Available online: August 17, 2018

Commun.Fac.Sci.Univ.Ank.Series C
Volume 27, Number 1, Pages 61-84 (2018)
DOI: 10.1501/commuc_0000000192
ISSN 1303-6025
http://communications.science.ankara.edu.tr/index.php?series=C

THE MORPHOLOGICAL PROPERTIES OF LEAVES, CONES, SEEDS OF SOME JUNIPERUS SPECIES NATIVE TO TURKEY

AYŞEGÜL KÖROĞLU, GÜLSEN KENDİR, DERYA ŞİMŞEK, NATALIZIA MICELI, NUR MÜNEVVER PINAR

ABSTRACT. This work was designed to evaluate morphologic and micromorphological properties of leaf, cone and seed of some *Juniperus* species from Turkey: *Juniperus drupacea* (*Caryocedrus* section), *Juniperus communis* var. *communis*, *Juniperus communis* var. *saxatilis*, *Juniperus oxycedrus* subsp. *oxycedrus*, *Juniperus oxycedrus* subsp. *macrocarpa* (*Juniperus* section). Features of *Juniperus* species of leaf, cone and seed are investigated by Leica S8 Apo digital photomicrograph system and Jeol JSM 6490LV scanning electron microscope. The leaves usually carry double stomatal band on the inner surface except that *J. communis* subspecies. The resin pits number on the seed surface is varied 1-11. This resin pits on the seed surface was not observed in *J. drupacea*.

1. INTRODUCTION

The genus *Juniperus* L. (Cupressaceae) is composed of evergreen shrubs or trees which form extremely different genera with taxa found from sea level to above the timberline. The genus is monophyletic, consists of 75 species and is divided into three sections according to the relationship of leaf form, female flower features and cone scale to the seed bud. These are sect. *Caryocedrus* Endlicher [contains only one species (*J. drupacea* Labill. (syn: *Arceuthos* Antoine)], sect. *Juniperus* L. [sect. *Oxycedrus* Spach, includes 14 species, 12 of them in the eastern hemisphere], and Sect. *Sabina* (Miller) Spach. [approximately 60 species distributed in the eastern and western hemisphere] [1]. *Juniperus oxycedrus* L. (*J. oxycedrus* subsp. *macrocarpa* (Sibth.& Sm.) Ball, *J. oxycedrus* subsp. *oxycedrus*) and *J. communis* L. (*J. communis* var. c*ommunis*, *J. communis* var. *saxatilis* Pall.) are in the section of *Juniperus*; *J. drupacea* belongs to *Caryocedrus* section. These species are spread from sea level to the alpine zone at different altitude levels in Turkey [1-4].

Received by the editors: July 03, 2018; Accepted: July 27, 2018.
Key word and phrases: *Juniperus*, leaf morphology, cone morphology, seed morphology, Turkey.

This genus has the basic chromosome number, x= 11, all taxa are diploid but a few triploid and tetraploid taxa have been noted [5]. Adams and Demeke (1993) [6] have shown that RAPDs (Random Amplified Polymorphic DNA) can be used in *Juniperus* taxonomy, ranging from sectional to infraspecific levels. Adams et al. (2002) [7] applied RAPDs to *Juniperus* species from eastern Asia (especially Japan and Taiwan).

The basic morphological features of leaves, cones and seeds in three populations of *J. oxycedrus* subsp. *macrocarpa* from Italy were investigated biometrically. In addition, the intra- and inter-population variation of *J. oxycedrus* subsp. *oxycedrus* in the Mediterranean region were determined biometrically on the basis of the morphological features of leaves, seeds and cones [8]. The morphological properties (leaf length and weight, unripe cones weight) of *J. communis* within different ecological situations in habitats in Lithuania were investigated [9]. The variety of morphological and anatomical features of *J. communis* and *J. oxycedrus* from the area of Kopaonik Mountain have been investigated by Vasic et al.. The taxa were collected at different heights (420-1420 m) in the study area. Three morphological and 16 anatomical characteristics of the taxon were analyzed [10].

The leaf anatomy of *J. communis* and *J. chinensis* L. from Romania was demonstrated in the comparative anatomical study of six Gymnospermae species [11]. The anatomical properties of the leaves of *Juniperus* taxa in the *Juniperus section (Juniperus drupacea, J. communis* var. *communis, J. communis* var. *saxatilis, J. oxycedrus* subsp. *oxycedrus* and *J. oxycedrus* subsp. *macrocarpa*) naturally growing in Turkey were examined using transverse and surface sections from the leaves [12]. Lakusic and Lakusic (2011) [13] investigated the variability of anatomical features of leaves and stems in the sect. *Juniperus* (*J. communis* subsp. *communis* var. *communis, J. communis* subsp. *communis* var. *intermedia* Sanio, *J. communis* subsp. *alpina* (Suter) Čelak and *J. deltoides* Adams) from Balkan Peninsula. They showed that the anatomical features of leaves and stems of *Juniperus* genus have taxonomic importance at the species and infraspecies levels. Comparative anatomy of the leaves (needle-like or scales) was conducted on Juniperus species growing in Iran with the use of a light microscope (*J. foetidissima*, *J. excelsa, J. sabina, J. communis* and *J. oblonga* M. Bieb.) [14]. Kim (2012) [15] analyzed scale leaf surface structures of *J. chinensis* from Korea using scanning electron microscopy. The anatomical characteristics of *J. oxycedrus* leaves from Kopaonik Mountain (Serbia) which were collected from different altitudes were examined [16].

The cones and leaves of this species have medicinal properties [17, 18]. Cones are used as a spice, mainly in European cuisine; they are used in Northern European and particularly Scandinavian cuisine to impart a sharp, clear flavour to meat dishes [19]. The dried ripe cone of *J. communis* is registered as Iunioeri pseudo-fructus in the European Pharmacopoeia, 6th edition [20].

According to reports in the literature, morphological studies have been conducted on intraspesific differentiation of *Juniperus* species in particular. Few reports have recorded the micromorphological descriptions of leaves, cones and seeds of *Juniperus* species and their medicinal values. In this study, we analysed the morphological properties of leaves, cones and seeds of *Juniperus* naturally growing in Turkey in the *Juniperus* and *Caryocedrus* sections and determined morphological differences between the *Juniperus* species.

2. Materials and Method

2.1. Plant Material

The studied plant materials were collected at dissimilar seasons and from the different locations of Turkey. The specimens were deposited in the Ankara University Faculty of Pharmacy Herbarium (AEF). Locations and collectors of investigated specimens are present in Table 1.

Table 1. The collection data of the studied *Juniperus* species

Taxon	Locality and collection year	Voucher and specimen code
J. drupacea Labill.	C3 Konya, 10.09.2005	*A. Güvenç, U. Güvenç* (AEF 23609)
J. communis L.var. *communis*	B9 Ağrı, 16.10.2004	*M. Koyuncu, A. Erdem* (AEF 23854)
J. communis L.var. *saxatilis* Pall.	A4 Ankara, 22.05.2004	*A. Güvenç, E. Şatır* (AEF 23801)
J. oxycedrus L. subsp. *oxycedrus*	A4 Ankara, 22.05.2004	*A. Güvenç, E. Şatır* (AEF 23799)
	A1 Çanakkale, 13.06.2009	*A. Güvenç, U. Güvenç* (AEF 25524)
J. oxycedrus L. subsp. *macrocarpa* (Sibth. & Sm.) Ball.	B1 İzmir, 25.09.2004	*A. Erdem, E. Şatır* (AEF 23855)

2.2. Morphological Analysis

Each value is the average of ten measured of leaf, cone and seed from each species were recorded for each morphological features. Morphological photographs of leaf,

cone and seed from each species were taken under the Leica S8 Apo digital photomicrograph system (Germany).

In the scanning electron microscopy (SEM) investigations, leaf, cone and seed parts were attached to aluminum stubs and covered with gold for 4 min in a sputter-coater. Morphological observations were done in a Jeol JSM 6490LV scanning electron microscope at Turkish Petroleum International Company (TPAO) research center SEM laboratory, Ankara.

