

COMPARISON OF MORPHOLOGICAL CHARACTERS IN VEGETATIVE AND GENERATIVE ORGANS OF ENDEMIC TWO *SEMPERVIVUM* L. TAXA (CRASSULACEAE) IN TÜRKİYE

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ABSTRACT. In this study, the morphological characters of the vegetative and generative organs of two endemic *Sempervivum* taxa (*Sempervivum brevipilum* and *Sempervivum gillianiae*), which are very similar to each other in terms of their morphological characters, were compared. Morphological examinations were carried out on fresh plant and herbarium samples, and light and stereo microscopes were used. Some similar (rosette leaves are curled and fleshy, apex structure of rosette leaves, root colour, stem is erect and densely hairy, stem leaf structure and pubescence, pedicel length, sepals are adjacent, pubescence and number of sepals, free petals, width, shape and hairiness of petals, anther colour, anther attachment to filaments, fruit structure and number of seeds, seed colour and size) and different (plant height, length and structure of roots, structure and diameter of stolon, rosette diameter, condition of rosette leaves (common and collective), shape, colour and number of rosette leaves, width, length and hairiness of rosette leaves, stem height and colour, width, length and colour of stem leaves, number of flowers in the panicle on the stem, colour, width and length of sepals, the apex structure of the sepals, fleshy condition of sepal, petal colour, apex structure, length and number of petals, filament colour, length and number of stamens, ovary structure and length, stylus length, female organ length, habitats, height, flowering time) morphological characters were determined in the vegetative and generative organs of these taxa. The Mann-Whitney U test was applied to the measurement results of morphological characters. The different morphological characters were found to be valuable taxonomic features that can be used to distinguish two *Sempervivum* taxa.

Keywords: *Sempervivum* taxa, endemic, morphology, Türkiye.

INTRODUCTION

The Crassulaceae family consists of plants with Crassulacean Acid Metabolism (CAM). Unlike C₃ and C₄ plants, CAM plants convert atmospheric CO₂ into C₄ acids at night, making carbohydrates from this CO₂ the next day [1]. This family mostly includes perennial, herbaceous and shrubby plants with succulent leaves and stems [2, 3]. The species of this family show high similarity in terms of vegetative organs, flowers, and embryonic characteristics [4]. Moreover, high degrees of hybridization and phenotypic plasticity are observed in the species of this family. Members of the Crassulaceae family are closely related to members of the Saxifragaceae and Penthoraceae families [5]. Because of these causes, there are some problems in distinguishing subfamilies and genera [6]. Mort *et al.* [7] comprehensively investigated the molecular phylogeny and evolution of the Crassulaceae family. This family is divided into two subfamilies: Crassuloideae and Sempervivoideae. The *Sempervivum* L. genus is located in the Sempervivoideae subfamily.

The genus *Sempervivum* is distributed mainly in semiarid or arid rocky habitats in the mountain and alpine belts of the mountain massifs of the Iberian Peninsula, the Apennines and the Balkan Peninsula, Asia Minor and the Caucasus [2, 8-11]. The center of diversity is the European-Siberian, Mediterranean, and Irano-Turanian Regions [12]. Species of this genus are herbaceous, perennial

succulent plants with monocarpic rosettes that give them superiority in vegetative reproduction. The *Sempervivum* genus is represented by 50 taxa worldwide and 18 taxa in Türkiye [13-17].

Sempervivum is a taxonomically complex and highly polymorphic genus [13]. Many of the genus's taxonomic problems arise from its unique biological characteristics, which are due to phenotypic plasticity and frequent hybridization in nature [10]. Although *Sempervivum* species are easily recognized morphologically, their life form diversity, interspecific hybridization abilities in natural habitats, and cytological and chromosomal variability create some problems in the taxonomic status of many species [3, 18]. Strong phenotypic plasticity causes insufficient information about this genus.

In Turkey, the juice obtained by squeezing the leaves of some *Sempervivum* species (especially *S. tectorum* L.) is widely used in the treatment of earache and dermatophyte (skin disease) infections [19]. Some species of the genus are used as ornamental plants (*S. marmoreum* Griseb.), some are used in traditional medicine practices (*S. davisii* Muirhead, *S. armenum* Boiss. et Huet., *S. marmoreum* and *S. tectorum*), and the lower leaves of *S. sosnowsky* Ter-Chatsch. are consumed as salad [20-25]. They are among the most commonly used succulent plants, especially in rock gardens and green roofs, since *Sempervivum* taxa are the most frost-resistant plants [2]. *S. brevopilum* Muirhead, one of our species, is a species native to Central Anatolia and is called the "destiny flower" [23]. *S. gillianiae* Muirhead is known as the "desire flower". The biological activities and chemical composition of essential oils in fresh flowers, leaves, and stems of *S. brevopilum* were investigated by Kahrman *et al.* [26]. It was reported that the essential oils did not have antibacterial and antifungal activity against the tested bacteria (*Escherichia coli*, *Pseudomonas aeruginosa*, *Mycobacterium smegmatis*, and *Staphylococcus aureus*) and fungi (*Candida albicans* and *Saccharomyces cerevisiae*). However, it was found to have high antituberculostatic activity against *M. smegmatis*. In recent years, it has been recorded that some *Sempervivum* species have high antimicrobial and antioxidant activity [27].

