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Original paper

Morphological traits of *Sedum album* sensu stricto (Crassulaceae): variability patterns across the Balkan Peninsula

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Summary. The present study analyzes morphological variability of *Sedum album* in a sample collected on the Balkan Peninsula. The objectives were to determine the degree of morphological variability of the quantitative characters and their importance in possible differentiation within *S. album* sensu stricto populations. Variability was analyzed within 315 individuals from 21 populations. A total of 28 quantitative characters, including characters of the vegetative region, inflorescence and floral parts, were examined. Quantitative data was processed in STATISTICA 8.0, including descriptive statistics, correlation analysis and univariate variance analysis (ANOVA). The obtained results indicate moderate to highly expressed variability of most of the analyzed traits, as well as differences in the mean values of all characters, indicating a high level of morphological diversity of *S. album* in the Balkan Peninsula.

Keywords: Balkan Peninsula, Crassulaceae, morphological traits, morphometry, *Sedum album*, variability pattern.

INTRODUCTION

Crassulaceae DC. is a medium-sized family of mostly succulent plants that includes 1300 to 1500 species, classified in 33-35 genera, with a mainly cosmopolitan distribution (Eggli 2003; Thiede and Eggli 2007; Mort et al. 2010; Christenhusz and Byng 2016). Throughout the Mediterranean region in Europe, it is represented by 177 species of 12 genera along with parts of the Balkan Peninsula ('t Hart 1997). However, although most research to date has focused on precisely classifying the entire Crassulaceae family (van Ham and 't Hart 1998; Mort et al. 2001; Gontcharova and Gontcharov 2008; Mort et al. 2010) the greater problem of clarifying the boundaries and relations between individual taxa in the genus *Sedum* remains to be addressed (Nikulin et al. 2016).

Genus *Sedum* L. with its variety of species is the richest genus of the Crassulaceae family, and it is also morphologically and taxonomically the most diversified and complex genus of this family (Nikulin et al. 2016; Zlatković et al. 2016). Thus, this genus has attracted the attention of many researchers. The genus consists of 400-500 species (Strid and Tan 2002), predominantly distributed in subtropical and temperate regions of the Northern Hemisphere (Strid 1986; 't Hart 1991; Thiede and Eggli 2007). Besides North and Central America, North Africa and much of Asia, *Sedum* is also present in Europe, as represented by 69 species classified in more than 25 series ('t Hart 1997). Of the several dozen species of this genus, autochthonous in the flora of Europe, almost 2/3 can be found in southern Europe and countries with an coast on the Mediterranean Sea (Webb 1964).

The entire classification of Crassulaceae is problematic because a large number of species exhibit similar morphological and cytological traits as well as a high degree of variability, especially in their vegetative features (Strid 1986; Webb et al. 1993; Strid and Tan 2002; Mifsud et al. 2015; Zlatković et al. 2016). *Sedum album*, the focus of the present study, is

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a good example of a species that exhibits clear spatial and environmental morphological variability.

Sedum album L. (*Sedum* ser. *Alba* Berger) is a caespitose, perennial, leafy, succulent plant, often with crawling, rooting stems, subterete, alternately arranged leaves and inflorescence composed of a large number of relatively small, white to pinkish colored flowers. This species predominantly inhabits warm and dry habitats on rocky soils in hills and mountains. Its distribution is represented throughout Europe to Central Scandinavia, in North Africa, Asia Minor, and northern and western Asia (Davis 1972; Strid 1986; Stid and Tan 2002; Eggli 2003). It is one of the most common species of the genus *Sedum* within the Mediterranean region and the Balkan Peninsula. In a morphological sense, it is highly variable with a series of transient morphological forms which has led to complicated intraspecific classification and the allocation of low-level taxa (Eggli 2003). In literature sources, it is often referred to as a complex of the species *S. album*, which is in addition to the typical taxon *S. album*, regarded in the narrow sense (Zlatković et al. 2016). However, there remains a dilemma which representatives of the complex are so-called "stable" or valid taxa, and which characters can be used as reliable to distinguish them. Despite the above described issues, detailed studies of the variability of morphological traits for the typical species *S. album* have not been conducted for either the Balkan Peninsula or the wider region. Scarce data on the variability of a certain number of traits of the species within the complex *S. album* can be found in various regional floras (Jordanov 1970; Davis 1972; Gajić 1972; Strid 1986; Webb et al. 1993; Micevski 1998; Strid and Tan 2002).

In this paper, morphological characters from both vegetative (stem and leaf) and reproductive (flowers and inflorescences) regions of selected *S. album* s.s. populations were examined to provide additional data for systematic delimitation of this species from other interspecific and intraspecific taxa. Accordingly, several aims were highlighted at the beginning of the present study: (1) providing data for selected morphological quantitative characteristics and determining the degree of their variability, using material sampled from the territory of the Balkan Peninsula, (2) separation of potentially significant characters, that are considered reliable for the taxonomy of allied plant groups, by reviewing the results of descriptive analyses, correlation analysis and univariate variance analysis (ANOVA).

MATERIAL AND METHODS

Plant material

The selected morphological characters were analyzed on individuals from 21 populations of *S. album* collected from the territory of the Balkan Peninsula (Albania, Bulgaria, Greece, Macedonia, Montenegro and Serbia). The locations where plant material were collected are indicated on Fig. 1. Detailed information on localities and habitat characteristics are given in Table 1. Representative individuals from each population were deposited in the Herbarium of the Department of Biology and Ecology, Faculty of Sciences and Mathematics, University of Niš (HMN). All employed entities have been identified as *Sedum album* subsp. *eu-album* Syme (*Sedum album* s.s.). The identification of the collected plant material was performed using a key for species constructed by Maire (1977) and including intraspecific *Sedum* taxa.