2.3. Numerical analysis

The Simpson and Roe graphical test [21] was used for statistical analysis (Figure 1). Leaf, cone and seed characters of the 5 taxa coefficients of correlation were determined, and they were grouped using the clustering analysis method (UPGMA, dissimilarity, standardized variables).

Firstly, three characters for leaf, four characters for cone and three characters for seed were selected to distinguish the five taxa of the genus *Juniperus*. Then whole characters which belong to leaf, cone and seed were analyzed together in the method (Table 2). Every morphological characters state and their values or scales are given in Tables 3, 4 and 5.

TABLE 2. Ten morphological characters to distinguish the 5 taxa of the genus *Juniperus*

Taxa/characters	Needle L/W	Stomata long (µm)	Apex	Cone L/D	Cone outline	Cone color	Cone ornamentation	Seed L/W	Seed outline	Seed color
J. drupacea	7,93	0	0	1,11	0	0	0	2,57	0	0
J. communis var. *communis*	8,92	1	1	0,77	1	1	0	1,55	1	1
J. communis var. *saxatilis*	5,26	0	2	0,76	1	1	0	1,53	2	1
J. oxycedrus subsp. *oxycedrus*	8,33	2	3	0,75	1	0	1	1,14	3	1
J. oxycedrus subsp. *macrocarpa*	6,67	3	1	1,30	0	2	0	1,23	3	2

TABLE 3. Needle morphology of *Juniperus* (values in mm)

Taxa	Length (L)			Width (W)			*L/W*	Stomatal band width			Stomata long (µm)	Apex
	Min	Max	Mean	Min	Max	Mean		Min	Max	Mean		
J. drupacea	4	22	11,9	1	2,5	1,5	7,93	0,16	0,83	0,46	Ca. 50	Acuminate
J. communis var. *communis*	6	14,5	10,7	1	1,5	1,2	8,92	0,33	0,55	0,47	Ca. 75	Acute or Acuminate
J. communis var. *saxatilis*	4,5	8,5	6,58	1	1,5	1,25	5,26	0,44	0,63	0,56	Ca. 50	Acute
J. oxycedrus subsp. *oxycedrus*	6	16,5	11,5	1	1,5	1,38	8,33	0,16	0,36	0,27	Ca. 70	Acuminate or Mucronate
J. oxycedrus subsp. *macrocarpa*	4,5	16	9	1	1,5	1,35	6,67	0,2	0,8	0,41	Ca. 100	Acute or Acuminate

TABLE 4. Cone morphology of *Juniperus* (values in mm)

Taxa	Length (L)			Diameter (D)			*L/D*	Seed number	Outline	Color	Ornamentation (SEM)
	Min	Max	Mean	Min	Max	Mean					
J. drupacea	19	25	21	17	22	19	1,11	2-3	Globose-ovoid	Brown	Reticulate
J. communis var. *communis*	5,5	8	6,3	7,5	9	8,15	0,77	2-3	Globose	Purplish black	Reticulate
J. communis var. *saxatilis*	4,5	7	5,83	6	9	7,67	0,76	1-3	Globose	Purplish black	Reticulate
J. oxycedrus subsp. *oxycedrus*	6	10	7,17	8	11	9,5	0,75	2-3	Globose	Brown	Reticulate-Echinate
J. oxycedrus subsp. *macrocarpa*	11	14	12,7	9	12,5	9,8	1,30	2-4	Globose or ovoid	Red-Brown	Reticulate

TABLE 5. Seed morphology of *Juniperus* (values in mm)

Taxa	Length (L)			Width (W)			*L/W*	Outline	Color	Resin pits number	Ornamentation (SEM)
	Min	Max	Mean	Min	Max	Mean					
J. drupacea	7	8	7,5	2,5	3,5	2,92	2,57	Oblong	Brownish	-	Striate- Reticulate
J. communis var. *communis*	4,5	5,5	5,05	2,5	4	3,25	1,55	Ovate-lanceolate	Orange	5-7	Striate- Reticulate
J. communis var. *saxatilis*	3,5	5,5	4,33	1,5	3,5	2,83	1,53	Broadly elliptical-ovate	Orange	3-6	Striate- Reticulate
J. oxycedrus subsp. *oxycedrus*	4	5	4,71	2,5	5	4,14	1,14	Ovate or Broadly elliptical	Orange	3-11	Striate- Reticulate
J. oxycedrus subsp. *macrocarpa*	5	6,5	6,15	4	6	5	1,23	Ovate or Broadly elliptical	Brown	1-4	Striate- Reticulate

The clustering analysis was based on Gower's (1971) general coefficient similarity [22], which can be used directly with a mixture of binary, qualitative and quantitative characters. Unweighted pair group method using arithmetic averages

(UPGMA) was selected because of the most commonly used method [23]. Also It has advantages compared to other methods. These are accurate reflection similarity matrix as measured by the co-phenetic correlation coefficient of Sokal and Rohlf [24], symmetrical hierarchical structure [25] and congruence with classification derived by traditional methods [26]. In order to interpret and summarize the data, Principle Component Analysis (PCA) was used for identification of valuable morphological characters used for taxonomy. All computations were made by the MVSP 3.2 software.

3. Results And Discussion

3.1. Leaf Morphology

The leaves are green, usually needle-like and rigid at the young branches; the mature leaves are also needle-like, rigid and combined at the base, in whorls of three, or scale-like and decussate, seldom short, needle-like and not combined [2]. Leaves are 6.58-11.9 mm long and 1.2-1.38 mm wide (Table 3, Figure 1). *J. drupacea* leaves have two white stomatal bands on the inner surface, acuminate at apex. *J. communis* var. *communis* and *J. communis* var. *saxatilis* leaves have a single stomatal band on the inner surface (seldom uncertain midrib splitting the band in the lower half). *J. communis* var. *communis* leaves are acute or acuminate at apex, *J. communis* var. *saxatilis* leaves are acute at apex. *J. oxycedrus* subsp. *oxycedrus* leaves have double white stomatal bands on the inner surface, apex acuminate or mucronate. *J. oxycedrus* subsp. *macrocarpa* leaves have two distinct white stomatal bands on the inner surface, apex acute or acuminate. Stomatal bands are 0.27- 0.56 mm wide. The stomata is ovoid and 50-100 μm long. Stomatal guard cells surrounding stomatal pores were pronouncedly elevated from the contiguousing epidermis (Table 3). Epicuticular waxes coated the stomatal pores, stomatal guard cells, and their enclosing regions (Figures 2 and 3).

3.2. Numerical Data Analysis of the Leaves

A dendrogram of cluster analysis of *Juniperus* taxa based on three leaf character states (L/W, stomata long (μm) and apex) of five taxa has been constructed. This dendrogram shows the similarities or dissimilarities which exist among the taxa being studied. Cluster analysis divided the taxa into two main groups, namely Cluster A and B. Cluster A includes *J. drupacea, J. communis* var. *communis* and

J. communis var. *saxatilis*, Cluster B includes *J. oxycedrus* subsp. *oxycedrus* and *J. oxycedrus* subsp. *macrocarpa* (Table 2, Figure 4A).

3.3. Cone Morphology

Juniperus species have male and female flowers. Male flowers consist of numerous stamens. Female flowers are encircled at the base by small permanent bracts and composed of fleshy female cone. The cone scales are merged. This cone is usually known as the "fruit" or "berry" and ripens in 1-3 years. It is globose to ovoid, usually glaucous, with permanent scales, 1-5 couples or whorls of three, peltate or valvate and firmly united [1, 2]. The cone surface is usually glabrous (Table 4, Figure 1). Cones are 7.67-19 mm in diameter, 5.83-21 mm long and 0.11-4.18 gr weight. *J. drupacea* is found to have the biggest cone and this cone is globose and brown. *J. communis* var. *communis* and *J. communis* var. *saxatilis* cones are globose and purplish black; furthermore, the smallest cone is *J. communis* var. *saxatilis*. The cone of *J. oxycedrus* subsp. *oxycedrus* is globose and brown. That of *J. oxycedrus* subsp. *macrocarpa* cone is globose or ovoid and red-brown. The cone stalk is 0.7-5.17 mm long. *J. communis* var. *communis* and *J. communis* var. *saxatilis*, *J. oxycedrus* subsp. *oxycedrus* cone stalks bear 6 scale leaves, arranged in two rows (Table 4). *J. drupacea* and *J. oxycedrus* subsp. *macrocarpa* cone stalks are densely clothed with scale leaves. Ornamentation is generally reticulate. However, *J. oxycedrus* subsp. *oxycedrus* has reticulate-echinate ornamentation (Figures 5 and 6).