The aim of this study was to compare the morphological characteristics of two endemic *Sempervivum* taxa that are very similar in terms of their morphological characteristics and to determine the distinctive morphological features that have taxonomic value.

MATERIALS AND METHODS

Samples from the examined two taxa were collected from their natural distribution areas in 2023 (Table 1). Some of the plant samples were turned into herbarium specimens. The taxa were described according to Muirhead [13] and Eggli [28].

Table 1. The locality information of *S. brevopilum* and *S. gillianiae*

Taxa	Localities	Coordinates	Altitude	Collectors
<i>S. brevopilum</i>	Akdağ (Derebaşalan- Amasya) 07.08.2023	40°52'34.4"N 35°51'34.3"E	1500m	Tuğba Şahin
<i>S. gillianiae</i>	Sakarat Mountain (Yuva Village- Amasya) 02.07.2023	40°38'47.2"N 36°10'49.1"E	1100m	Tuğba Şahin

Light and stereo microscopes were used to measure morphological features. For morphological analysis, 10 plant samples belonging to each taxon were selected (since the examined taxa were endemic and had a limited distribution), and measurements were made

on these samples' vegetative and generative organs. Different morphological characters of the vegetative and generative organs of the examined taxa are given in Table 2.

Table 2. Different morphological characters of *S. brevopilum* and *S. gillaniae*

Different Morphological characters	Taxa	
	<i>S. brevopilum</i>	<i>S. gillaniae</i>
Stolon	Wide	Narrow
Stolon diameter	10-14 mm	7-11mm
Rosette diameter	2-3 cm	4-6 cm
Rosette structure	Leaves prolated	Leaves corporate
Structure of rosette leaves	Ovate	Oblong-spatulate
Colour of rosette leaves	Reddish purple towards bluish green tips	Reddish brown towards silvery green tips
Number of rosette leaves.	A lot (30-47)	A lot (35-49)
Rosette leaf length-width	17-29 x 9-12 mm	18-32 x 10-14 mm
Stem height	13-17 cm	12-14 cm
Plant height	18.1- 26.3 cm	15-20 cm
Stem colour	Greenish yellow	Green
Stem leaf colour	Greenish, reddish purple at the tip	Green
Stem leaf length-width	17-25 x 6-11 mm	19-21 x 6-9 mm
Number of flowers in inflorescence	6-10 flowers	10-15 flowers
Sepal colour	Green, violet towards the tips	Greenish yellow, purplish towards the tips
Sepal structure	Very fleshy, contiguous, ovate, obtuse tips	Fleshy, contiguous, ovate-lanceolate tips acute
Sepal length-width	2-4 x 1-2 mm	1-2x 0.5-1 mm
Petal colour	Greenish yellow	Whitish yellow
Petal structure	obtuse ended	acute ended
Apex structure of petals	Straight	Obviously curved
Petal length	6-7 mm	4-7 mm
Filament colour	Violet	Light violet-white
Number of stamens	20-30	18-28
Ovary structure	Conspicuously wide	Narrow
Ovary length	3-4 mm	2-3 mm
Phytogeographic region	Irano-Turanian element	Euxine element
Flowering time	August	July-August

The minimum, maximum, mean, and standard deviation values of the morphological characters of the studied taxa are shown in Table 3.

Table 3. Standard deviation and mean values of *S. brevopilum* and *S. gillianiaie* (Measurements are given in mm)

Characters	Taxa								
	<i>S. brevipilum</i>					<i>S. gillianiaie</i>			
	Sample number	Mean	Miniumum	Maximum	Standard deviation	Mean	Miniumum	Maximum	Standard deviation
Rosette leaf length	10+10	22.7	17.0	29.0	4.1	24.5	18.0	32.0	4.0
Rosette leaf width	10+10	10.4	9.0	16.0	2.2	11.2	9.0	14.0	1.5
Rosette diameter	10+10	33.4	28.0	40.0	3.8	49.7	29.0	60.0	10.0
Number of rosette leaves	10+10	40.10	30.00	47.00	5.00	42.60	35.00	49.00	5.34
Stem leaf length	10+10	20.0	15.0	25.0	3.3	20.7	19.0	26.0	2.2
Stem leaf width	10+10	8.7	6.0	11.0	1.8	7.8	6.0	11.0	1.5
Stem height	10+10	160.3	130.0	170.0	12.4	131.5	120.0	158.0	11.0
Stolon diameter	10+10	11.5	10.0	14.0	1.4	9.5	7.0	11.0	1.4
Sepal length	10+10	3.0	2.0	4.0	0.8	1.5	1.0	3.0	0.7
Sepal width	10+10	1.5	1.0	2.0	0.5	0.9	0.5	1.0	0.2
Number of sepals	10+10	11.60	11.00	12.00	0.52	11.10	10.00	12.00	0.88
Petal length	10+10	6.8	6.0	8.0	0.6	5.8	4.0	7.0	1.0
Petal width	10+10	1.8	1.0	2.0	0.4	1.5	1.0	2.0	0.5
Number of petals	10+10	12.50	12.00	13.00	0.53	11.40	11.00	12.00	0.52
Stamen length	10+10	4.6	3.0	5.0	0.7	3.8	2.0	6.0	1.3
Number of stamens	10+10	24.8	20.0	30.0	3.6	23.9	18.0	28.0	4.2
Stylus length	10+10	1.8	1.0	2.0	0.4	1.5	1.0	2.0	0.5
Pedicle length	10+10	1.60	1.0	2.0	0.45	1.45	1.0	2.0	0.49
Ovary length	10+10	3.7	3.0	5.0	0.7	2.8	2.0	3.0	0.4
Plant height	10+10	221.8	181.0	263.0	30.2	173.4	150.0	200.0	21.2
Number of flowers in inflorescence	10+10	7.70	6.00	10.00	1.57	13.00	10.00	16.00	2.21