In order to eliminate the influence of ecological factors in their original, native destinations, all populations were subjected to a period of acclimatization in a greenhouse over a period of at least 12 months prior to morphometric analysis. Cultivation was conducted in a series of plastic pots of the same diameter, on Floradur® substrate (FloraGard, Vertriebs GmbH für Gartenbau, Germany) mixed with sand at a ratio of 4:1.

For the purpose of morphometric analyzes, 15 individuals from each population were isolated (a total of 315 individuals). In the process of further preparation, each individual was labeled with a number for the population and individual.

Characters of vegetative plant region

Measurements of the 13 quantitative characters of the vegetative plant region (1-13, Table 2) were made using a Mahr Federal 4107107 16U digital caliper (Mahr Gmbh, Esslingen, Germany, resolution 0.02 mm) or using a ruler to measure the height of the plant (HP). Measurement of each character was performed in triplicate, with the exception of the characters: height of the plant (HP), diameter of the stem (DS) and length of internodes in the lower and upper part of the stem (LIL, LIU).

Characters of reproductive plant region

Measurements of the 15 quantitative characters of the flowering parts (14-28) were exclusively performed with a digital caliper, while the number of flowers in the main inflorescence (NF) and number of side branches of the main inflorescence (NB) were counted within all examined individuals. The two last characters can have a meristic character. Flowers for each individual were photographed using a Leica MZ-16A stereo microscope (Leica Microsystems©, Wetzlar, Germany) after preparing the appropriate permanent slides. Floral structures were prepared by dissecting the flowers followed by careful separation of flower parts. Millimeter paper was used as a background for photographing the minute perianth segments; while a high-contrast (black)

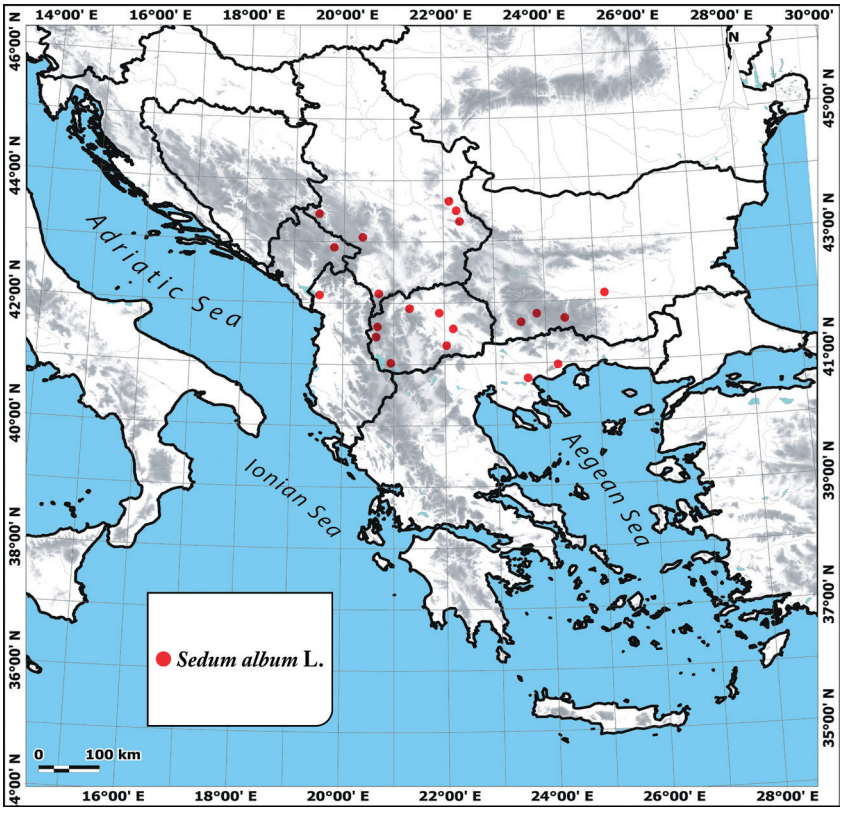

Fig. 1. Locations of analyzed *Sedum album* populations from the Balkan Peninsula.

background was used for photographing filaments and carpels. In order to determine the characters of the nectaries, open flowers with removed carpels were placed on adhesive tape and photographed in the same way. Each permanent slide was marked with a code that indicates the number of the population and the individual from whom the flower originates. All the measurements of the above-mentioned structures were performed in triplicate, using Digimizer Image Analysis software (MedCalc Software©, Belgium) and previously recorded images.

Statistical analysis

All measured data were incorporated into a spreadsheet (Microsoft Office, Excel 2007), and were statistically processed using STATISTICA 8.0 (StatSoft, Inc., Tulsa, USA). The overall analysis involved: analysis of basic statistical parameters (descriptive statistics), correlation analysis and univariate variance analysis (ANOVA).

RESULTS

Characters analysis

The variability of the quantitative characters was visualized through analysis of a total of 28 measured characters. The results of all analyses are presented in tabular form, as well as graphically, using Whisker Plot graphics to illustrate results obtained by descriptive statistical analysis.

