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Review Article
(Derleme Makale)

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Selection of succulent species to be used on green roofs according to phytogeographic regions: Türkiye example

Yeşil çatılarda kullanılacak sukulent türlerinin fitocoğrafik bölgelere göre seçimi: Türkiye örneği

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ABSTRACT

The objective of this study was to determine the succulent plant species that can be used on green roofs to be recommended for 3 phytogeographic regions in Türkiye.

Three phytogeographic regions in Türkiye and the succulent taxa found in the natural flora of these regions were chosen as the study material. In the study, firstly, literature search was conducted. Then, family, endemism, hairiness, climate, altitude and habitat status of succulent species obtained from the literature were determined. In line with the information obtained in the last stage, taxa that can be recommended for green roofs in 3 different phytogeographic regions are listed.

As a result of the study, it was determined that *Saxifraga* spp. and *Sempervivum* spp. in cool climates, *Umbilicus* spp. and *Rosularia* spp hot climates that the genera are the genera with the highest number of taxa. Also, ranked in both cool and warm climates, *Sedum* spp. and *Rosularia* spp. first in terms of the species richness of its genera

The findings of this study are of importance in terms of helping the selection of the right succulent species that can be used on green roofs for countries located in similar phytogeographic regions around the world.

ÖZ

Bu çalışmadaki amaç Türkiye'de 3 fitocoğrafik bölge için tavsiye edilecek yeşil çatılarda kullanılabilecek sukkulent bitki türlerinin belirlenmesidir.

Çalışma materyali olarak Türkiye'deki üç fitocoğrafik bölge ve bu bölgelerin doğal florasında bulunan sukkulent taksonlar seçilmiştir. Çalışmada öncelikle literatür araştırması yapılmıştır. Daha sonra literatürden elde edilen sukulent türlerinin familyası, endemizmi, tüylülüğü, iklimi, rakımı ve habitat durumu belirlendi. Son aşamada elde edilen bilgiler doğrultusunda 3 farklı fitocoğrafik bölgede yeşil çatı için önerilebilecek taksonlar listelenmiştir.

Çalışma sonucunda *Saxifraga* spp. ve *Sempervivum* spp. serin iklimlerde *Umbilicus* spp. ve *Rosularia* spp sıcak iklime sahip cinsler en fazla takson içeren cinslerdir. Ayrıca hem serin hem de sıcak iklimlerde yer alan *Sedum* spp. ve *Rosularia* spp. cinsinin tür zenginliği açısından birinci sırada yer almaktadır.

Bu çalışmanın çıktıları dünya çapında benzer fitocoğrafik bölgelerde bulunan ülkeler için yeşil çatılarda kullanılabilecek doğru sukkulent türlerinin seçimine yardımcı olması açısından önemlidir.

INTRODUCTION

Plants in cities have an important effect on lowering air temperatures. However, the amount of space available for green infrastructure is less in cities where the built-up area is high (Fernandez et al., 2013; Van Mechelen et al., 2015). Roofs can cover about 20-30% of the horizontal surface in a city (Zhang et al., 2021). This makes roofs the primary area for vegetation (Farrell et al., 2012; Monteiro et al., 2017). Green roofs have a flat or sloping structure designed to support vegetation (Dvorak & Volder, 2010). Green roofs are heavily preferred in urban areas as they offer solutions to environmental problems. Thanks to green roofs, surface water runoff can be reduced (Wilkinson & Feitosa, 2015), can provide a habitat for wildlife, may mitigate the urban heat island effect (Klein & Coffman, 2015), building insulation and energy efficiency can be upgraded (Jim, 2014; Scharf & Zluwa, 2017), can improve air quality, create aesthetic and comfortable value and provide opportunities for urban food production (Razzaghmanesh et al., 2014; Vanuytrecht et al., 2014; Vahdati et al., 2017).