Measurement results of morphological features were uploaded to the IBM SPSS Statistics 27.0, and the Mann-Whitney U test was applied to these results. Since the obtained data did not show normal distribution, the Mann-Whitney U test was used to reveal differences between similar groups more clearly. Mann-Whitney U test results are given in Table 4. The vegetative and generative organs were photographed.

Table 4. Mann-Whitney U test results of the morphological characters of *S. brevopilum* and *S. gillianiae* (*: $p < 0.05$)

Morphological characters	Mann-Whitney U		
	Sample number	U	P
Rosette leaf width	20	29.000	0.103
Rosette leaf length	20	37.500	0.340
Rosette diameter	20	9.500	0.002*
Number of leaves in rosette	20	37.000	0.322
Stem leaf width	20	35.500	0.263
Stem leaf length	20	43.000	0.593
Stem height	20	5.500	0.001*
Plant height	20	10,500	0,003*
Stolon diameter	20	16,500	0.008*
Sepal width	20	17.500	0.005*
Sepal lenght	20	9.500	0.001*
Number of sepals	20	34.000	0.185
Petal width	20	35.000	0.170
Petal length	20	22.500	0.027*
Number of petals	20	10.000	0.001*
Number of flowers in inflorescence	20	2.000	0.001*
Pistil length	20	1.500	0.000*
Stamen length	20	30.000	0.109
Number of stamens	20	45.500	0.733
Stylus length	20	35.000	0.170
Ovary length	20	16.000	0.003*
Pedicle length	20	41.500	0.484

RESULTS

Morphological Characters of Sempervivum brevopilum

Plant height is 18.1-26.3 cm, perennial, and light brown roots (Figure 1 A-C). Stem is erect, densely hairy, greenish-yellow, and 13-17 cm. Stolon is large, light brown, and 10-14 mm in diameter (Figure 1C). Rosette diameter is 2-3 cm. Rosette leaves are numerous (30-47), bluish green, reddish purple towards the apex, densely multicellular biseriate glandular hairy and fleshy, 18-29 x 9-12 mm, and symmetrical (Figures 2 A-C). Stem leaves (cauline leaves) are without petiole, ovate-elliptic, greenish, and the leaf apex is acute, reddish purple, 17-25 x 6-11 mm, densely multicellular biseriate glandular hairy (Figure 2D). The inflorescence has 6-10 flowers (Figure 3A). Pedicle length 1-2 mm (Figure 3 B). Sepals are fleshy, adjacent, and ovate, with obtuse tips, green, violet towards the tips, and dense multicellular biseriate glandular hairy on the outer surface and margins. Each flower has numbers of 11-12 (Figures 4A-C). Sepals 2-4 x 1-2 mm. Petals greenish yellow, free, dense multicellular biseriate glandular hairy on the margins and outside, linear-lanceolate, with obtuse and straight apex, and 12-13 in number. Petals 6-7 x 1-2 mm (Figures 4 A-C). Stamens 3-5 mm and 20-30 in number (Figures 3B and 4B, C). Another is yellow, attached to the filament from the base (basifix), and the filaments are violet. The ovary is quite wide, 3-4 mm long, and the style is 0.1-0.2 mm. Follicles are free, with a few seeds. Seeds are light brown and small (Figure 4C). The species is an endemic Irano-Turanian element and spreads in limestone soils. It blooms in August and is found at 1500-2300 m altitudes.



