	1.66	1.25	0.83	0.83	0.83
SEL	$\bar{X}$	3.55	5.39	3.73	3.73	3.86	5.19
	min	2.49	3.32	2.07	2.49	2.49	2.90
	max	5.81	9.96	5.81	4.57	5.39	8.3
SEN	$\bar{X}$	3.37	5.4	3.49	3.15	3.90	5.35
	min	2.905	1.66	1.66	2.49	2.49	2.49
	max	4.98	9.13	4.98	4.58	5.39	8.30



The mean values of the back cuticle thickness of *Juniperus oxycedrus* showed a great variety with the altitude change, so at 420 m they were 1.79  $\mu\text{m}$ , and lowest at 1020 m (1.24  $\mu\text{m}$ ). At the altitude of 1420 m the highest mean value was 2.88  $\mu\text{m}$

The thickness of outer wall of the front epidermis showed that *Juniperus oxycedrus* had the highest mean value at 1420 m (1.92  $\mu\text{m}$ ), and the lowest at 1020 m (1.13  $\mu\text{m}$ ) and with an increase in altitude the thickness of the outer wall of the front epidermis gradually rose.

Table 5. Descriptive statistics of anatomic characters of Common Juniper (*Juniperus oxycedrus*).

Anatomic characters of leaf ( $\mu\text{m}$ )		Altitude (m)					
		420	620	820	1020	1220	1420
VEL	$\bar{X}$	3.34	4.16	5.44	3.00	3.33	4.26
	min	2.49	1.66	2.49	1.66	1.66	2.08
	max	4.46	6.64	4.98	4.15	4.57	7.47
VEN	$\bar{X}$	3.29	4.08	3.22	3.01	3.32	3.83
	min	2.49	1.66	0.83	1.66	2.08	2.08
	max	4.57	5.81	5.39	4.15	4.15	7.47
UDPS	$\bar{X}$	74.04	107.7	72.95	63.96	64.95	125.45
	min	49.80	85	55	36.52	49.80	60
	max	106.24	245	90	83	79.68	175
ŠDPS	$\bar{X}$	33.85	44.27	29.55	26.33	28.73	48.90
	min	24.90	25	25	19.92	19.92	30
	max	41.50	55	40	33.20	34.86	75
DUZEN	$\bar{X}$	1.54	1.52	0.59	0.53	0.59	0.49
	min	0.415	0.415	0.415	0.415	0.415	0.415
	max	2.075	2.49	1.25	1.25	1.25	0.83
DSZEN	$\bar{X}$	1.54	2.31	1.66	0.99	1.74	2.05
	min	0.415	0.83	0.83	0.83	0.83	0.83
	max	2.09	3.32	2.90	1.66	2.49	4.15
UDSMK	$\bar{X}$	21.98	41.50	23.90	17.40	25.07	33.13
	min	13.28	15.15	14.94	11.62	16.60	19.92
	max	29.88	58.10	39.84	23.24	33.20	49.80
ŠDSMK	$\bar{X}$	23.68	43.50	23.64	17.63	23.16	33.13
	min	13.28	24.90	16.60	11.62	14.94	19.92
	max	33.22	74.70	39.84	24.90	33.20	49.80

The differences were also observed in the thickness of the inner wall of the front epidermis where the lowest value measured was at 1420 m (0.31  $\mu\text{m}$ ), while the highest value was at 1220 m (0.56  $\mu\text{m}$ ) (Table 4).

Measuring the front epidermis width of *Juniperus oxycedrus* showed the lowest width at 1020 m (3.17  $\mu\text{m}$ ), and with increasing altitude the front epidermis width increased, so at altitudes of 1220 m и 1420 m their mean values were 3.86 $\mu\text{m}$  и 5.19  $\mu\text{m}$ .

As for the mean value of the back epidermis width, the lowest value was at 1020 m (3.15  $\mu\text{m}$ ), and as the altitude changed, the front epidermis width also changed, reaching 3.9  $\mu\text{m}$  and 5.35 $\mu\text{m}$  at 1220 m and 1420 m.