Despite these functions of green roofs, the demanding and stressful growing environment routinely allows only a limited number of plant species to survive (Vahdati et al., 2017; Zhang et al., 2021). Therefore, the number of plant species that can be used on green roofs is limited (Nagase & Dunnett, 2010; Rayner et al., 2016). Succulent plants are known to perform well in large green roof systems in hot-arid climates both in summer and winter. These plants tolerate many climatic conditions, including high temperatures experienced on the roof, high winds, drought, frost, and salinity (Vendramini et al., 2002; Dvorak & Volder, 2012; Grace et al., 2019; Di Miceli et al., 2022). Succulents are plants that adapt to extreme environmental conditions such as water shortage and high temperatures with their habitus and lifestyle. In addition to these features, the interestingness of their flowers and seeds, and the shape, texture and color of their leaves make these plants aesthetically interesting. Succulent plant species, which have the ability to grow at different altitudes from 0 to 3200 meters, have a wide distribution area in our country (Karahan & Angın, 2008; Bilgili & Karahan, 2011). For example, in a one-year study conducted in Sydney, succulent plant species were found to live without any care (Wilkinson & Feitosa, 2015; Johannessen et al., 2017). Another study found that using succulent plants on green roofs in parts of Australia could provide a low-cost, drought-tolerant, lightweight option to reduce heat gain and heat loss. (Wilkinson & Feitosa, 2015).

A study by Di Miceli et al. (2022) determined that there are more than 12,500 succulent plant species in the world. Most of these species belong to the Crassulaceae family. These plants can grow in many habitats around the world (Williams et al., 2010; Bousselot et al., 2011; Monteiro et al., 2017; Zhang et al., 2018). Türkiye flora includes almost 70-80% of all succulent plants in Europe, and some of these species are ground cover or parterre plants. Succulent species, with their compact structure and fleshy, feathery or leathery leaf characteristics, have the ability to maintain their vitality with the amount of water that falls only during the rainy periods of the year (Bilgili & Karahan, 2011). Most green roof applications use succulent plant species such as *Sedum* spp. because they tolerate dry conditions (Williams et al., 2010; Bousselot et al., 2011; Monteiro et al., 2017; Zhang et al., 2018). These plants are ideal species for survival in green roof systems. Because it has a shallow root system and conservative water use strategies. This means that they can withstand drought during periods of drought (Wolf & Lundholm, 2008; Vahdati et al., 2017; Zhang et al., 2018). For example, in one study, *Sedum album* could survive for more than 100 days without water, while species of *Sedum acre, Sedum kamtschaticum ellacombianum, Sedum pulchellum, Sedum reflexum*, and *Sedum spurium* were able to survive drought for 88 days (Rowe et al., 2012).

The phytogeographic region where the green roofs were built is important. In the Mediterranean region, for example, plants face severe water stress, often caused of rising temperatures and prolonged summer drought. Plant species commonly used in green roofs are exposed to additional stress factors when applied in the Mediterranean climate (van Mechelen et al., 2015). In temperate climates, however,

green roofs may encounter problems as many of the plants currently used come from cool temperate climates and are not adjusted to withstand long dry periods, extreme temperatures, or heavy rainfall events. Green roof design and especially vegetation selection need to be adjusted to future climatic conditions. Green roof design and especially vegetation selection need to be adjusted to future climatic conditions (Vanuytrecht et al., 2014). Today, it is necessary to increase the diversity of plant species used in green roof systems, especially by focusing on the use of natural plants (Vahdati et al., 2017). Because natural plants are more resistant to harsh environmental conditions and drought.