Fig. 1. A= Flowering appearance in nature habitat of *S. brevopilum*, B= Herbarium specimen of *S. brevopilum*, a= root, b= rosette, c= stem leaf, d= leaf, e= flower, C= Stolon of *S. brevopilum*, f= root, g= stolon, h= rosette leaf

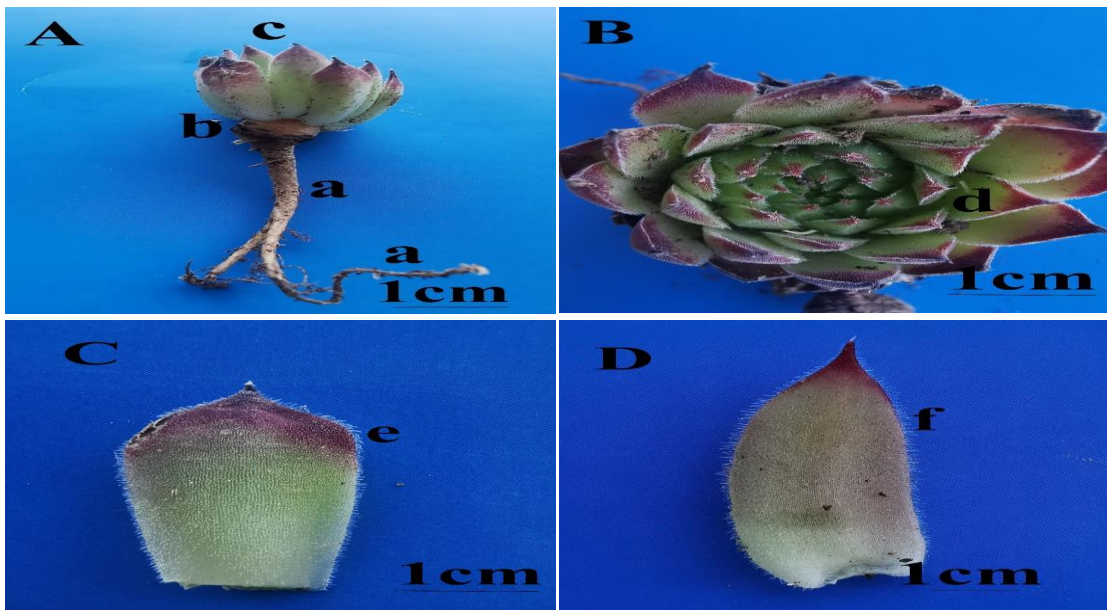


Fig. 2. A=Young rosette of *S. brevopilum*, a= root, b= stolon, c= rosette leaves, B= Developed rosette of *S. brevopilum*, d= rosette leaves, C, e= Rosette leaf of *S. brevopilum*, D, f= Stem leaf of *S. brevopilum*

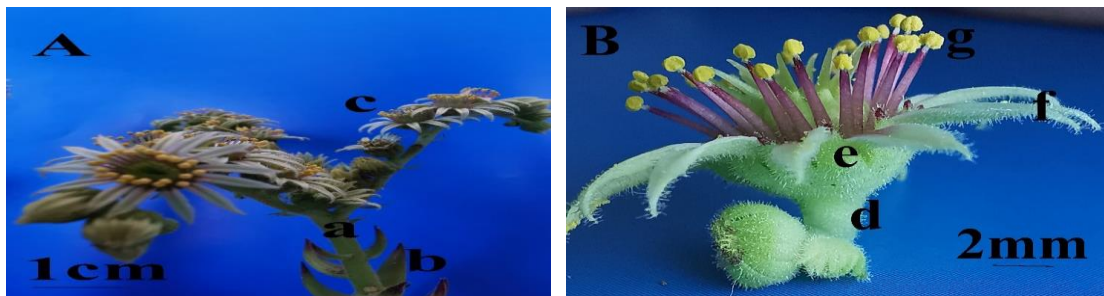


Fig. 3. A= Inflorescence of *S. brevopilum*, a= stem, b= stem leaf, c= flower, B= Flower of *S. brevopilum*, d= pedicle, e= sepal, f= petal, g= stamens

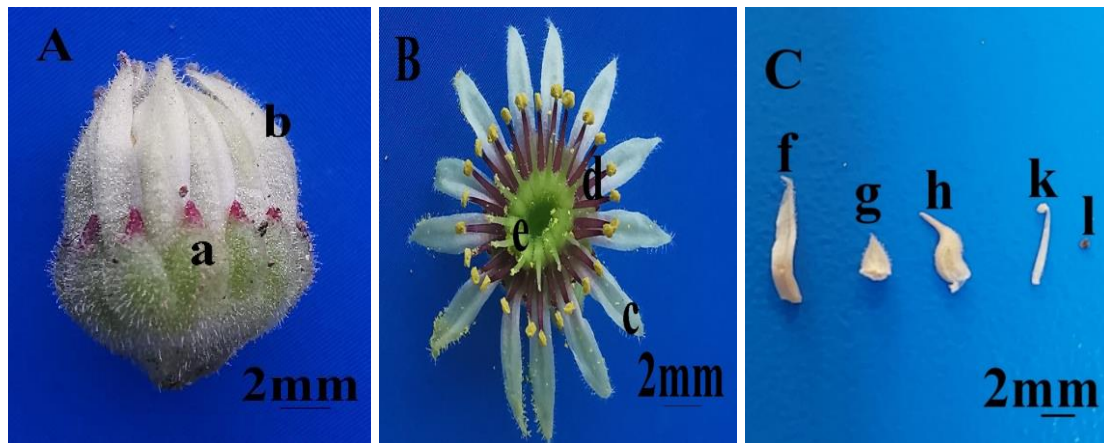


Fig. 4. A= Sepals and petals of *S. brevipilum*, a= sepal, b= petal, B= Petals, stamens and pistil of *S. brevipilum*, c= petal, d= stamens, e= pistil, C= Separated flower parts of *S. brevipilum*, f= petal, g= sepal, h= pistil, k= stamen, l= seed