The measured mean values of the back epidermis height of *Juniperus oxycedrus*, demonstrated the smallest and largest values at 1020 m (3.01  $\mu\text{m}$ ), and 1420 m (3.83  $\mu\text{m}$ ) (Table 5).

The front epidermis height of *Juniperus oxycedrus* had the smallest mean value at 1020 m (3.00  $\mu\text{m}$ ), and increased at 1220 m to 3.33  $\mu\text{m}$ , and at 1420 m to 4.26  $\mu\text{m}$ .

The mean values of the thickness of the inner wall of the back epidermis of *Juniperus oxycedrus* from altitude of 420 m up to 1420 m, ranged from 0.48  $\mu\text{m}$  to 0.59  $\mu\text{m}$  with slight differentiations.

The thickness of the outer wall of the back epidermis was lowest at 1020 m (0.99  $\mu\text{m}$ ), but at 1420 m it was 2.05  $\mu\text{m}$ .

In Table 5 we can see that the lowest and highest values of the thinner diameter of the conductive vessel were measured at 1020 m (63.96  $\mu\text{m}$ ) and at 1420 m (125.45  $\mu\text{m}$ ).

The wider diameter of the conductive vessel of *Juniperus oxycedrus* had the lowest and highest values (26.33  $\mu\text{m}$ ) at 1020 m, and (48.9  $\mu\text{m}$ ) at 1420 m.

The mean values of the thinner and wider diameter length of the resin canal of *Juniperus oxycedrus* demonstrated that the lowest and highest values were at 1020 m (17.4  $\mu\text{m}$  и 17.63  $\mu\text{m}$ ) and at 1420 m (3.13  $\mu\text{m}$  и 33.13  $\mu\text{m}$ ).

## CONCLUSIONS

The results obtained by processing the data of the morphological characteristics of the leaves of *Juniperus communis*, *Juniperus oxycedrus*, species by means of descriptive statistical analysis, have shown that the leaf length, width and thickness distinctively change with an increase in altitudes.

The leaf length of *Juniperus communis* and *Juniperus oxycedrus* species is continuously decreasing with an increase in altitude. The leaves of both types of juniper are longest at the lowest altitude (420 m), and shortest at the highest altitude (1420 m). The leaf width and thickness regularly increase with increasing altitude, so they are widest and thickest at the highest altitude (1420 m).

If the length, width and thickness values of the leaves of the species studied are compared, it can be observed that *Juniperus communis* in relation to *Juniperus oxycedrus* has wider and thicker leaves at all analysed altitudes. With an increase in altitude, the leaf lengths of *Juniperus communis* and *Juniperus oxycedrus* decrease, while simultaneously, the leaf thickness and width increase,

which clearly indicates the intensification of xeromorphic properties with altitude changes.

The correlations in changes related to the morphological character of a juniper leaf with a change in altitude can be explained by acclimatisation to the environment where the plants live. The active adjustability makes the investigated species efficient and economical in exploiting the available resources of the environment and make them competitive in relation to other habitat species. These correlations in changes of morphological properties of a leaf with increasing altitude can be explained by the fact that in the mountain region, with the increase of altitude, going towards the top, the ecological conditions become less favourable due to which trees and other plants change their shape and size, becoming shorter, with smaller crown and smaller and thicker leaves.

The descriptive analysis of the cuticle on the adaxial and abaxial side of *Juniperus communis* and *Juniperus oxycedrus* leaves has shown that thickness changes with a change in altitude, but the change does not have a continuous increase or decrease. Both species have the thickest leaf front cuticle at 620m. At this altitude the back side of the cuticle is thicker. The cuticle is the thinnest on the front and back sides of leaf samples of *Juniperus communis* taken from 420m, while the *Juniperus oxycedrus* leaves have the thinnest cuticle on both sides at 1020 m.

The *Juniperus communis* and *Juniperus oxycedrus* species have the most distinctive xeromorphic properties (cuticle thickness and epidermis wall thickness) at the altitude of 620 m, which indicates that these species are optimally adjusted to the ecological conditions at higher altitudes, adapting differently at lower and higher altitudes. These species are as the evergreen sclerophytes (xerophytes with xerophyte structure) exposed to difficulty in accessing water in the leaves during winter, as well as in spring, due to the frozen ground and insufficiently warm surface (psychophytes).