Türkiye was determined as the study area in this research. Türkiye has three main phytogeographical regions: Europe-Siberia, Mediterranean, and Iran-Turan (Avcı, 1993). The highest species diversity in these phytogeographic regions is followed by the Irano-Turanian region, then the Mediterranean and finally the Euro-Siberian region (Küçük & Ertürk, 2013). This is due to different topographic thresholds and climate. The objective of this study was to develop green roof models by taking into account the climate, water consumption, life form, altitude, and habitat characteristics of each phytogeographic region within the scope of future planning and design studies of succulent taxa. While determining the plant species to be used in green roofs, succulent plants naturally found in Türkiye and climate, life form, altitude, endemism, and habitats specific to the phytogeographic region where each plant is found were determined. This study is unique as it contains information that enables the development of succulent plant species suitable for future green roofs in Türkiye can set an example in the development of green roofs by using succulent plant species suitable for green roofs planned to be built in Türkiye and other similar phytogeographic regions.

General Features of the Working Area

The main material of the study is three phytogeographic regions located within the provincial borders of Türkiye: Euro-Siberian, Mediterranean and Irano-Turanian as depicted in Figure 1.

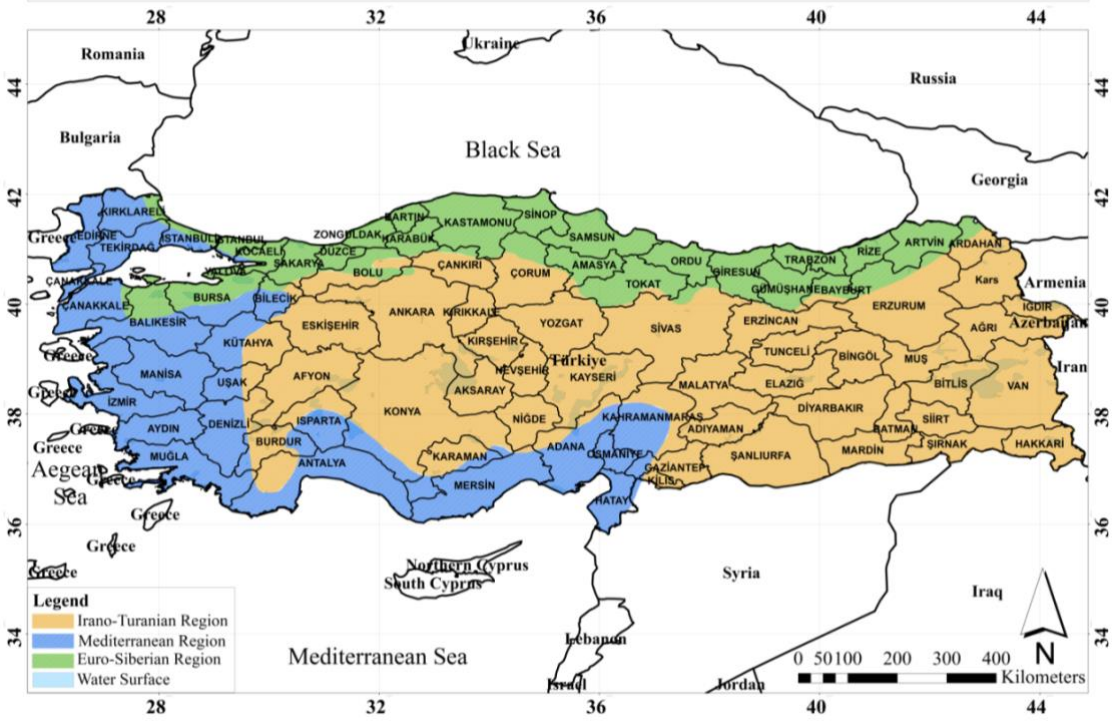

Figure 1. *Distribution of provinces within the borders of the Türkiye in phytogeographical regions.*

Şekil 1. *Türkiye sınırları içerisindeki illerin fitocoğrafik bölgelere göre dağılımı.*