Morphological Characters of *Sempervivum gillianiae*

Plant height 15-20 cm (Figures 5 A-C). It is a perennial plant with a fragile root structure. Roots are light brown. Stolon is small, light brown, and 7-11 mm in diameter (Figure 5D). Stem is erect, green, densely hairy, and 12-12.5 cm. Rosette diameter 4-6 cm. Rosette leaves are symmetrical, oblong-spatulate, acuminate at the ends, silvery-green, reddish-brown towards the ends, pointed and apex curved, numerous (35-49), 18-32 x 10-14 mm, and moderately multicellular biseriate glandular hairy (Figures 6 A, B). Stem leaves are green, moderately hairy, ovate-elliptic, acute at the ends, without petioles, and 19-21 x 6-9 mm (Figures 6C, D). There are 10-15 flowers in the inflorescence. Pedicle length 1-2 mm (Figure 3A). Sepals adjacent, fleshy, greenish-yellow, purplish at the tips, ovate-lanceolate, apex acute (extremely pointed). Sepals 1- 2x 0.5-1 mm, 10-12 in number, margins and outer surface densely multicellular biseriate glandular hairy (Figures 7 A-C). Petals free, 4-7 x 1-2 mm, whitish yellow, 11-12 in number, margins, outer surface, and apex densely multicellular biseriate glandular hairy, linear-lanceolate, tips acute and clearly curved (Figures 7 A-C). Stamens 2-6 mm and 18-28 in number. Anthers are yellow and attached to the filament from the base. Filaments light violet and white (Figures 3A, B). Ovary 2-3 mm, narrow, style 1-2 mm. Follicles are free and have a few seeds. Seeds are pretty small and dark brown (Figure 7C). The species is an endemic Euxine element and blooms in July-August. It spreads at altitudes of 1100-2100 m. and in limestone rock crevices.



Fig. 5. A= Appearance of rosettes in nature habitat of *S. gillianiae*, B= Herbarium specimen of *S. gillianiae*, a= root, b= stem, c= stem leaf, d= flower, C= Young sample of *S. gillianiae*, e= root, f= rosette, g= stem leaf, h= flower, D= Stolon and rosette, k= rosette leaves, l= stolon

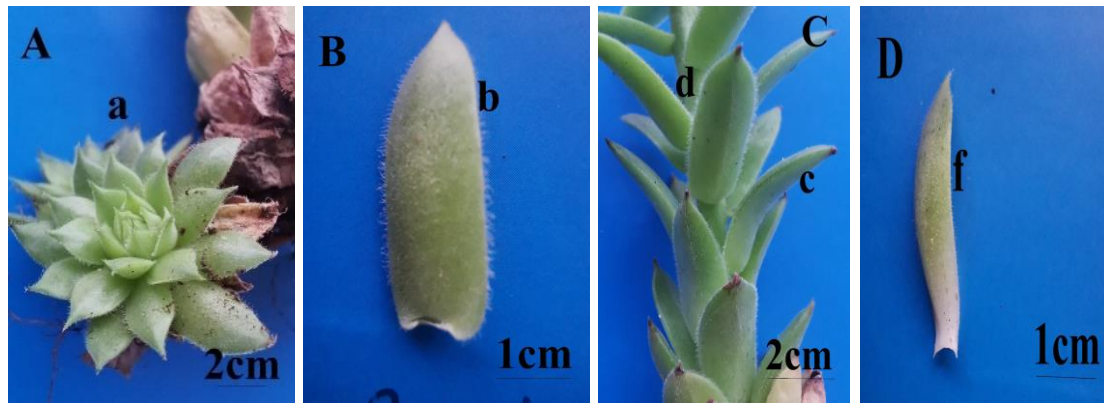


Fig. 6. A= Rosette of *S. gilliania*, a= rosette leaf, B, b= Rosette leaf of *S. gilliania*, C= Stem leaves of *S. gilliania*, c= stem leaf, d= stem, D, f= Stem leaf of *S. gilliania*