Descriptive analysis

On the basis of the obtained values, all characters show a moderate to high degree of variability. Generally, characters of the vegetative region show a high degree of variability while characters of the flowering parts show a moderate degree of variability (Table 2). Thus, as the most variable characters, characterized by large scale deviation of maximum and minimum values from the mean values, and consequently high standard deviation values, the following characters can be segregated: number of flowers in the main inflorescence with the highest standard deviation (NF, 46.6 ± 26.60) within all characters, followed by length of the main inflorescence (LI, 29.6 ± 9.34) and width of the

Table 1. The list of analyzed populations and habitat characteristics of *Sedum album* from the Balkan Peninsula.

No.	Locality	Legator	Substratum	Habitat	Altitude (m)
1.	Macedonia, Rožden, Majdanska reka gorge	Zlatković B, Tomović G	limestone	rocks	541
2.	Greece, Asprovalta, Stavros	Bogosavljević S	limestone	rocks	5
3.	Macedonia, Bistra, Medenica	Zlatković B et al.	limestone	rocks	1941
4.	Bugarska, Dospat, Tešel	Zlatković B et al.	limestone	rocks	859
5.	Serbia, Novi Pazar, Ribariće, Ibar gorge	Zlatković B, Tosić S	limestone	rocks	840
6.	Macedonia, Prespa, Stenje	Zlatković B, Tomović G	limestone	rocks	995
7.	Macedonia, Demir Kapija, Demir Kapija	Zlatković B, Tomović G	limestone	rocks	146
8.	Serbia, Podvis, Svrljiški Timok gorge	Zlatković B, Bogosavljević S	limestone	rocks	280
9.	Macedonia, Bistra, Sence	Zlatković B et al.	limestone	screes	1299
10.	Bulgaria, Goce Delčevo, Dobrotino	Zlatković B, Randjelović V	limestone	rocks	974
11.	Serbia, Mileševo, Mileševka gorge	Zlatković B, Marković M	limestone	screes	661
12.	Serbia, Čiflik	Zlatković B, Marković M	limestone	rocks	379
13.	Greece, Mt. Pangeion	Lakušić D	limestone	rocks	-
14.	Serbia, Mt. Stara Planina, Topli Do	Zlatković B	silicate	rocks	732
15.	Macedonia, Matka gorge	Zlatković B et al.	limestone	screes	367
16.	Bulgaria, Asenovgrad, Kuru Dere	Zlatković B et al.	limestone	screes	343
17.	Bulgaria, Pirin, Banderica	Lakušić D et al.	silicate	rocks	-
18.	Macedonia, Veles, Rajko Žinzifov	Zlatković B, Tomović G	ultramafic	rocks	191
19.	Montenegro, Berane, Donji Zaostro	Zlatković B, Tomović G	limestone	rocks	695
20.	Albania, Skadar, Qafe	Zlatković B et al.	limestone	rocks	71
21.	Serbia, Prizren, Prizrenska Bistrica gorge	Zlatković B et al.	limestone	rocks	540

main inflorescence (WI, 27.2 ± 7.65). The number of flowers in the main inflorescence, the most variable character, is represented by a range from a minimum of 11 flowers to 174 flowers in some individuals. A slightly less variable character, length of the main inflorescence, ranges from a minimum value of 12.0 mm to a maximum value of 66.7 mm. Values for the character, width of the main inflorescence, range from a minimum of 11.6 mm to a maximum of 50.9 mm. The least variable characters of the vegetative region are: thickness of the upper leaf (TU, 1.7 ± 0.45), width of the upper leaf (WU, 2.3 ± 0.51) and thickness of the lower leaf (TL, 2.5 ± 0.56). Within characters of the flowering parts, that overall show moderate to low variability, characters such as length of the nectaries (LN, 0.4 ± 0.06), width of the nectaries (WN, 0.4 ± 0.07) and width of sepals (WS, 0.8 ± 0.12) are distinguished as the least variable. Characters of the nectaries have shown the least variability within all characters, interestingly with the same mean values for length and width of the nectar-secreting structure. Because they are less variable, the following characters for reproductive region could also be distinguished: width of carpels (WO), width of petals (WP) and length of petals (LS). Results from descriptive statistics are also shown in Fig. 2 (NB and NF not represented).

According to values for the coefficient of variation, the following characters: number of side branches in the main inflorescence (NB, CV = 86%), number of flowers in the main inflorescence (NF, CV = 57%) and length of internodes in the lower part of the stem (LIL, CV = 34%) are presented as the most variable, while several floral characters were found to be the least variable: length of petals (LP, CV = 9%), width of petals (WP, CV = 11%), length of filaments (LF) and length of carpels (LO), both with values of CV = 13%.

Correlative variability

Based on the obtained results from correlation analysis (Table 3), it was found that all three degrees of correlation were represented, but a greater number of characters show a very weak positive linear connection (+0.00> r >+0.50). A very strong linear connection (+0.80> r >+1.00) was established in 3 pairs of characters from the vegetative region, which at the same time represents the strongest linear connection within all analyzed characters: These are the following pairs of characters: thickness of the lower leaf/ width of the lower leaf (TL/WL), thickness of the middle leaf/ width of the middle leaf (TM/WM) and thickness of the upper leaf/

width of the upper leaf (TU/WU), and all have the same value of linear connectivity ($r = 0.9$). A linear connection of medium strength ($+0.50 > r > +0.80$) was established in 21 pairs of characters, equally represented in both vegetative and characters of reproductive region. Pairs of characters of the reproductive region with a linear connection of medium strength: width of the bracts/length of the bracts (WB/LB), length of carpels/length of petals (LO/LP) and width of nectaries/length of nectaries (WN/LN), are represented with the same value of linear connectivity ($r = 0.7$). The correlation between vegetative and characters of the reproductive region is very weak, and a linear connection with middle strength ($r = 0.5$) was represented only by three pairs of characters. A negative linear connection is represented in 41 pairs of characters, where all pairs of characters possess a linear connection of low strength ($-0.00 > r > -0.50$).