Türkiye is located in the Northern Hemisphere between 36-42° north latitude and 26-45° east longitude (Aktürk & Güney, 2021). The total surface area of the study area, which includes these 3 phytogeographical regions, is 779.646 km^2 (Ozturk et al., 2002; Aktürk & Güney, 2021). The Irano-Turanian phytogeographic region covers most of the Central Anatolian and Eastern Anatolian plateaus and has a Hard Continental climate type (Avcı, 1993). The Mediterranean phytogeographic region, which is another phytogeographic region, covers an area of 198.165 km^2 as a part of the 2.5 million km^2 basin, and the Mediterranean climate type is observed (Avcı, 1993; Ozturk et al., 2002). Another phytogeographic region, called the Euro-Siberian region, covers a large part of the North Anatolian and Black Sea lands (Avcı, 1993; Aktürk & Güney, 2021). In the Euro-Siberian region, the temperate oceanic climate type is observed. In addition to this research, succulent taxa constitute the other material of the study.

Theoretical Framework

Data on succulent plant species are included in the 'Flora of Turkey' created by Davis between 1965 and 1985, and in the Tübives database created in 2004. Records of newly identified succulent species in recent years and the characteristics of the area where succulent species live were determined using sources such as Ozhatay & Kültür (2006), Karaer & Celep (2008), Vladimirov et al. (2008) Ozhatay et al. (2011), Güner et al. (2012), Minareci et al. (2012), Ozhatay et al. (2013), Thiede, (2017), Uludag et al. (2017), Bozyel et al. (2021), Şükran & Abamor Bahar (2022), Ozhatay et al. (2022), Karaer et al. (2010), Suehs et al. (2004), Stancu & Stancu (2003), Daşkın et al. (2006), Bilgili & Karahan (2011), Karahan et al. (2006) Karahan (2004), Karahan & Angın (2008), Karahan & Yılmaz (2001) and Uotila et al. (2012). [CSFN 2023], [KEW 2023], [JSTOR 2023], [S&S 2023], [SL 2023], [PT 2023], [OP 2023] and [IDA 2023] web pages related to the habitat, geography and climate of succulent species were obtained from natural succulent plant taxa that belongs to the flora of Turkey obtained from herbarium examinations, Observation notes were recorded taken during field studies, and photographs taken. Additionally, , herbarium examinations of succulent species, notes taken during field studies and photographs taken were taken into account during data collection.

The endemic status, life form, phytogeography, altitude, and habitats of plant species were determined from Flora of Turkey (1965-1985), Tübives (2004), and articles published for newly registered succulent species. Information not available from these sources is available in Botanical Garden records, herbariums and [CSFN, 2023], [KEW, 2023], [JSTOR, 2023], [S&S, 2023], [SL, 2023], [PT, 2023], [OP, 2023] and [IDA, 2023] websites were examined. The hairiness of the plant species was generally determined by examining web pages.

Within the scope of the literature data examined later, succulent plants in 3 different phytogeographies; family, endemism status, distribution of natural distribution areas according to altitudes, climate, hairiness, which is the symbol of drought resistance, and habitat conditions, which are signs of resistance to harsh living environment conditions, were determined. In the last stage, landscape design and planning strategies were evaluated for green roofs to be designed in 3 different phytogeographic regions. While making these evaluations, a direct evaluation was made with some of the data obtained from the literature data. However, some data were interpreted by cross-comparison with each other. The main reason for cross- comparison was to increase the diversity that emerges as a result of the interaction between the data. Thus, it will be possible to choose the right species for green roofs to be made in 3 phytogeographic regions. In this context, the growth potentials of the succulent plants examined in cool, warm regions were evaluated. It has also been identified in species that can grow in both (cool and warm) regions. After evaluating all these data, strategies for landscape design and planning were developed.

SUCCULENT PLANTS IN TÜRKİYE

Within the scope of the study, family, taxa, life form, leaf hairiness, phytogeographic region, altitude, habitats, and endemism status of 157 succulent taxa were determined (Table 1). A total of 157 taxa belonging to 5 families (Aizoaceae, Cactaceae, Crassulaceae, Portulacaceae, and Saxifragaceae) were identified. The family with the highest number of taxa in the examined families is the Crassulaceae family. This family includes 71,9% of the succulent species studied with 113 taxa. The family with the highest number of taxa following the Crassulaceae family is the Saxifragaceae family. This family includes 17,8% of the examined succulent species with 28 taxa. The least number of taxa belongs to the Cactaceae family with 1 taxon.