To overcome this problem, a thick cuticle and a thick epidermis wall are of major importance as they reach their maximum value at 620 m, where these plants are best adjusted. At higher altitudes it is more difficult for the plants to subsist and they do not manage to develop sufficiently strong defensive mechanisms: for this reason, they have thinner walls in their epidermis. This helps them in the physiological drought conditions caused by low temperatures reduce cuticular transpiration to minimum. The genus *Juniperus*, as a conifer, does not have tracheas but only tracheid's (phylogenetic character), which makes the leaf water supply difficult. Apart from changes in cuticle thickness and epidermis, conifers struggle with the lack of water by shortening their leaves and reducing the number of their stomata.

Regarding the epidermis properties, descriptive statistics shows that they change with an increase in altitudes. The thickness of the outer and inner walls of the epidermis on the adaxial and abaxial side of the leaf of *Juniperus communis* and *Juniperus oxycedrus* gradually increases with an increase in altitude. The

leaves of *Juniperus oxycedrus* have a slightly thinner epidermis on the adaxial and abaxial side at 1020 m. The juniper leaves at 620 m have the thickest outer and inner wall of epidermis on the adaxial and abaxial side. Their epidermis, compared to the leaves from other altitudes, is distinctively thicker; double the size in some cases. It was particularly visible on the outer walls of the epidermis.

The epidermis width and height on the adaxial and abaxial side of the leaves of *Juniperus communis* and *Juniperus oxycedrus* show similar relations as the epidermis wall thickness. Namely, the epidermis width and height gradually increase with increasing altitude. Only *Juniperus oxycedrus* species shows a trend of rapid increase in the value of the front epidermis height of leaf samples taken from 820 m. As for the width and height of the front and back side epidermis, both species share a common feature: the epidermis is widest and highest in plant samples taken from 620 m.

Unlike the epidermis properties of *Juniperus communis* and *Juniperus oxycedrus* that demonstrated the same trend of changing the character with an increase in altitude, there is the absence of these changes in the length and width of the conductive vessels. These values increase with the altitude increase. However, the increase is interrupted at 1020 m and the value starts slightly to decrease up to 1420 m. As for most other anatomical characters, the highest values are at 620 m, while the thinner and wider diameters of conductive vessels of *Juniperus oxycedrus* become smaller with the altitude increase, so at the largest height of 1420 m, their values rapidly increase reaching their maximum. The juniper leaves of *Juniperus communis* and *Juniperus oxycedrus* species were taken from 620 m and had the highest values of the thinner and wider diameters of a resin canal. At this altitude, the resin canals were considerably longer and wider than at other altitudes. Their width was almost double the width at the lowest altitude and almost by a third larger than the width from higher altitudes.

Regarding other altitudes, it was observed that these two juniper species showed a slight increase in the resin canal length and width with the altitude increase. It should be emphasised that the *Juniperus communis* species had considerably longer and wider resin canals at all altitudes than *Juniperus oxycedrus* species.

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**Predrag VASIĆ, Zoran KRIVOŠEJ,**  
**Marina TOPUZOVIĆ, Darko DUBAK and Danijela PRODANOVIĆ**

**MORFOLOŠKO - ANATOMSKE KARAKTERISTIKE DVIJE**  
**VRSTE KLEKE (*Juniperus communis* I *Juniperus oxycedrus*) S**  
**PODRUČJA KOPAONIKA SRBIJI**

**SAŽETAK**

Ovaj rad ima za cilj istražiti različita anatomska i morfološka obilježja dvaju različitih vrsta kleke (*Juniperus communis*, *Juniperus oxycedrus*) s područja Kopaonika. Analizirani su primjerci vrsta *Juniperus communis* i *Juniperus oxycedrus* koji su prikupljeni sa nadmorskih visina od 420 metara i 1420 metara. Ovaj rad predstavlja analizu tri morfološke i šesnaest anatomske karakteristike navedenih vrsta.

**Ključne riječi:** *Juniperus communis*, *Juniperus oxycedrus*, morfološko-anatomske karakteristike, nadmorska visina