Analysis of variance (ANOVA)

The results of the ANOVA test are shown in Table 2, including analysis of data for all the quantitative traits examined. The significance of differences in the mean values of certain characters were tested, in particular traits that can have the greatest significance in distinguishing groups of individuals (populations) within the analyzed species. The ANOVA test shows that all characters are statistically significant at an extremely high level ($p < 0.001$). According to the Fisher's coefficient (**F**), the following characters, presented with the highest F values, can be treated as the most significant: thickness of the middle leaf (TM, F = 34.47), width of the middle leaf (WM, F = 37.11), diameter of the stem (DS, F = 35.90), thickness of the lower leaf (TL, F = 34.95) as well as width (WN, F = 31.83) and length (LN, F = 31.43) of nectaries. The above-mentioned set of characters can be considered, on the basis of the results of these analyses, as the most suitable for illustrating morphological differences between populations of *S. album* in the area of the Balkan Peninsula. Characters that showed the lowest F values are: number of side branches of main inflorescence (NB, F = 7.86), width of carpels (WO, F = 8.16), width of the main inflorescence (WI, F = 11.44) and length of internodes in the upper part of the stem (LIU, F = 11.61).

DISCUSSION

High plasticity among almost all characters, including floral characters in *S. album* has been emphasized in the recent literature (Webb et al. 1993; 't Hart 2002). As a widespread species in the Balkans, that usually occurs on dry and rocky terrains, at carbonate (limestone), ultramafic or siliceous substrates, within a large altitudinal scale, *S. album* is expected to demonstrate high plasticity among its morphological features. Results of our present study confirmed that the majority of examined characters manifest a comparatively large degree of variability, especially those including leaves and stems. Generally speaking, the selected characters of the vegetative region show a higher extent of variability in comparison with flower and inflorescence characters. This phenomenon may be due to the fact that vegetative characters are more plastic and, hence more difficult to use in taxonomy (Stuessy 2009), bearing in mind that *S. album* is a succulent plant that stores most of its water in its leaves. On the other hand, generative features, in particular characters of inflorescence and flower parts, are largely used in taxonomical purposes, as oscillation of their values is less pronounced. But regardless of the previously mentioned observations, traits with a very pronounced degree of variability in our study were also the number of flowers in the main inflorescence (NF), as well as length (LI) and width of the main inflorescence (WI). This fact is in accordance with Eggli (2003), who stated that strong variation in *S. album* morphology, except size and shape of the leaves, usually includes flowering parts of that plant. However, analyses have shown that the least variable characters concern several floral structures: length of nectaries (LN), width of nectaries (WN), as well as sepals width (WS), which could have larger taxonomical importance among other characters. Along with given floral characters, width of carpels (WO), width of petals (WP) and length of sepals (LS), could be additionally suggested as moderately stable characters. It is interesting to note that the analyzed leaf characters of *S. album*, regardless of their position at the stem (lower, middle, upper), showed a relatively low degree of variability, which could be contrary to expectations. As it was already stated, characters of the vegetative region in natural habitats usually pronounce high variability (Webb et al. 1993; Eggli 2003), but in the present study the extent of variability of the leaves was to some degree neutralized, probably during the process of acclimatization.

However, the present study employed a large list of characters, including those that can be expected in the current editions of regional floras of Balkan countries (Jordanov 1970; Davis 1972; Gajić 1972; Strid 1986; Micevski 1998) that could be interesting to compare. The majority of available information concerned the group of leaf characters with high incompatibility of character values, depending on different literature sources. For the length of leaves the following values can be found: 4-12 mm (Davis 1972; Gajić 1972; Micevski 1998), 4-18 mm (Jordanov 1970) and 4-20 (25) mm (Strid 1986). In comparison with given values, measured values are almost the same or could vary in a somewhat narrower scale (4.3-12.7 mm), while the maximum measured values are generally less (Table 2). Also, concerning the width of the leaf, the measured minimum (1.5 mm) is below values

Table 2. Results of descriptive statistics of analyzed morphological characters and ANOVA of analyzed populations of *Sedum album* from the Balkan Peninsula.