Table 1. *Family, endemism, life form, leaf hairiness, phytogeographic region, altitude and habitat characteristics of succulent taxa naturally found in Türkiye*

Çizelge 1. *Türkiye'de doğal olarak bulunan sukkulent taksonların familya, endemizm, yaşam formu, yaprak tüylülüğü, fitocoğrafik bölge, rakım ve habitat özellikleri*

	Family	Species	Endemic	Life form				Leaf hairiness	Phyto geography			Altitude							Habitat						References*
				Herbaceous annual	Herbaceous biennial	Herbaceous perennial	Herbaceous monocarpic		Mediterrenian	Europe-Siberian	Irano-Turanian	0-500 m	500-1.000 m	1.000-1.500 m	1.500-2.000 m	2.000-2.500 m	2.500-3.000 m	3.000< m	Rocky areas	Moist grassy areas	Wetlands (Sweet)	Seaside (Salt)	Open areas	Forest areas	
1	Saxifragaceae	*Chrysosplenium alternifolium*				x				x			x							x	x				(7,16,19,20, 21,25)
2	Saxifragaceae	*Chrysosplenium dubium*				x				x		x	x							x					(1,2,7,16,19, 20,21)
3	Crassulaceae	*Crassula tillaea*		x					x	x		x									x				(1,2,7,16,19, 20,21)
4	Crassulaceae	*Crassula vaillanti*				x			x			x										x			(12,13,14,16, 19,20,21)
5	Crassulaceae	*Hylotelephium telephium*				x				x		x	x	x	x	x	x						x	x	(1,2,7,16,19, 20,21)
6	Aizoaceae	*Mesembryanthemum acinaciforme*				x			x	x		x										x			(7,6,10,16,19,20, 21,24)
7	Aizoaceae	*Mesembryanthemum edule*							x	x		x										x			(7,6,10,16,19,20, 21,23)
8	Aizoaceae	*Mesembryanthemum nodiflorum*		x					x					x								x			(1,2,7,16,19, 20,21)
9	Portulacaceae	*Montia arvensis*		x						x		x								x	x				(1,2,7,16,19, 20,21)
10	Portulacaceae	*Montia fontana* subsp. *amporitana*		x					x			x								x	x				(1,2,7,16,19, 20,21)
11	Cactaceae	*Opuntia ficus-barbarica*				x			x	x		x							x						(7,16,19,20,21)
12	Crassulaceae	*Phedimus stellatus*		x					x			x							x						(1,2,7,16,19, 20,21)
13	Crassulaceae	*Phedimus obtusifolius*				x			x	x	x	x	x	x	x	x	x		x						(1,2,7,16,19, 20,21)
14	Crassulaceae	*Phedimus spurius*				x				x				x	x	x	x		x						(1,2,7,16,19, 20,21)
15	Crassulaceae	*Phedimus stoloniferus*				x			x	x	x		x	x	x					x				x	(1,2,7,16,19, 20,21)
16	Portulacaceae	*Portulaca edulis*		x					x			x											x		(7,16,19,20,21)
17	Portulacaceae	*Portulaca grandiflora*		x					x	x		x											x		(7,16,19,20,21)
18	Portulacaceae	*Portulaca granulatostellulata*								x		x											x		(9,16,19,20,21)
19	Portulacaceae	*Portulaca nitida*		x						x		x											x		(7,9,16,19,20,21)
20	Portulacaceae	*Portulaca oleracea*		x					x	x		x									x				(1,2,7,16,19, 20,21,23)
21	Portulacaceae	*Portulaca papillatostellulata*		x						x		x											x		(7,16,19,20,21)
22	Portulacaceae	*Portulaca rausii*		x					x	x		x											x		(7,9,16,19,20,21)
23	Portulacaceae	*Portulaca sativa*				x					x	x									x				(9,16,17,19, 20,21,27)