3.4. Numerical Data Analysis of the Cone

A dendrogram of cluster analysis of four cone character states (L/D, outline, color and ornamentation) has been taken into consideration. Cluster analysis divided the taxa into two main groups namely cluster A and B. Cluster A includes *J. drupacea*, *J. communis* var. *communis*, *J. communis* var. *saxatilis* and *J. oxycedrus* subsp. *oxycedrus*, Cluster B includes only *J. oxycedrus* subsp. *macrocarpa* (Table 2, Figure 4B).

3.5. Seed morphology

The seeds are wingless and have different shapes: ovate, ovate-lanceolate, broadly elliptical-ovate and oblong. The surface is usually glabrous. Seed number varies between 1 and 4. The size of the seeds is between 4.33-7.5 mm in length and 2.83-5 mm width (Table 5, Figure 1). The color is observed to be orange (*J. communis* var. *communis*, *J. communis* var. *saxatilis*, *J. oxycedrus* subsp. *oxycedrus*), brown

(*J. oxycedrus* subsp. *macrocarpa*), and brownish (*J. drupacea*). The seed bases are usually obtuse. *J. communis* var. *saxatilis*'s seed base is observed to be obtuse or emerginate. The apex is acute (*J. communis* var. *communis*, *J. communis* var. *saxatilis*, *J. oxycedrus* subsp. *macrocarpa, J. oxycedrus* subsp. *oxycedrus*) or obtuse (*J. drupacea*, *J. oxycedrus* subsp. *macrocarpa*). The number of resin pits on the surface of seeds is determined to be usually between 1 and 11. The resin pits are not observed in the *J. drupacea* seed. The *J. oxycedrus* subsp. *macrocarpa* seed usually has 1-4 resin pits, but they are sometimes absent. Ornamentation is striate-reticulate (Table 2, Figures 7 and 8).

3.6. Numerical data analysis of the seed

A dendrogram as been made of cluster analysis of three seed character states (L/W, outline and color). Cluster analysis has divided the taxa into two main groups, namely cluster A and B. Cluster A includes only *J. drupace* whereas Cluster B includes the other taxa (Table 2, Figure 4C).

3.7. Numerical analysis of the morphological character states

A dendrogram resulting from the cluster analysis based on ten morphological characters of five taxa of *Juniperus* is presented in Figure 4D. The dendrogram constructed by UPGMA revealed two main groups with a 45% level of similarity, namely Cluster A and B. Cluster A includes only *J. drupacea* whereas Cluster B includes other taxa. Cluster B is divided into two main groups, namely Cluster B1 and Cluster B2. Cluster B1 includes *J. communis* var. *communis, J. communis* var. *saxatilis* and *J. oxycedrus* subsp. *oxycedrus* while Cluster B2 includes only *J. oxycedrus* subsp. *macrocarpa* (Table 2, Figure 4D).

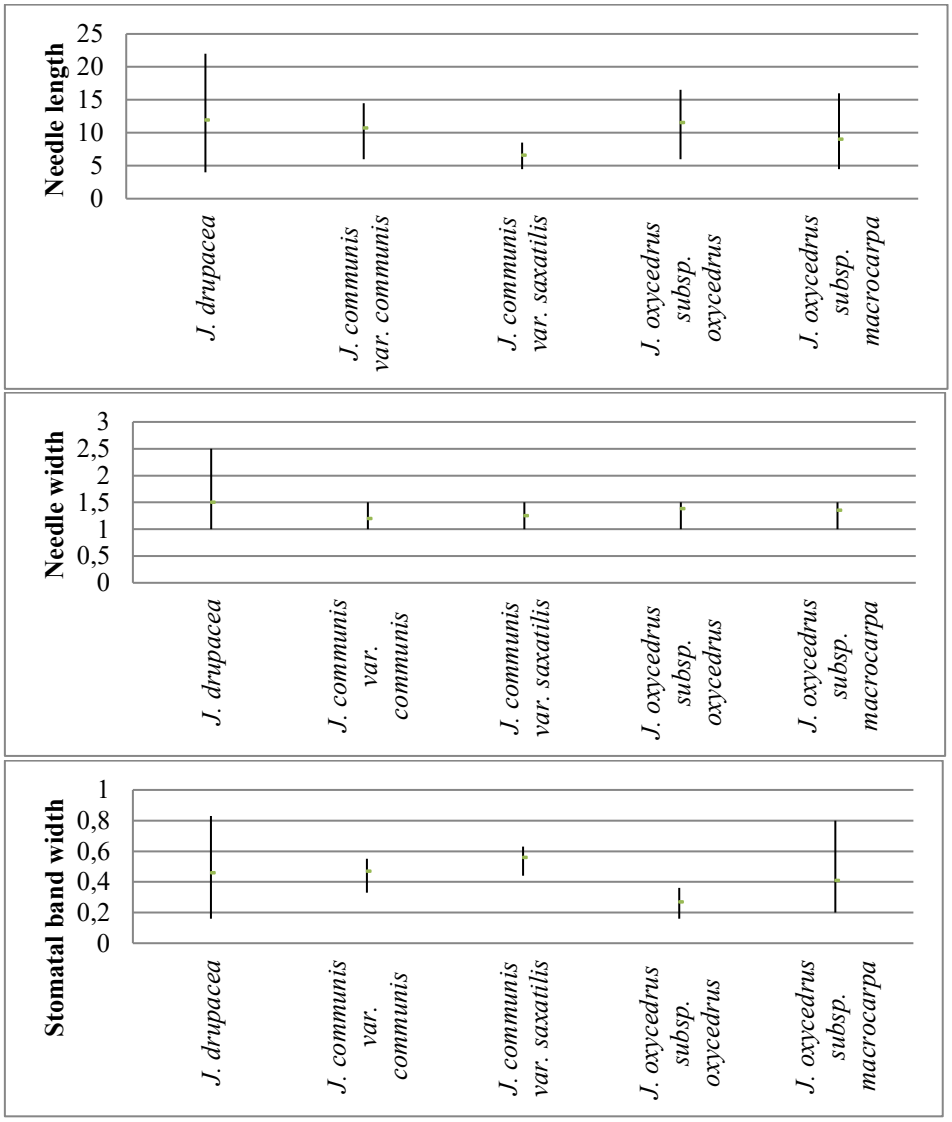
PCA analysis was performed to determine which variables are important in explaining the total variation among the five taxa examined. PCA case scores are given in Figure 9. The PCA loadings and the eigenvalues are given in Table 6. In view of their eigenvalues, only the first three components were taken into account for most of the variance in the data. This is specifically because out of the ten possible components only three explain 92.297% of the total variation. The first principal component explains 44.152% of the total variation in the examined taxa. Seed L/W and seed outline are the most significant variables in the first principal component because they have the highest relative variation rate. Cone L/D and cone color provided the strongest influence on the taxa in the second principal