	Character abbreviation, name and unit		N	Mean	Min.	Max.	Std. Dev.	CV %	F	p
Vegetative part	1. LL	Length of the lower leaf (mm)	315	6.8	4.1	12.1	1.54	23	19.67	0.000
	2. WL	Width of the lower leaf (mm)	315	3.3	1.6	5.9	0.68	21	31.34	0.000
	3. TL	Thickness of the lower leaf (mm)	315	2.5	0.9	3.8	0.56	23	34.95	0.000
	4. LM	Length of the middle leaf (mm)	310	7.2	4.3	12.7	1.71	24	20.27	0.000
	5. WM	Width of the middle leaf (mm)	310	3.3	1.5	5.2	0.75	23	37.11	0.000
	6. TM	Thickness of the middle leaf (mm)	310	2.4	0.8	4.2	0.65	27	37.47	0.000
	7. LU	Length of the upper leaf (mm)	309	5.5	3.0	9.1	1.10	20	14.10	0.000
	8. WU	Width of the upper leaf (mm)	309	2.3	1.0	3.6	0.51	22	26.16	0.000
	9. TU	Thickness of the upper leaf (mm)	309	1.7	0.5	3.0	0.45	26	28.01	0.000
	10. DS	Diameter of the stem (mm)	315	1.7	0.7	3.6	0.54	31	35.90	0,000
	11. HP	Height of the plant (cm)	315	18.0	9.3	30.8	3.63	20	21.53	0.000
	12. LIL	Length of internodes in the lower part of the stem (mm)	315	4.7	1.4	10.7	1.61	34	12.21	0.000
	13. LIU	Length of internodes in the upper part of the stem (mm)	315	10.2	4.4	21.7	3.15	31	11.62	0.000
Flowering part	14. LB	Length of the bracts (mm)	304	2.6	1.1	4.7	0.69	27	15.51	0.000
	15. WB	Width of the bracts (mm)	304	1.3	0.5	2.8	0.33	26	20.62	0.000
	16. LI	Length of the main inflorescence (mm)	315	29.6	12.0	66.7	9.34	32	16.43	0,000
	17. WI	Width of the main inflorescence (mm)	315	27.2	11.6	50.9	7.65	28	11.44	0,000
	18. NB	Number of side branches of main inflorescence	315	1.4	0.0	7.0	1.23	86	7.86	0.000
	19. NF	Number of flowers in main inflorescence	315	46.6	11.0	174.0	26.60	57	24.12	0.000
	20. LS	Length of sepals (mm)	315	1.0	0.5	1.5	0.16	16	17.55	0.000
	21. WS	Width of sepals (mm)	315	0.8	0.5	1.1	0.12	15	12.14	0.000
	22. LP	Length of petals (mm)	315	4.9	3.6	6.6	0.45	9	22.48	0.000
	23. WP	Width of petals (mm)	315	1.6	1.0	2.2	0.18	11	14.90	0.000
	24. LF	Length of filaments (mm)	315	3.1	1.9	4.4	0.39	13	13.88	0.000
	25. LO	Length of carpels (mm)	315	3.5	2.4	4.7	0.46	13	28.15	0.000
	26. WO	Width of carpels (mm)	315	0.9	0.4	1.3	0.20	22	8.16	0.000
	27. LN	Length of nectaries (mm)	315	0.4	0.2	0.6	0.06	16	31.43	0.000
	28. WN	Width of nectaries (mm)	315	0.4	0.3	0.6	0.07	15	31.83	0.000

(N – number of measured cases, Mean – Mean value, Min. – Minimum value, Max. – Maximum value, Std. Dev. – Standard Deviation, CV% – Coefficient of Variation, F – Fisher's coefficient, p – level of significance)

Table 3. Correlations of analyzed morphological characters of *Sedum album* from the Balkan Peninsula (marked correlations significant at p <0.05).