Table 1. *Continued*

Çizelge 1. *Devamı*

	Family	Species	Endemic	Life form				Leaf hairiness	Phyto geography			Altitude							Habitat						References*
				Herbaceous annual	Herbaceous biennial	Herbaceous perennial	Herbaceous monocarpic		Mediterrenian	Europe-Siberian	Irano-Turanian	0-500 m	500-1.000 m	1.000-1.500 m	1.500-2.000 m	2.000-2.500 m	2.500-3.000 m	3.000< m	Rocky areas	Moist grassy areas	Wetlands (Sweet)	Seaside (Salt)	Open areas	Forest areas	
24	Portulacaceae	*Portulaca trituberculata*		X	X					X	X	X											X		(7,9,16,19,20,21)
25	Portulacaceae	*Portulaca zaffaranii*		X						X		X											X		(7,9,16,19,20,21)
26	Crassulaceae	*Prometheum aizoon*				X		X	X	X	X				X	X	X	X	X						(1,2,7,16,19, 20,21)
27	Crassulaceae	*Prometheum chrysanthum*	E				X	X	X						X	X			X						(1,2,6,7,16,19,20, 21)
28	Crassulaceae	*Prometheum chrysanthum* subsp. *chrysanthum*	E			X		X	X	X				X	X	X			X						(1,2,7,16,19, 20,21,26)
29	Crassulaceae	*Prometheum chrysanthum* subsp. *Uludagense*	E			X		X		X					X	X			X				X	X	(1,2,7,16,19, 20,21,26)
30	Crassulaceae	*Prometheum muratdaghense*	E			X		X	X	X						X			X						(1,2,7,16,19, 20,21)
31	Crassulaceae	*Prometheum pilosum*			X			X		X	X			X	X	X			X						(1,2,7,16,19, 20,21)
32	Crassulaceae	*Prometheum rechingeri*				X		X			X					X	X		X						(1,2,7,16,19, 20,21)
33	Crassulaceae	*Prometheum sempervivoides*			X			X			X			X	X	X	X		X						(1,2,7,16,19, 20,21)
34	Crassulaceae	*Prometheum serpentinicum* var. *giganteum*	E				X	X	X			X							X						(1,2,7,16,19, 20,21)
35	Crassulaceae	*Prometheum serpentinicum* var. *serpentinicum*	E				X		X							X	X		X						(1,2,7,16,19, 20,21)
36	Crassulaceae	*Rosularia blepharophylla*	E			X		X			X	X	X						X						(1,2,7,16,19, 20,21)
37	Crassulaceae	*Rosularia davisii*	E			X					X						X		X						(1,2,7,16,19, 20,21)
38	Crassulaceae	*Rosularia elymaitica*					X				X				X				X						(1,2,7,16,19, 20,21)
39	Crassulaceae	*Rosularia globulariifolia*	E				X	X	X			X	X						X						(1,2,7,16,19, 20,21)
40	Crassulaceae	*Rosularia haussknechtii*	E			X					X				X	X	X		X						(1,2,7,16,19, 20,21)
41	Crassulaceae	*Rosularia libanotica*				X		X	X		X	X	X	X	X	X			X						(7,16,19,20,21)
42	Crassulaceae	*Rosularia paluensis*									X			X					X						(13.14,16,19, 20.21)
43	Crassulaceae	*Rosularia radiciflora*				X					X		X	X	X	X			X						(7,16,19,20,21)
44	Crassulaceae	*Rosularia sempervivum* subsp. *amanensis*	E			X			X						X				X						(1,2,7,16,19, 20,21)
45	Crassulaceae	*Rosularia sempervivum* subsp. *glaucophylla*	E			X			X					X	X	X			X						(1,2,7,16,19, 20,21)
46	Crassulaceae	*Rosularia sempervivum* subsp. *kurdica*				X		X			X		X	X	X	X	X		X						(1,2,7,16,19, 20,21)
47	Crassulaceae	*Rosularia sempervivum* subsp. *libanotica*				X		X	X		X	X	X	X					X						(1,2,7,16,19, 20,21)
48	Crassulaceae	*Rosularia sempervivum* subsp. *persica*				X			X	X	X				X	X	X		X						(1,2,7,16,19, 20,21)
49	Crassulaceae	*Rosularia sempervivum* subsp. *pestalozzae*				X			X	X			X	X	X	X			X					X	(1,2,7,16,19, 20,21)
50	Crassulaceae	*Rosularia sempervivum subsp. sempervivum*				X			X	X	X		X	X	X	X	X		X						(1,2,7,16,19, 20,21)
51	Crassulaceae	*Rosularia serrata*				X			X			X	X						X						(1,2,7,16,19, 20,21)
52	Saxifragaceae	*Saxifraga artvinensis meryemii*				X				X				X										X	(14,16,19,20, 21)
53	Saxifragaceae	*Saxifraga adscendens subsp. adscendens*		X						X	X				X	X	X		X						(1,2,16,19,20,21)
54	Saxifragaceae	*Saxifraga artvinensis*	E			X				X						X			X						(1,2,6,7,16,19,20, 21)
55	Saxifragaceae	*Saxifraga bulbifera*				X		X			X		X							X					(7,16,19,20,21)