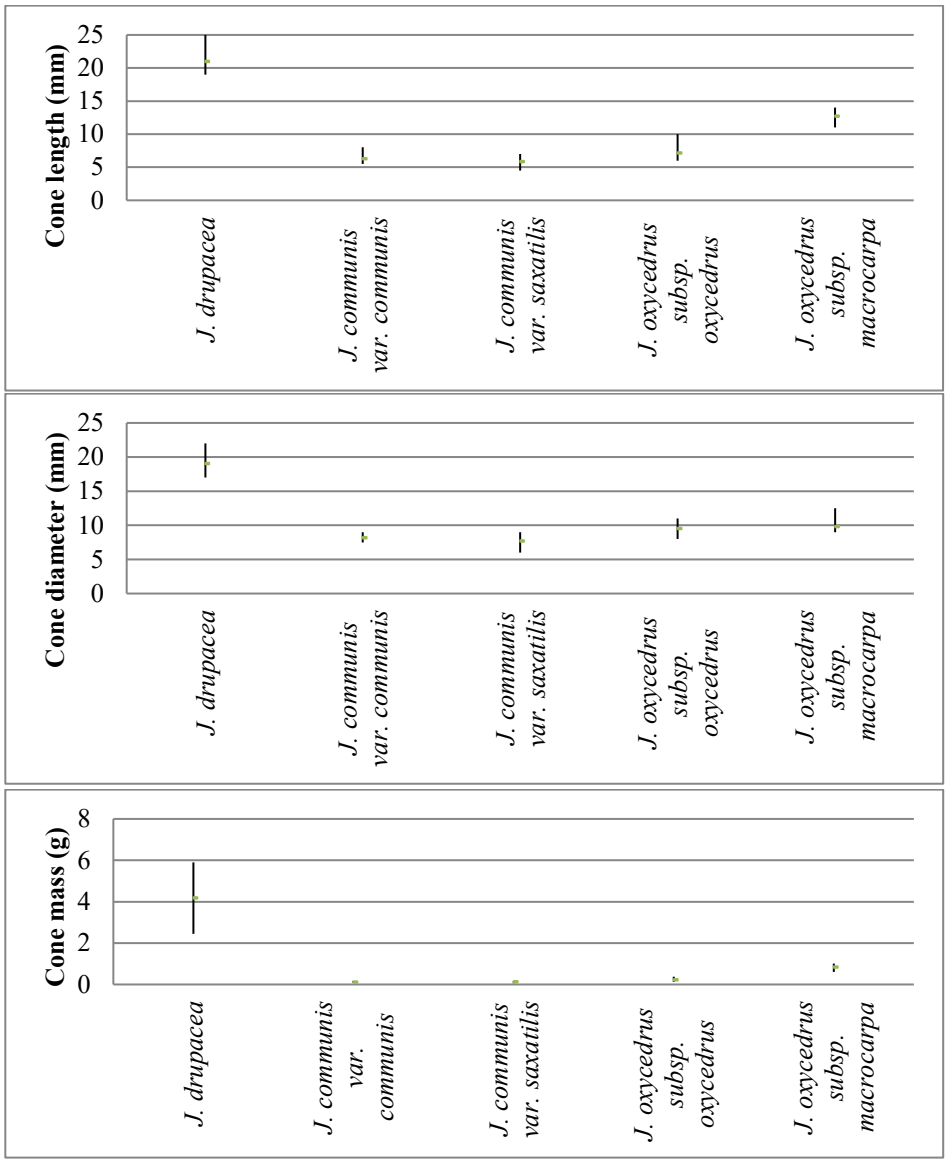
component. These explain 33.477% of the total variation. The third principal component explains 14.668% of the total variation, mainly through the variables of leaf L/W and stomata length (Table 6).

TABLE 6. PCA variable loadings for the first 3 components

VARIABLES	PC 1	PC 2	PC 3
Needle L/W (V1)	-0.087	-0.191	0.607
Stomata Long (μM) (v2)	0.353	0.234	0.420
Apex (V3)	0.372	-0.315	-0.072
Cone L/D (V4)	-0.082	0.488	0.287
Cone Outline (V5)	0.188	-0.422	-0.325
Cone Color (V6)	0.201	0.431	-0.280
Cone Ornamentation (V7)	0.245	-0.346	0.418
Seed L/W (V8)	-0.470	0.013	0.043
Seed Outline (V9)	0.460	0.060	0.037
Seed Color (V10)	0.393	0.291	-0.067
Eigenvalues	4.415	3.348	1.467
Percentage	44.152	33.477	14.668
Cumulative Percentage	44.152	77.629	92.297

In this study, we examined the morphological properties of *Juniperus drupacea, J. communis* var. *communis, J. communis* var. *saxatilis, J. oxycedrus* subsp. *oxycedrus* and *J. oxycedrus* subsp. *macrocarpa* growing in Turkey and used in traditional medicine. To this end, some features of leaf, cone and seed were analyzed. Morphological properties of the taxon were demonstrated with microphotographs from light and scanning electron microscopies.


Needle length
25
20
15
10
5
0
J. drupacea
J. communis var. communis
J. communis var. saxatilis
J. oxycedrus subsp. oxycedrus
J. oxycedrus subsp. macrocarpa
Needle width
3
2,5
2
1,5
1
0,5
0
J. drupacea
J. communis var. communis
J. communis var. saxatilis
J. oxycedrus subsp. oxycedrus
J. oxycedrus subsp. macrocarpa
Stomatal band width
1
0,8
0,6
0,4
0,2
0
J. drupacea
J. communis var. communis
J. communis var. saxatilis
J. oxycedrus subsp. oxycedrus
J. oxycedrus subsp. macrocarpa


Cone length (mm)
25
20
15
10
5
0
J. drupacea
J. communis var. communis
J. communis var. saxatilis
J. oxycedrus subsp. oxycedrus
J. oxycedrus subsp. macrocarpa
Cone diameter (mm)
25
20
15
10
5
0
J. drupacea
J. communis var. communis
J. communis var. saxatilis
J. oxycedrus subsp. oxycedrus
J. oxycedrus subsp. macrocarpa
Cone mass (g)
8
6
4
2
0
J. drupacea
J. communis var. communis
J. communis var. saxatilis
J. oxycedrus subsp. oxycedrus
J. oxycedrus subsp. macrocarpa