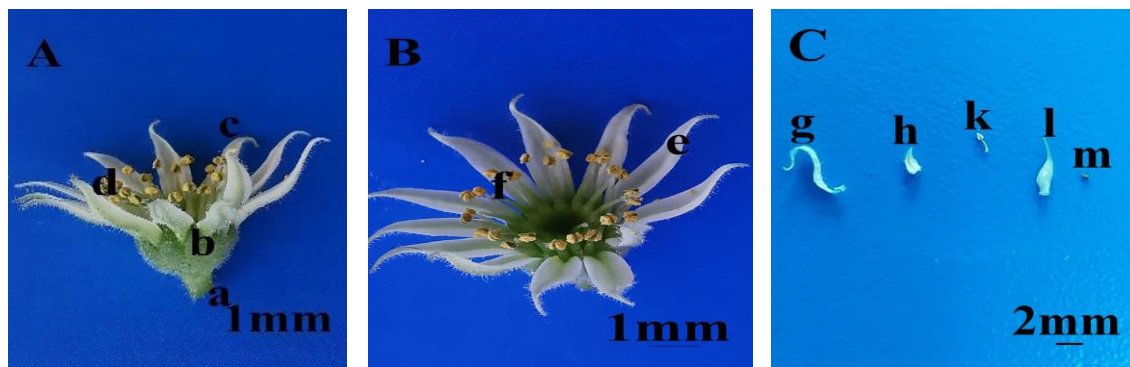


Fig. 7. A= Flower of *S. gilliania*, a= pedicle, b= sepals, c= petals, d= stamens, B= Flower parts of *S. gilliania*, e= petals, f= stamens, C= Separated flower parts of *S. gilliania*, g= petal, h= sepal, k= stamen, l= pistil, m= seed

DISCUSSION

In this study, similar and different morphological characters were detected in the vegetative and generative organs of the studied *Sempervivum* taxa. According to the Mann Whitney U test results, it was determined that differences in some morphological characteristics such as stolon diameter, sepal width and length, petal length, petal number, flower number in inflorescence, pistil length, ovary length, plant and stem height and rosette diameter were significant ($p < 0.05$) (Table 4). In the literature, there are some morphological studies with other taxa of the *Sempervivum* genus [10, 13, 29-40]. Flower colour (yellow or pink), filament colour (from white or pale lavender to violet), pubescence of fully developed rosette leaves (glandular or hairless), and nectar scale shape are stated as the most reliable characters of the genus [10]. It has also been reported that for *Sempervivum* species, the condition and length of the trichomes covering the rosette leaves, stem, and inflorescence, and the morphological characters of the petals and sepals are essential diagnostic characters used in their identification [30, 31, 38, 41]. Since the morphological character mentioned above is not affected by environmental conditions, it is thought to be a reliable character used to distinguish species of this genus. On the other hand, morphological studies conducted with species of this genus also showed that these characters were reliable (these studies are given below and discussed with the findings in this research). Between the two examined taxa, there were significant morphological

differences in characters such as width, length, rosette and stem leaves hairiness, colour, length, and tip structures of sepals and petals, filament colour, and number of stamens. Our findings are consistent with the findings of Karaer *et al.* [10], Hagemann [30], 't Hart [31], Jovanović *et al.* [38], and Micevski [41].

According to Muirhead [29], *S. artvinense* Muirhead, *S. brevipetalum*, *S. davisii* Muirhead, and *S. furseorum* (Muirhead) Karaer represent a complex group with variable morphological characters. The main distribution areas of these taxa overlap in Northeastern Anatolia. According to Flora of Turkey [13], *S. artvinense* differs from *S. davisii* by having green and inwardly curved rosette leaves and stiff bristly hairs. In contrast, *S. brevipetalum* differs from *S. davisii* by having smaller rosettes, narrower leaves, and shorter petals. Karaer *et al.* [10] also reported that *S. artvinense*, *S. brevipetalum*, *S. davisii*, and *S. furseorum* have whitish filaments. *S. brevipetalum* and *S. gillianiae* can be easily separated from each other by the different structure of their rosette leaves and petals, the hairiness of their rosette leaves, and the different colours of their filaments. The findings in this study are parallel to the findings of Karaer *et al.* [10] and Muirhead [13].

In another research, Neeff [33] accepted the relationships of *S. artvinense* and *S. furseorum* as they are, without making any comments, and stated that the "pure forms" of *S. davisii* are close to *S. artvinense*, but are distributed at slightly lower altitudes in the Kaçkar Mountains. Moreover, he accepted *S. brevipetalum* as the form of *S. davisii* that spreads at lower altitudes. However, Karaer *et al.* [10] found no specimens of *S. brevipetalum* in the mentioned areas. This is thought to be due to the species becoming extinct in the region, incorrect information regarding the type localization, or the dispersal of the species to other locations. Karaer *et al.* [10] observed that the vegetative and generative organs (especially rosette and flower diameter, sepal and petal numbers) of samples grown in culture medium were strongly affected by different environmental conditions. In particular, the stem and leaf length of the specimens increased, and the flower clusters became longer. These results suggest that significant phenotypic plasticity should be considered in taxonomic and morphological studies in the *Sempervivum* genus and that comparisons should not be made between measurements of cultured forms and forms grown in natural habitats. A similar situation was also detected in the leaf morphological characteristics of *Kalanchoe* Adans. species (*K. pinnata* (Lam.) Pers. and *K. crenata* (Andrews) Haw.). In other words, the two *Kalanchoe* taxa were grown in sunlight and shade, and some changes in leaf morphological characteristics (such as leaf thickness, leaf shape, different coloration on the petiole and leaf blade) were observed [37]. *K. pinnata* and *K. crenata*, which belong to the *Kalanchoe* genus, are very similar in their leaf morphological characteristics. Due to their similarities, both species are known by similar names in Brazil and are often confused [42-44]. Similar features of the taxa include curved, fleshy, and hairless leaves, oval to elliptical leaf blades, and crenate margins [45]. Although *K. crenata* has simple leaves, *K. pinnata* has both simple and compound leaves. These two taxa are very similar, especially when *K. pinnata* has only simple leaves. The leaves of both taxa are frequently used in folk medicine.