	LL	WL	TL	LM	WM	TM	LU	WU	TU	DS	HP	LIL	LIU	LI	WI	NB	NF	LB	WB	LS	WS	LP	WP	LF	LO	WO	LN	WN
LL	**1.0**	**0.5**	**0.5**	**0.5**	**0.1**	**0.2**	**0.4**	**0.2**	**0.2**	**0.4**	**0.4**	**0.2**	**0.2**	**0.3**	**0.2**	**0.1**	**0.3**	**0.2**	0.0	**0.3**	**-0.2**	**0.2**	0.1	**0.2**	**0.3**	0.0	**0.1**	**0.2**
WL	**0.5**	1.0	**0.9**	**0.1**	**0.3**	**0.3**	0.1	**0.3**	**0.3**	**0.3**	0.1	0.1	0.1	**0.3**	**0.2**	**-0.2**	**0.2**	**0.2**	**0.1**	**0.2**	**-0.3**	**0.4**	**0.1**	**0.1**	**0.5**	0.1	**0.1**	**0.2**
TL	**0.5**	**0.9**	1.0	**0.2**	**0.3**	**0.3**	**0.2**	**0.3**	**0.3**	**0.3**	**0.2**	0.0	0.1	**0.3**	**0.1**	**-0.2**	**0.2**	**0.1**	0.1	**0.3**	**-0.3**	**0.4**	**0.1**	**0.2**	**0.5**	0.1	**0.1**	**0.3**
LM	**0.5**	**0.1**	**0.2**	1.0	**0.4**	**0.4**	**0.7**	**0.4**	**0.4**	**0.4**	**0.4**	**0.3**	**0.3**	**0.4**	**0.3**	**0.3**	**0.4**	**0.2**	0.0	**0.4**	0.1	**0.2**	-0.1	**0.2**	**0.2**	**0.2**	0.0	**0.2**
WM	**0.1**	**0.3**	**0.3**	**0.4**	1.0	**0.9**	**0.3**	**0.7**	**0.7**	**0.3**	0.1	**0.3**	**0.3**	**0.3**	**0.3**	-0.1	**0.4**	**0.2**	**0.2**	**0.4**	0.0	**0.3**	-0.1	0.1	**0.3**	**0.2**	0.1	**0.3**
TM	**0.2**	**0.3**	**0.3**	**0.4**	**0.9**	1.0	**0.3**	**0.7**	**0.7**	**0.3**	0.1	**0.3**	**0.3**	**0.4**	**0.3**	-0.1	**0.4**	**0.2**	**0.1**	**0.4**	-0.1	**0.3**	**-0.1**	0.1	**0.3**	**0.2**	0.1	**0.4**
LU	**0.4**	0.1	**0.2**	**0.7**	**0.3**	**0.3**	1.0	**0.5**	**0.5**	**0.4**	**0.4**	**0.2**	**0.2**	**0.3**	**0.2**	**0.2**	**0.4**	**0.3**	0.1	**0.3**	0.1	**0.1**	-0.1	0.1	0.1	0.1	0.0	**0.1**
WU	**0.2**	**0.3**	**0.3**	**0.4**	**0.7**	**0.7**	**0.5**	1.0	**0.9**	**0.4**	**0.1**	**0.2**	**0.3**	**0.4**	**0.3**	-0.1	**0.4**	**0.2**	**0.2**	**0.3**	0.0	**0.3**	-0.1	0.1	**0.2**	**0.1**	0.1	**0.3**
TU	**0.2**	**0.3**	**0.3**	**0.4**	**0.7**	**0.7**	**0.5**	**0.9**	1.0	**0.4**	**0.1**	**0.2**	**0.2**	**0.4**	**0.3**	-0.1	**0.4**	**0.2**	**0.2**	**0.3**	0.0	**0.3**	-0.1	0.1	**0.2**	**0.1**	0.1	**0.3**
DS	**0.4**	**0.3**	**0.3**	**0.4**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	1.0	0.1	**0.1**	**0.2**	**0.4**	**0.3**	0.1	**0.5**	**0.3**	0.1	**0**	0.0	**0.2**	**0.1**	**0.2**	**0.3**	0.1	0.0	**0.2**
HP	**0.4**	**0.1**	**0.2**	**0.4**	**0.1**	0.1	**0.4**	**0.1**	**0.1**	0.1	1.0	**0.4**	**0.3**	**0.3**	**0.3**	0.0	**0.2**	0.1	0.0	0.1	**-0.1**	0.0	0.0	**0.1**	0.0	0.0	0.0	-0.1
LIL	**0.2**	0.1	0.0	**0.3**	**0.3**	**0.3**	**0.2**	**0.2**	**0.2**	**0.1**	**0.4**	1.0	**0.4**	**0.3**	**0.3**	0.1	**0.2**	0.1	0.0	**0.2**	0.0	0.1	0.0	**0.2**	**0.1**	0.1	0.0	0.1
LIU	**0.2**	0.1	0.1	**0.3**	**0.3**	**0.3**	**0.2**	**0.3**	**0.2**	**0.2**	**0.3**	**0.4**	1.0	**0.4**	**0.3**	0.0	**0.2**	0.1	-0.1	**0.3**	-0.1	**0.2**	**-0.1**	0.1	**0.2**	0.1	0.1	**0.2**
LI	**0.3**	**0.3**	**0.3**	**0.4**	**0.3**	**0.4**	**0.3**	**0.4**	**0.4**	**0.4**	**0.3**	**0.3**	**0.4**	1.0	**0.6**	**-0.2**	**0.6**	**0.2**	**0.2**	**0.2**	-0.1	**0.1**	0.0	0.1	**0.1**	0.1	0.1	**0.2**