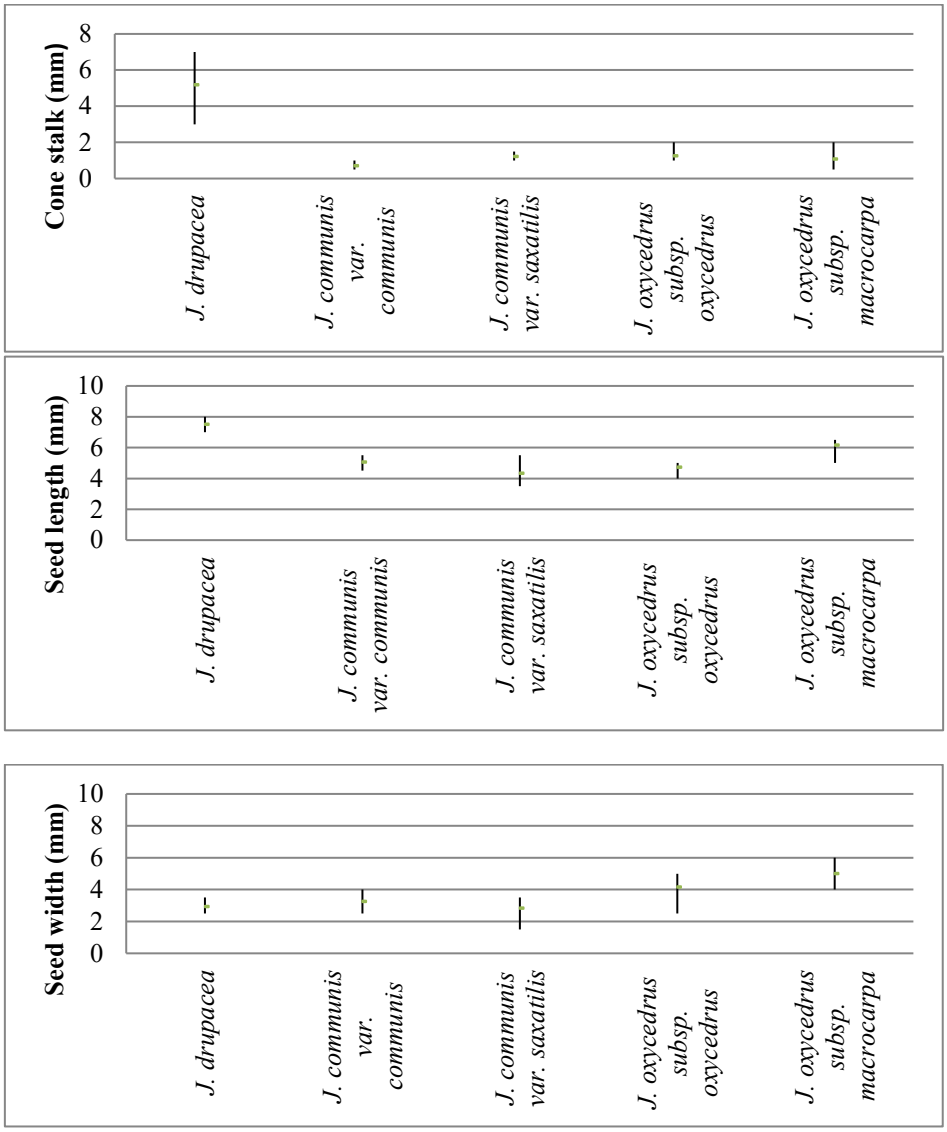


FIGURE 1. Simpson and Roe test for needle, cone and seed of *Juniperus*

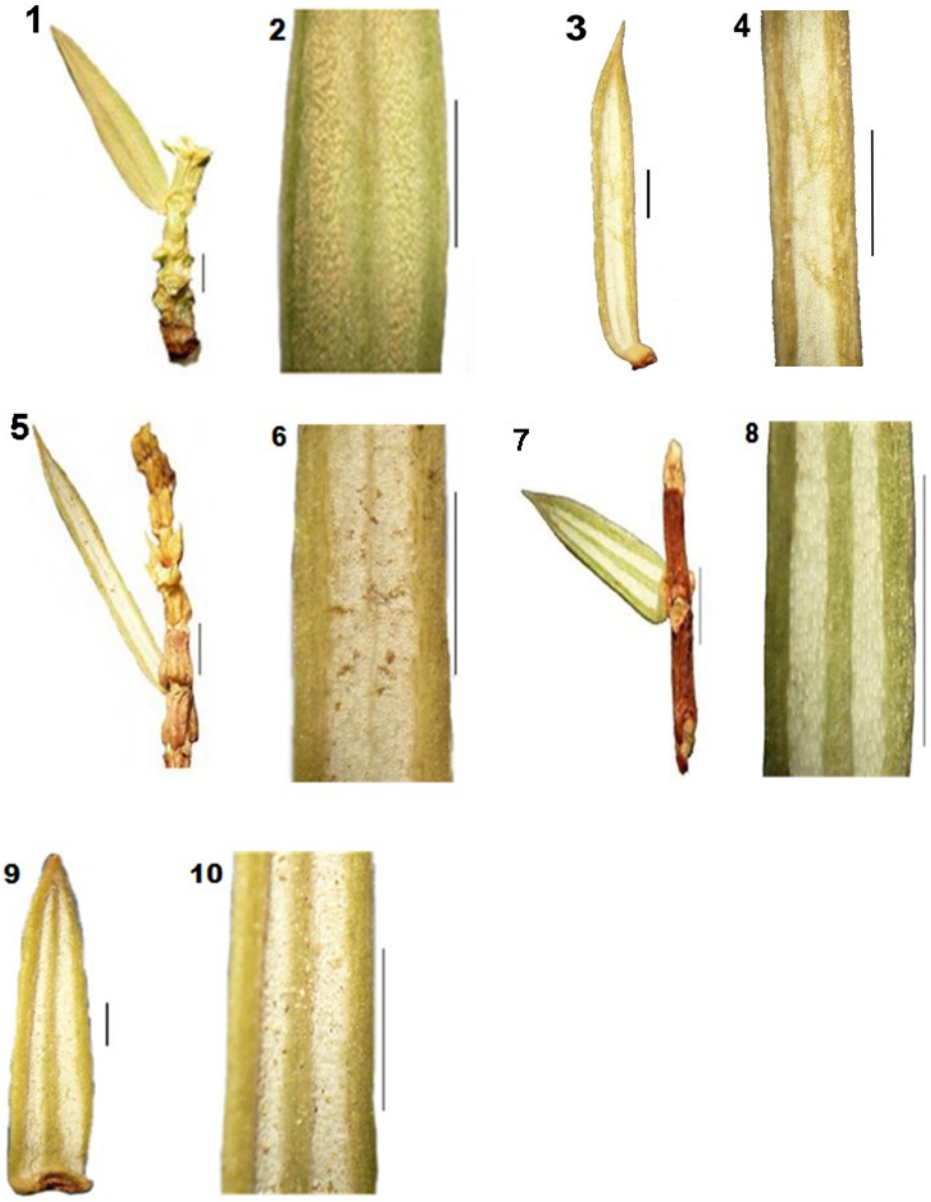


FIGURE 2. Needle of *Juniperus* by light microscope (LM). **1-2** *J. drupacea,* **3-4** *J. communis* var. *communis,* **5-6** *J. communis* var. *saxatilis,* **7-8** *J. oxycedrus* subsp. *oxycedrus,* **9-10** *J. oxycedrus* subsp. *macrocarpa* (scale bar needle; 1 mm).

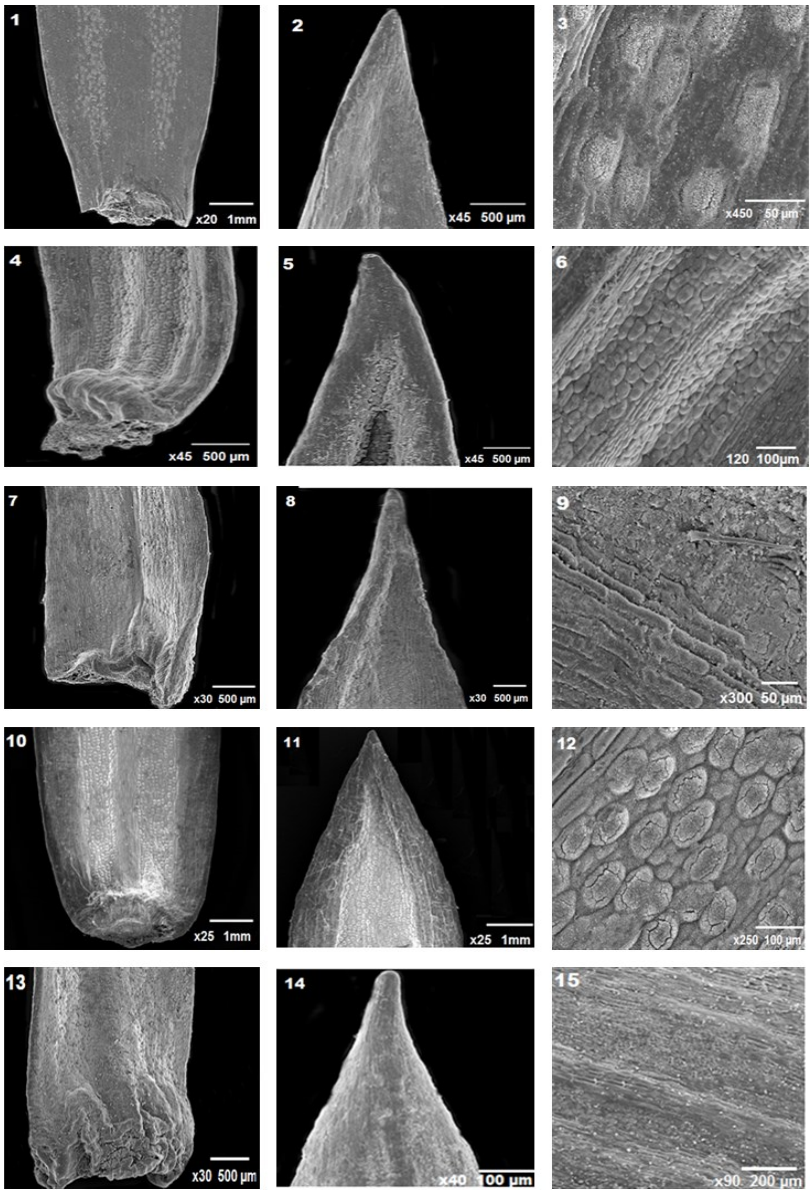


FIGURE 3. Needle surface of *Juniperus* by scanning microscope (SEM). **1-3** *J. drupacea,* **4-6** *J. communis* var. *communis,* **7-9** *J. communis* var. *saxatilis,* **10-12** *J. oxycedrus* subsp. *oxycedrus,* **13-15** *J. oxycedrus* subsp. *macrocarpa*.