In Flora of Turkey, Muirhead [13] reported that *S. transcaucasicum* Muirhead is related to *S. davisii*. But, *S. transcaucasicum* is easily distinguished from *S. davisii* by its pale lavender to purple filaments. On the other hand, Karaer *et al.* [10] stated that *S. transcaucasicum* is more closely related to *S. brevipetalum*, *S. pisidicum* and *S. gillianiae* species in Turkey. On the contrary, Neeff [33] never discussed the kinship relationships of *S. transcaucasicum*. Although *S. staintonii* Muirhead is similar to *S. davisii* by having whitish filaments, *S. staintonii* is clearly distinguished from *S. davisii* by its glabrous rosette leaves, fully twisted petals, and narrow oblong nectar scales. Due to these differences in morphological features, both Karaer *et al.* [10] and Muirhead [29] evaluated *S. staintonii*

and *S. davisii* as different taxa that are not related. The results of Muirhead [29] and Karaer *et al.* [10] are consistent with the results of this study. Namely, *S. staintonii* and *S. davisii* are distinguished from each other according to the hairiness of their rosette leaves and the difference in their petals. This study used the hairiness of their rosette leaves and the differences in their petal structures to distinguish *S. brevopilum* and *S. gillianiae* (Table 2).

In another study, *S. armenum* Boiss. & A. Huet was reported as a synonym of *S. globiferum* L. by Boissier [46]. After extensive field and herbarium studies by Karaer and Celep [36], it was determined that *S. armenum* var. *armenum* and *S. armenum* var. *insigne* have numerous and consistent morphological (rosette diameter, stem length, colours of stem leaves, number and diameter of flowers, apex colour of calyx, and filament colours), ecological, and geographical differences. For this reason, it was reported that these two taxa should be recognized as subspecies rather than varieties, *S. armenum* subsp. *armenum* and *S. armenum* Boiss & A. Huet and subsp. *insigne* (Muirhead) F. Karaer. The results of this study are compatible with the results of Karaer and Celep [36]. In another research, *S. minus* Turill ex Wale var. *glabrum* has been observed that it has different morphological features (such as rosette diameter, hairiness of mature rosettes, shape of rosette leaves and colour of the base parts, inflorescence shape and length, number of flowers, pedicel length and pollen shape) than *S. minus* var. *minus*. Therefore, *S. minus* var. *glabrum* was raised to species level and its name was changed to *S. ekimii* F. Karaer [34]. Some results (rosette diameter, hairiness of mature rosettes, shape of rosette leaves, shape and length of inflorescence, number of flowers) in this study are consistent with the results of Karaer and Celep [34] (Table 2).

The morphological, palynological, and ecological characteristics of *S. sosnowskyi* Ter-Chatsch were investigated in detail, and its distribution area and conservation status were re-evaluated [35]. *S. sosnowskyi* is very similar in terms of morphological features to *S. armenum* and *S. glabrifolium* Boriss., which are endemic to Turkey. The characteristics of these three species' vegetative and reproductive organs were compared, and different morphological features were found between the species. While the filaments are white or pale yellow in *S. glabrifolium*, the filaments are pale lavender or violet in *S. armenum* and *S. sosnowskyi*. Rosettes in *S. armenum* are 2-8 cm in diameter; scape leaves (stem leaves) are not ligulate; inflorescence 15-50 (-60) flowers; pedicel 1-1.5 cm; the flowers are 1.5-2.5 cm in diameter. *S. sosnowskyi* has rosettes (8-) 10-15 (-20) cm in diameter; scape leaves broadly ligulate; inflorescence many-flowered (40-) 60-210; pedicel 2-3 cm; flowers 3-3.5 cm in diameter. In summary, Karaer *et al.* [35] used morphological characteristics such as filament colour, rosette diameter, structure of stem leaves, number of flowers in the inflorescence, pedicel length, diameter of flowers, and shape of pollen grains in distinguishing three species. The findings of Karaer *et al.* [34] are parallel to the findings in our study (except pedicle length).

Jovanovic *et al.* [47] investigated the morphological variability of rosette leaves of the *S. ciliosum* and *S. ruthenicum* complexes. They reported that the differences in the shape and size of rosette leaves among complexes and species were essential features. They suggested that the rosette leaf shape could be reliable for solving taxonomic problems within the *S. ciliosum* complex. However, it has been recorded that there are some problems with rosette leaves' variability within species of the *S. ruthenicum* complex.