WI	**0.2**	**0.2**	**0.1**	**0.3**	**0.3**	**0.3**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.6**	1.0	-0.1	**0.6**	**0.3**	**0.2**	**0.1**	-0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1
NB	0.1	**-0.2**	**-0.2**	**0.3**	-0.1	-0.1	**0.2**	-0.1	-0.1	0.1	0.0	0.1	0.0	**-0.2**	-0.1	1.0	-0.1	0.0	**-0.2**	0.0	**0.2**	**-0.1**	**-0.2**	-0.1	-0.1	0.0	**-0.2**	-0.1
NF	**0.3**	**0.2**	**0.2**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.5**	**0.2**	**0.2**	**0.2**	**0.6**	**0.6**	-0.1	1.0	**0.4**	**0.3**	**0.2**	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1
LB	**0.2**	**0.2**	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**	**0.2**	**0.2**	**0.3**	0.1	0.1	0.1	**0.2**	**0.3**	0.0	**0.4**	1.0	**0.7**	**0.1**	**0.1**	**0.2**	0.0	**-0.1**	0.1	**0.2**	**-0.1**	0.0
WB	0.0	**0.1**	0.1	0.0	**0.2**	**0.1**	0.1	**0.2**	**0.2**	**0.1**	0.0	0.0	-0.1	**0.2**	**0.2**	**-0.2**	**0.3**	**0.7**	1.0	0.0	**0.2**	**0.1**	0.1	**-0.2**	0.0	**0.2**	-0.1	-0.1
LS	**0.3**	**0.2**	**0.3**	**0.4**	**0.4**	**0.4**	**0.3**	**0.3**	**0.3**	**0.3**	0.1	**0.2**	**0.3**	**0.2**	**0.1**	0.0	**0.2**	**0.1**	0.0	1.0	**0.3**	**0.4**	**0.1**	**0.2**	**0.3**	**0.2**	0.0	**0.3**
WS	**-0.2**	**-0.3**	**-0.3**	0.1	0.0	-0.1	0.1	0.0	0.0	0.0	**-0.1**	0.0	-0.1	-0.1	-0.1	**0.2**	0.0	**0.1**	**0.2**	**0.3**	1.0	0.1	**0.3**	-0.1	**-0.1**	**0.3**	-0.1	0.0
LP	**0.2**	**0.4**	**0.4**	**0.2**	**0.3**	**0.3**	**0.1**	**0.3**	**0.3**	**0.2**	0.0	0.1	**0.2**	**0.1**	0.1	**-0.1**	0.1	**0.2**	**0.1**	**0.4**	0.1	1.0	**0.4**	**0.2**	**0.7**	**0.3**	**0.3**	**0.5**
WP	0.1	**0.1**	**0.1**	-0.1	-0.1	**-0.1**	**-0.1**	-0.1	-0.1	**0.1**	0.0	0.0	**-0.1**	0.0	0.0	**-0.2**	0.0	0.0	0.1	**0.1**	**0.3**	**0.4**	1.0	**0.3**	**0.2**	**0.2**	**0.2**	**0.2**
LF	**0.2**	**0.1**	**0.2**	**0.2**	0.1	0.1	**0.1**	0.1	0.1	**0.2**	**0.1**	**0.2**	0.1	0.1	0.0	-0.1	0.0	**-0.1**	**-0.2**	**0.2**	-0.1	**0.2**	**0.3**	1.0	**0.4**	**0.2**	**0.4**	**0.3**
LO	**0.3**	**0.5**	**0.5**	**0.2**	**0.3**	**0.3**	**0.1**	**0.2**	**0.2**	**0.3**	0.0	**0.1**	**0.2**	**0.1**	0.0	-0.1	0.1	0.1	0.0	**0.3**	**-0.1**	**0.7**	**0.2**	**0.4**	1.0	**0.4**	**0.3**	**0.5**
WO	0.0	0.1	0.1	**0.2**	**0.2**	**0.2**	**0.1**	**0.1**	**0.1**	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	**0.2**	**0.2**	**0.2**	**0.3**	**0.3**	**0.2**	**0.2**	**0.4**	1.0	**0.2**	**0.4**
LN	**0.1**	**0.1**	**0.1**	0.0	0.1	**0.1**	**0.0**	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	**-0.2**	0.0	**-0.1**	-0.1	0.0	-0.1	**0.3**	**0.2**	**0.4**	**0.3**	**0.2**	1.0	**0.7**
WN	**0.2**	**0.2**	**0.3**	**0.2**	**0.3**	**0.4**	0.1	**0.3**	**0.3**	**0.2**	-0.1	0.1	**0.2**	**0.2**	0.1	-0.1	0.1	0.0	-0.1	**0.3**	0.0	**0.5**	**0.2**	**0.3**	**0.5**	**0.4**	**0.7**	1.0