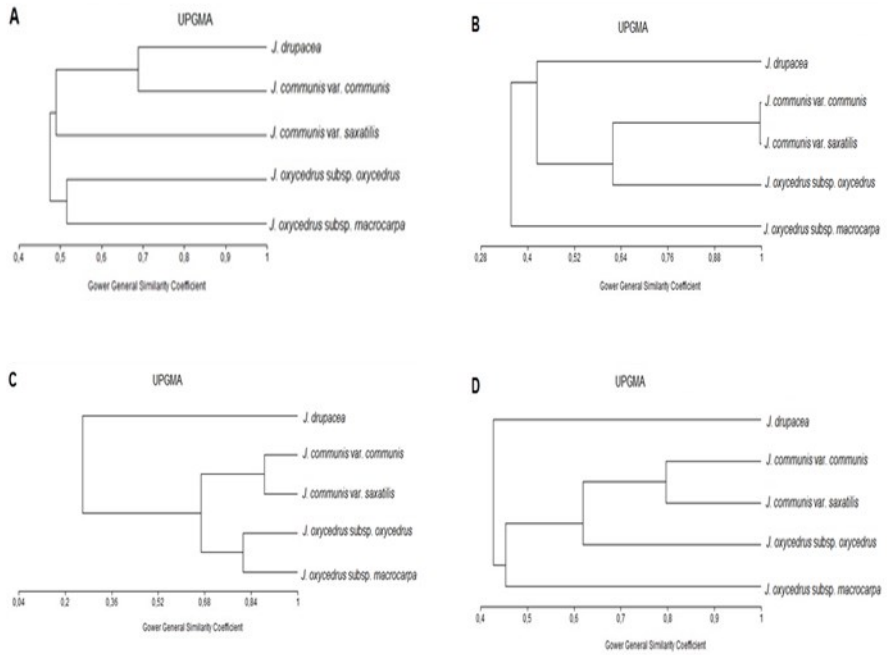


FIGURE 4. Dendrogram showing dissimilarity distance of the examined taxa of *Juniperus*. A-according to needle data, B- according to cone data, C- according to seed data, D-according to combined data of needle, cone and seed.

FIGURE 5. Cone of *Juniperus* by light microscope (LM). **1-** *J. drupacea,* **2-** *J. communis* var. *communis,* **3-** *J. communis* var. *saxatilis,* **4-** *J. oxycedrus* subsp. *oxycedrus,* **5-** *J. oxycedrus* subsp. *macrocarpa* (scale bar cone; 1 mm).

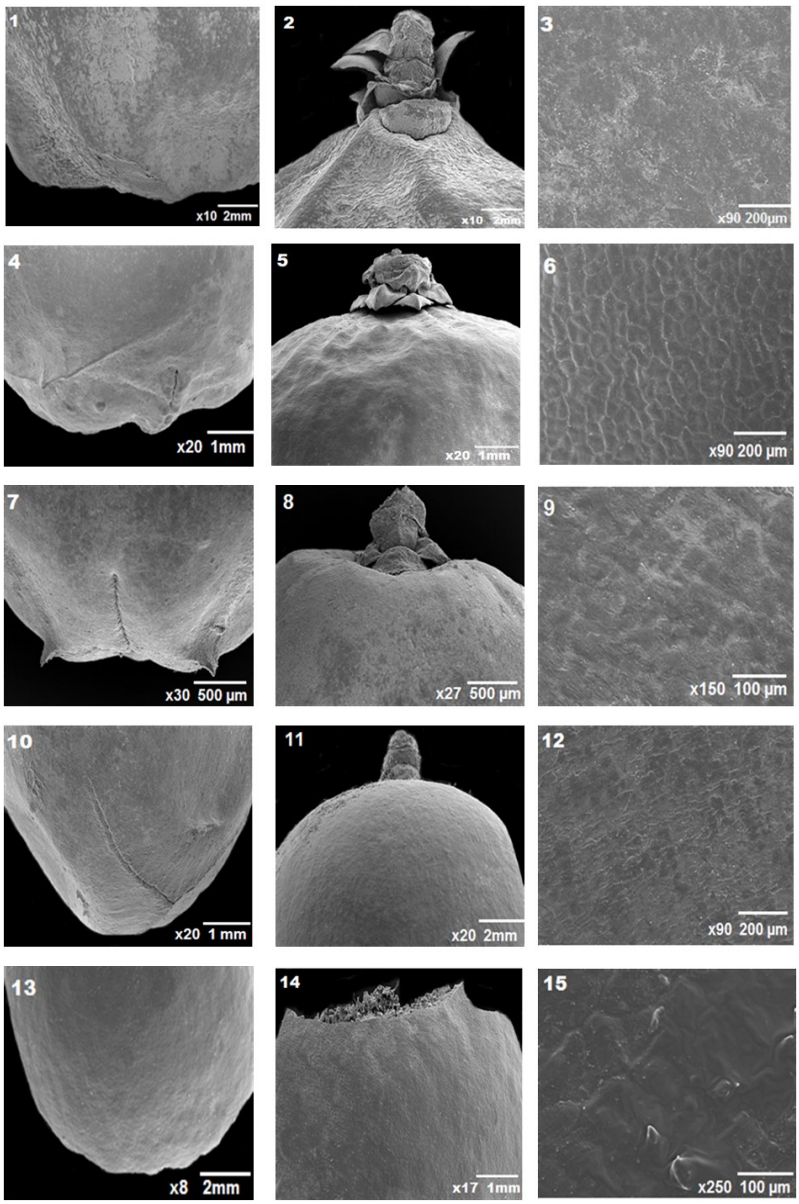


FIGURE 6. Cone surface of *Juniperus* by scanning microscope (SEM). **1-3** *J. drupacea,* **4-6** *J. communis* var. *communis,* **7-9** *J. communis* var. *saxatilis,* **10-12** *J. oxycedrus* subsp. *oxycedrus,* **13-15** *J. oxycedrus* subsp. *macrocarpa.*

FIGURE 7. Seed of *Juniperus* by light microscope (LM). **1-** *J. drupacea,* **2-** *J. communis* var. *communis,* **3-** *J. communis* var. *saxatilis,* **4-** *J. oxycedrus* subsp. *oxycedrus,* **5-** *J. oxycedrus* subsp. *macrocarpa* (scale bar seed; 1 mm).

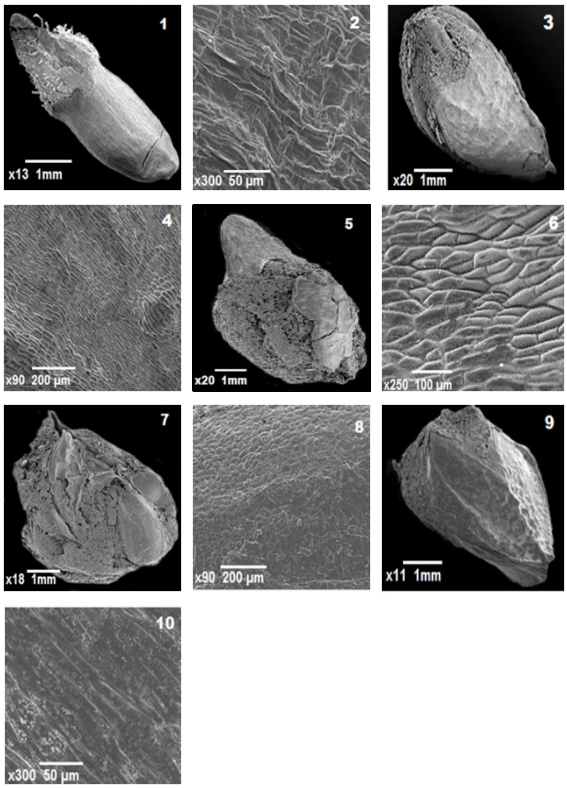


FIGURE 8. General view of seed and surface ornamentation of *Juniperus* by scanning microscope (SEM). **1-2** *J. drupacea,* **3-4** *J. communis* var. *communis,* **5-6** *J. communis* var. *saxatilis,* **7-8** *J. oxycedrus* subsp. *oxycedrus,* **9-10** *J. oxycedrus* subsp. *macrocarpa.*