Distribution, morphology, population parameters, and conservation status of *S. marmoreum* in the Ukrainian Carpathians were investigated by Kobiv *et al.* [32]. The species is placed in the CR category (critically endangered) in the Red Data Book of Ukraine. Since the species, especially its leaf colour and hairiness (indumentum) structure, is variable, it is sometimes divided into the following subspecies: *S. marmoreum* subsp. *marmoreum*, *S. marmoreum* subsp. *blandum* (Schott) Soó, *S. marmoreum* subsp. *ballsii*

(Gal) B.J.M. Zonneveld, *S. marmoreum* subsp. *eritreum* (Velen.) B.J.M. Zonneveld, *S. marmoreum* subsp. *reginae-amaliae* (Heldr. & Sartori eski Boiss.) B.J.M. Zonneveld, *S. marmoreum* subsp. *rubrifolium* (Schott) G.G. Bellia ve A. Andrade. However, their taxonomic status remains highly uncertain. There are many different forms sold as ornamental plants in markets. *S. marmoreum* has been traditionally used for medicinal purposes in some countries. It is a succulent, evergreen, herbaceous perennial with rosette leaves and stolons. The glandular trichomes (capitate) are short on the leaves and at the base of the flowering stems, and quite long on the inflorescence and its upper parts. *S. marmoreum* is closely related to *S. tectorum*. This species, which is highly preferred as an ornamental plant, is widely grown throughout Europe, including Ukraine.

Jovanovic *et al.* [39, 40] investigated the taxonomy of yellow-flowered *Sempervivum* species distributed in the Balkan Peninsula and the epidermal structures of rosette leaves. The yellow-flowered species are *S. ciliosum* (*S. ciliosum* Craib, *S. jakucsii* Pénzes, *S. klepa* Micevski, *S. octopodes* Turrill, and *S. galicum* (Sm.) Micevski) and *S. ruthenicum* complex (*S. ruthenicum* Schnittsp. & C. B. Lehm., *S. leucanthum* Pančić, *S. kindingeri* Adamović, and *S. zeleborii* Schott). Species within the *S. ciliosum* complex are characterized by relatively small and closed rosettes, mostly yellow or greenish leaves, yellow-green or purple filaments, long marginal trichomes of rosette leaves, and yellow petals [30, 31, 38, 41]. All species in the *S. ciliosum* complex are endemic. Some species of *S. ruthenicum* complex are also distributed outside the Balkan Peninsula. The species of this complex are recognized by their high stems, large and open rosettes, greenish-yellow or white petals (sometimes purple at the base), purple or white filaments, and short marginal trichomes (less than 2 mm) on the rosette leaves [30, 31].

Changes in morphological characteristics of different populations of the endemic *S. ciliosum* ssp. *ciliosum* distributed in the Balkan Peninsula (Bulgaria, Greece, and North Macedonia) was investigated [39]. 36 quantitative characteristics of vegetative and generative organs were measured in 45 individuals. As a result of the research, it was observed that the changes (differences) in the populations were moderate in some characteristics and high in some characteristics (in flowering times and leaf structures, plant height, length of rosette leaf, and length of upper part of rosettes). Statistical analyses also determined these differences. On the other hand, low levels of variability were determined in the morphological characteristics of the generative organs of the individuals (especially in the width and length of the flower parts) (except for the length, width, and number of flowers of the main inflorescence). One of the reasons for the difference in variability observed in the morphological characteristics of vegetative and reproductive organs is probably that the morphology of reproductive organs is more ecologically stable, and vegetative organs are more prone to water storage. Jovanovic *et al.* [39] emphasized that the reasons for the differences in the morphological characteristics of vegetative and generative organs from those mentioned in the current literature are due to the effect of growing conditions especially on vegetative organs, increased phenotypic plasticity, insufficient data on variability, many data available in the literature being outdated, and the unresolved taxonomic status of taxa within the *S. ciliosum* complex. For this purpose, it has been suggested that more detailed morphological, anatomical, and other studies should be conducted on the *S. ciliosum* complex.

S. brevipilum is in the LR category (LR: Low risk, nt: May be threatened), and *S. gillianiae* is placed in the LR category (LR: Low risk, cd: Protection required) [48]. Critical threats include climate change, overgrazing, field clearing, fires, and intensive transhumance in alpine and subalpine meadow areas in the habitats of the two studied taxa. To protect these endemic species, the habitats where they are distributed may be declared as protected areas, they may be grown in botanical gardens in our country, and herbarium

samples may be protected in the herbaria of different universities. In addition, the importance of these species can be explained to the local people, and people's awareness can be increased.

CONCLUSION

As a result, similar and different morphological characters were found for the vegetative and generative organs of the studied taxa. It was determined that the different morphological characters were valuable taxonomic characters that could distinguish these two taxa. The differences (such as stolon diameter, width, and length of sepal, petal length, petal number, number of flowers in the panicle, pistil length, ovary length, plant and stem height, and rosette diameter) were also detected to be statistically significant ($p < 0.05$). Due to the similarities in the morphological characteristics of vegetative and generative organs, it was also seen that these two taxa were very close to each other within the genus *Sempervivum*. It is thought that these taxa can be used as ornamental plants (rock gardens and wall landscaping) due to their showy rosette structure and different colors of rosette leaves. On the other hand, the lack of literature on the studied taxa and strong phenotypic plasticity constitute the limitations of this study.

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