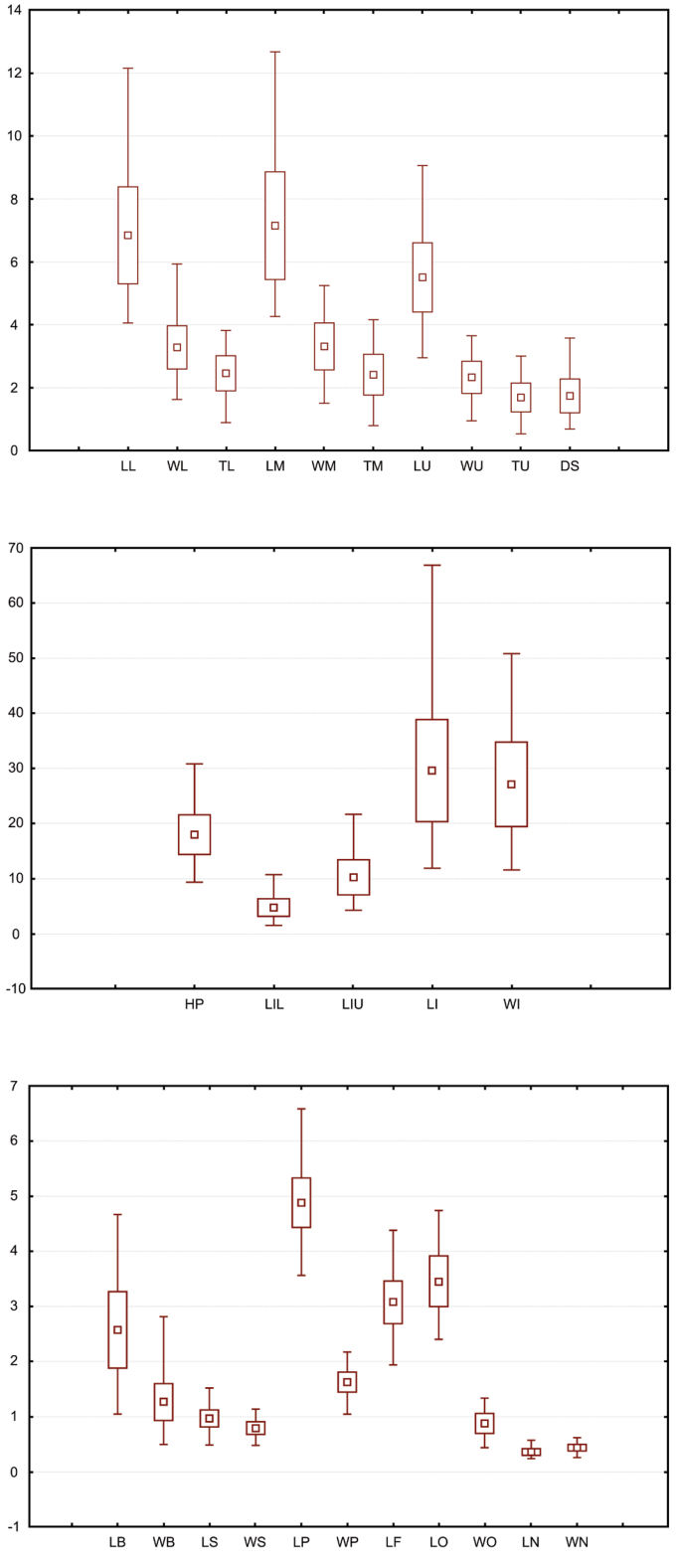

Fig. 2. Box and Whisker plots of basic statistic parameters of analyzed morphological characters of *Sedum album* from the Balkan Peninsula (middle point – Mean value; box – Mean ± SD; whisker – Minimum value - Maximum value).

reported in the literature (Jordanov 1970; Micevski 1998). Finally, values for plant height of the studied sample, including maximal as well as minimal heights, are considerably different (higher) than values reported in the literature. In referent floristic literature plant height is one of the most controversially reported characters. According to the majority of literature references plant height ranges from 5-18 (20) cm (Jordanov 1970; Davis 1972; Gajić 1972; Micevski 1998). Due to better conditions, individuals from growth experiments were generally higher, with a maximal height above 30 cm that could correspond only to data presented by Strid (1986). Regarding floral characters of *S. album*, it was possible to compare only the length of sepals and petals, as other characters are poorly represented in available descriptions. For the length of sepals, the following values have been reported in the literature: 1-2 mm (Strid 1986); 1-5 mm (Davis 1972) and less than 1 mm (Micevski 1998). According to our results, the mean value of the sepals length (1.0 mm) is in partial agreement with the literature data, but values for the minimum and maximum (0.5 mm, 1.5 mm) are below those in literature. The values of the length of petals are as follows: 2-4 mm (Davis 1972; Gajić 1972), 2-5 mm (Micevski 1998) and 3-5 mm (Jordanov 1970). Measured values from the present study range from 3.6-6.6 mm and differ from those presented in the literature, while again close to the values (3-6 mm) represented by Strid (1986). Also, in the literature sources it is stated that the length of the carpels (LO) can be up to 1 mm (Strid 1986), so the mean values measured from this study (3.5 mm) again do not coincide with the literature data. According to some recent data (Giuliani et al. 2017), that provide insight on nectary morphology based on the large number of *Sedum* species, values for both length and width of nectaries in *S. album* ranged from 0.25-0.50 cm. According to our results for the same characters, it is clear that measured values in our study (LN = 0.2-0.6 mm, WN = 0.3-0.6 mm) are not in a line with those from literature, i.e. nectaries of *S. album* are distinctly smaller in all dimensions.

In some degree, deviations of measured values in our present study from data given in the current literature may be the result of unresolved taxonomic positions of several similar taxa with *S. album*, forming specific aggregation in Balkan Peninsula (Zlatković et al. 2016). However, abbreviation among values could indicate current evolutionary trends of differentiation within populations of *S. album* in that area. Finally, it is highly possible that data exception, at least for some of the characters, could be a result of the specific methodological approach used in the present study, which includes a much larger area of those encompassed by regional floras.

To the best of our knowledge, the data on correlative variability of morphological characters in *Sedum* are not provided by the literature sources. However, the existence of already established relationships between the variables showed that all forms and degrees of correlation are present within the tested characters. The existence of correlative relationships indicates a similarity in the variation of certain pairs of characters (Stockburger 2016), which can be useful in determining their taxonomic role. In the present study the strongest linear connection exists among vegetative region characters, more precisely between the width and thickness of stem leaves. Because the connection is positive, leaf thickness increases with increasing leaf width, which is, among other reasons, probably a consequence of water storage in the leaves. According to the high correlative variability of the large number of leaf characters, not all of them are suggested to be used concurrently when exploring the level of morphological differentiation between populations. Comparing other characters in *S. album*, the relationship among characters of the reproductive region is middle to poor in strength, indicating a larger spectrum of characters that could be of some taxonomic importance. Correlation between characters of the vegetative and reproductive region is generally poorly represented, indicating differences in the shape of variability between structures with special functions in plants.

Generally speaking, any of the characters analyzed in the present study could be of use for delimitation of analyzed populations of *S. album* from the territory of Balkan Peninsula. In that way, the most important variables are the leaf characters, but some of the floral characters are also involved. Characters that are most important for the separation of the analyzed populations have been shown here to be thickness (TM) and width of leaf from the middle part of the stem (WM), diameter of the stem (DS), thickness of leaf from the lower part of the stem (TL), as well as width (WN) and length of nectaries (LN). It could be expected that variability of those properties (leaf length, width and thickness), to a greater degree than other vegetative characters, reflect morphological differences between *S. album* populations from the Balkan Peninsula, which is also supported by differences in a few less variable floral structures.

Despite a large number of characters whose variability was observed in studies dealing with the genus *Sedum* or in particular with the species *S. album*, it is necessary to emphasize that research should continue, in order to clarify the level of morphological variability and differentiation between *S. album* entities from Balkan Peninsula.

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