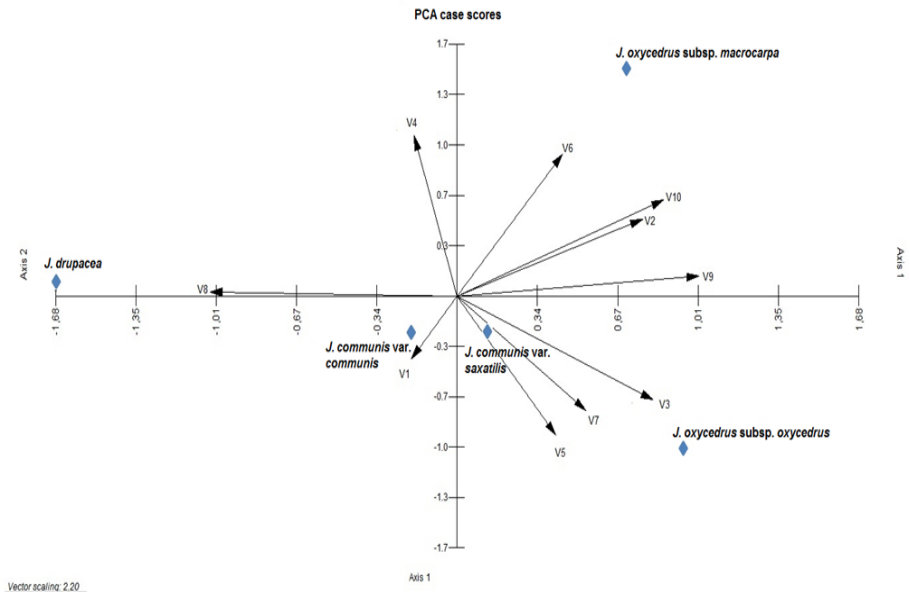


FIGURE 9. Principal component analysis of 5 taxa and 10 variables projected onto the first 2 axes. The signal (♦) is for taxa and variables are showed as vectors.

The leaf shape of the taxon is needle-like. Apart from *J. communis*, the other taxon of leaves bears two white stomatal bands on the inner surface. The largest stomatal band was observed in *J. communis* var. *saxatilis* (mean value: 0.56 mm). Stomata lenght varied betweeen 50-100 µm for these five taxa. The apex of the leaf is usually acute or acuminate. However, *J. oxycedrus* subsp. *oxycedrus* leaf apex is sometimes mucronate. The cone is composed of permanent and firmly united scales. It is usually globose and glabrous. The morphological measurement of the *J. drupacea* cone is different from the other taxon. The *J. drupacea* cone is the biggest cone in the taxon investigated. The color of the cone varies between brown, purplish-black and red-brown. The longest cone stalk is observed in *J. drupacea.* Cone stalks bear usually six scale leaves but *J. drupacea* and *J. oxycedrus* subsp. *macrocarpa* cone stalks are intensively covered with scale leaves. The cone consists of one to four seeds. The seeds range in shape from ovate, ovate-lanceolate, broadly elliptical-ovate to oblong. *J. communis* var. *saxatilis* has the smallest of all seeds. The seed colors are orange, brown and brownish. The number of resin pits on the seed surface varies between 1 and 11 in the four taxa; however, they are not found in *J. drupacea.*

Few studies have offered a morphological analysis of *Juniperus* species. Three remote populations of *J. oxycedrus* subsp. *macrocarpa* from Italy were investigated in terms of intra- and interpopulational alterations [8]. Acording to this study, the dimensional properties of the cone and seed were correlated. No prominent correlation was observed between the properties of the cone and leaf. Variations in cone shape were determined between individuals. Intra- and interpopulational alterations of *J. oxycedrus* subsp. *macrocarpa* were observed to be notably low. Klimko et al. (2007) [27] studied morphological alterations of *J. oxycedrus* subsp. *oxycedrus* in the Mediterranean region and investigated intra- and interpopulational alterations of this taxon. The leaf, cone and seed of *J. oxycedrus* subsp. *oxycedrus* were used for this study. At the end of the statistical analyses, distinct origins of the East and West Mediterranean populations of *J. oxycedrus* subsp. *oxycedrus* were identified. In both studies, eight morphological properties and three ratios were analyzed to identify the alterations in the taxon. Findings obtained from *J. oxycedrus* subsp. *oxycedrus* [27] were compatible with our findings. However, the values obtained from *J. oxycedrus* subsp. *macrocarpa* are found to be lower compared to the previous study [8]. Soil structure and climatic conditions in the place where the plant growth may have influenced these values. Vaičiulytė and Ložienė (2013) [9] investigated the morphological alterations of *J. communis* from different habitats in Lithuania. For this purpose, leaves and unripe cone samples of *J. communis* were obtained from 110 individuals in 11 different habitats. Substantial differences between populations were found in terms of leaf length and unripe cone weight. However, a positive correlation was assigned to the leaf length and leaf weight of the taxon. Not much similarity is observed between this study and our study. Vasic *et al.* (2014) [10] studied leaf length, leaf width and leaf thickness of *J. communis* and *J. oxycedrus* as morphological properties. The morphological properties altered with increasing altitude. The leaf lengths of the taxon decreased with increasing altitude. However, the leaf thickness and width increased. Our values are consistent with the values from the study conducted by Vasic et al. (2014) [10] in terms of leaf width. However, the lowest findings are recorded in terms of leaf length in our study.

In the dendrogram generated from data about the leaf, *J. drupacea* and *J. communis* var. *communis* were quite similar (70%). *J. oxycedrus* subsp. *oxycedrus* and *J. oxycedrus* subsp. *macrocarpa* were also similar (52%). In the dendrogram generated from data about the cone, the percentage of similarity between the *J. communis* var. *communis* and *J. communis* var. *saxatilis* taxa was nearly 98%. Also, *J. oxycedrus* subsp. *macrocarpa* was separated from the other taxa at first. In the dendrogram

generated from data about the seeds, the highest similarity was found not only in the group *J. communis* var. *communis* - *J. communis* var. *saxatilis* (87%) but also *J. oxycedrus* subsp. *oxycedrus* - *J. oxycedrus* subsp. *macrocarpa* (82%). In the three dendrograms, cluster analysis divided the taxa into two main groups and there were some small differences between the dendrograms. Moreover, a dendrogram generated from combined datasets (leaf, cone and seed) of cluster analysis of *Juniperus* taxa based on ten character states of five taxa has been constructed. The highest similarity in terms of characters used (80%) was found in the group *J. communis* var. *communis* and *J. communis* var. *saxatilis*. In addition, *J. drupacea* was separated from the other taxa at first. In the PCA analysis, the first three components underlined the fact that the most valuable morphological variables in separating the taxa of *Juniperus* examined in this study are seed L/W, seed outline and cone L/D. Results derived from the total data about leaf, cone and seed in this study showed that each taxon could be more objectively separated from the others.

4. Conclusion

The morphological properties of leaves, cones, seeds of *Juniperus* species at *Juniperus* and *Caryocedrus* sections naturally grown in Turkey were demonstrated with light and scanning microscopies. Five morphological properties of the leaf, six morphological properties of the cone and six morphological properties of the seed were investigated in this study. *Juniperus* species have needle-like leaves. The leaves usually carry double stomatal band on the inner surface except those *J. communis* species. The stomata are ovoid and ca. 50-100 µm long. The apex of the leaf is acute, acuminate or mucronate. Cones usually consist of 1-4 seeds. The shape of cones is globose, globose-ovoid or ovoid. The cones are different colors: brown, purplish black and red-brown. The seed shape is ovate-lanceolate, oblong, ovate or broadly elliptical-ovate. Seeds are brown, orange or brownish. The number of resin pits number varies from 1-11. Resin pits on the seed surface were not observed in *J. drupacea*. Ornemantations, fruit and seed color, seed shape, and the number of resin pits on the seed surface have been observed to be important morphological properties in terms of the systematics of the taxa.

References

[1] R.P. Adams, *The Junipers of the World: The Genus Juniperus*, 4th ed. Victoria, BC: Trafford Publ., (2014).

[2] M.J.E. Coode, J. Cullen, *Juniperus* L. In: Davis P.H. (ed.). *Flora of Turkey and the East Aegean Islands*, Vol. 1. Edinburgh Univ Press, Edinburgh, (1965) 78-84.
[3] A. Farjon, *Juniperus* L. In: Güner A., Özhatay N., Ekim T., Başer K.H.C. (eds.), *Flora of Turkey and the East Aegean Islands* (Suppl. 2), Vol. 11. Edinburgh Univ. Press., Edinburgh (2000) 8-10.
[4] T. Mataracı, *Juniperus* L. In: Güner A., Aslan S., Ekim T., Vural M., Babaç M.T. (Eds.), *Türkiye Bitkileri Listesi* (*Damarlı Bitkiler*), Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmalar Derneği Yayını, İstanbul, (2012) 12-14.
[5] M.R. Ahuja, Polyploidy in gymnosperms: Revisited, *Silvae Genetica*, 54, (2005) 59-69.
[6] R.P. Adams, T. Demeke, Systematic relationships in *Juniperus* based on random amplified polymorphic DNAs (RAPDs), *Taxon*, 42(3), (1993) 553-571.
[7] R.P. Adams, C. Hsieh, J. Murata, R.N. Pandey, Systematics of *Juniperus* from eastern Asia based on Random Amplified Polymorphic DNAs (RAPDs), *Biochemical Systematics and Ecology*, 30, (2002) 231-241.
[8] M. Klimko, K. Boratynska, A. Boratynski, K. Marcysiak, Morphological variation of *Juniperus oxycedrus* subsp. *macrocarpa* (Cupressaceae) in three Italian localities, *Acta Societatis Botanicorum Poloniae*, 73, (2004) 113-119.
[9] V.Vaičiulytė, K.Ložienė, Variation of chemical and morphological characters of leaves and unripe cones in *Juniperus communis*, *Botanica Lithuanica*, 19(1), (2013) 37-47.
[10] P. Vasić, Z. Krivošej, M. Topuzović, D. Dubak, D. Prodanović, Morphological-anatomical characteristics of two common Junipers (*Juniperus communis* and *Juniperus oxycedrus*) from the area of mountain Kopaonik in Serbia, *Agriculture & Forestry*, 60(1), (2014) 91-104.
[11] R. Bercu, L. Broasca, R. Popoviciu, Comparative anatomical study of some gymnospermae species leaves. *Botanica Serbica*, 34(1), (2010) 21-28.
[12] A. Güvenç, M.M. Hürkul, A. Erdem, The leaf anatomy of naturally distributed *Juniperus* L. (Cupressaceae) species in Turkey, *Turkish Journal of Botany*, 35, (2011) 251-260.
[13] B. Lakušić, D. Lakušić, Anatomy of four taxa of the Genus *Juniperus* sect. *Juniperus* (Cupressaceae) from the Balkan peninsula, *Botanica Serbica*, 35, (2011) 145-156.
[14] A. Hamidipour, T. Radjabian, D.A. Charlet, M. Zarrei, Leaf anatomical investigation of Cupressaceae and Taxaceae in Iran, *Wulfenia*, 18, (2011) 95-111.

[15] K.W. Kim, Epicuticular waxes and stomata of adult scale leaves of the Chinese *Juniper Juniperus chinensis*, *Applied Microscopy*, 42, (2012) 124-128.
[16] P.S. Vasic, D.V. Dubak, Anatomical analysis of red Juniper leaf (Juniperus oxycedrus) taken from Kopaonik Mountain, Serbia, *Turkish Journal of Botany*, 36, (2012) 473-479.
[17] T. Baytop, *Therapy with Medicinal Plants in Turkey* (Past and Present), Nobel Tıp Publication Press, Istanbul, (1999) 153.
[18] İ. Karaman, F. Şahin, M. Güllüce, H. Öğütçü, M. Şengül, A. Adıgüzel, Antimicrobial activity of aqueous and methanol extracts of *Juniperus oxycedrus* L., *Journal of Ethnopharmacology*, 85, (2003) 231-235.
[19] M.R. Loizzo, R. Tundis, F. Conforti, A.M. Saab, G.A. Statti, F. Menichini, Comparative chemical composition, antioxidant and hypoglycaemic activities of *Juniperus oxycedrus* ssp. *oxycedrus* L. berry and wood oils from Lebanon, *Food Chemistry*, 105, (2007) 572-578.
[20] European Pharmacopoeia, Juniper (Iunioeri pseudo-fructus). 01/2008:1532, *Directorate for the Quality of Medicines & HealthCare of the Council of Europe* (*EDQM*), 6(3), Germany, (2008).
[21] A. Van der Pluym, M. Hideux, Applications d'une methodologie quantitative a la palynologie d'*Eryngium maritimum* (Umbelliferae), *Plant Systematics and Evolution*, 127, (1997) 55-85.
[22] P.H.A. Sneath, R.R. Sokal, *Numerical Taxonomy: The Principles and Practice of Numerical Classification*, W. H. freeman and Company, San Francisco, (1973) 573.
[23] S.A. Mohammadi, B.M. Prasanna, Analysis of genetic diversity in crop plants. Salient statistical tools and considerations, *Crop Science*, 43, (2003) 1235-1248.
[24] R.R. Sokal, F.J. Rohlf, The comparison of dendrograms by objective methods, *Taxon*, 2, (1962) 33-40.
[25] J. McNeill, Structural value: a concept used in the construction of taxonomic classifications, *Taxon*, 28, (1979) 481-504.
[26] J.M. Ward, Systematics of New Zealand Inuleae (Compositae–Asteraceae) – A numerical phenetic study of Raoulia in relation to allied genera, *New Zealand Journal of Botany*, 31, (1993) 29-42.
[27] M. Klimko, K. Boratyńska, J.M. Montserrat, Y. Didukh, A. Romo, D. Gómez, M. Kluza-Wieloch, K. Marcysiak, A. Boratyński, Morphological variation of *Juniperus oxycedrus* subsp. *oxycedrus* (Cupressaceae) in the Mediterranean region, *Flora*, 202, (2007)133-147.
[28] T.N. Johnsen Jr., Anatomy of scalelike leaves of Arizona Junipers, *Botanical Gazette*, 124(3), (1963) 220-224.

[29] K. Marcysiak, M. Mazur, A. Romo, J.M. Montserrat, Y. Didukh, K. Boratyńska, A. Jasińska, P. Kosiński, A. Boratyński, Numerical taxonomy of *Juniperus thurifera*, *J. excelsa* and *J. foetidissima* (Cupressaceae) basedon morphological characters, *Botanical Journal of the Linnean Society*, 155, (2007) 483-495.
[30] M. Mazur, K. Klajbor, M. Kielich, M. Sowinska, A. Romo, J.M. Montserrat, A. Boratynski, Intra-specific differentiation of *Juniperus phoenicea* in the western Mediterranean region revealed in morphological multivariate analysis, *Dendrobiology*, 63, (2010) 21-31.

Current Address: Ayşegül KÖROĞLU: Department of Pharmaceutical Botany, Faculty of Pharmacy, Ankara University, 06100 Tandoğan, Ankara, Turkey.
E-mail:aguvenc@ankara.edu.tr
https://orcid.org/0000-0002-8450-1376

Current Address: Gülsen KENDİR (Corresponding author): Department of Pharmaceutical Botany, Faculty of Pharmacy, İstinye University, 34010 Zeytinburnu, İstanbul,Turkey.
E-mail :kendir08@gmail.com
https://orcid.org/0000-0001-8879-3751

Current Address: Derya ŞİMŞEK: Department of Biology, Science Faculty, Ankara University, 06100 Tandoğan, Ankara, Turkey.
E-mail:derya_cdpvz@hotmail.com
https://orcid.org/0000-0001-7286-5626

Current Address: Natalizia MICELI: Department of Chemical, Biological, Pharmaceutical and Enviromental Sciences, University of Messina, Vill. SS. Annunziata, 98168 Messina, Italy.
E-mail:nmiceli@unime.it
https://orcid.org/0000-0002-1611-6564

Current Address: Nur Münevver PINAR: Department of Biology, Science Faculty, Ankara University, 06100 Tandoğan, Ankara, Turkey.
E-mail: Nur.M.Pinar@science.ankara.edu.tr
https://orcid.org/0000-0001-5466-795X