Table 1. *Continued*

Çizelge 1. *Devamı*

	Family	Species	Endemic	Life form				Leaf hairiness	Phyto geography			Altitude							Habitat						References*
				Herbaceous annual	Herbaceous biennial	Herbaceous perennial	Herbaceous monocarpic		Mediterrenian	Europe-Siberian	Irano-Turanian	0-500 m	500-1.000 m	1.000-1.500 m	1.500-2.000 m	2.000-2.500 m	2.500-3.000 m	3.000< m	Rocky areas	Moist grassy areas	Wetlands (Sweet)	Seaside (Salt)	Open areas	Forest areas	
56	Saxifragaceae	*Saxifraga carpetana subsp. graeca*				x		x	x	x				x					x	x		x	x		(7,16,19,20,21)
57	Saxifragaceae	*Saxifraga cymbalaria var. cymbalaria*		x					x	x	x					x				x	x				(1,2,7,16,19, 20,21)
58	Saxifragaceae	*Saxifraga cymbalaria varyete huetiana*		x					x	x	x					x				x	x				(1,2,7,16,19, 20,21)
59	Saxifragaceae	*Saxifraga exarata* var. *adenophora*				x			x	x	x				x	x	x	x	x					x	(1,2,7,16,19, 20,21)
60	Saxifragaceae	*Saxifraga exarata* var. *exarata*				x		x	x	x	x						x	x	x	x					(1,2,7,16,19, 20,21)
61	Saxifragaceae	*Saxifraga hederacea* var. *hederacea*		x				x	x	x						x			x	x					(1,2,7,16,19, 20,21)
62	Saxifragaceae	*Saxifraga hederacea* var. *libanotica*		x				x	x		x	x	x	x					x	x					(1,2,7,16,19, 20,21)
63	Saxifragaceae	*Saxifraga hirculus*				x					x	x									x				(1,2,7,16,19, 20,21)
64	Saxifragaceae	*Saxifraga juniperifolia*				x				x							x	x	x						(1,2,7,16,19, 20,21)
65	Saxifragaceae	*Saxifraga kolenatiana*				x				x		x	x	x	x	x	x	x	x						(1,2,7,16,19, 20,21)
66	Saxifragaceae	*Saxifraga kotschyi*				x				x	x			x	x	x	x	x	x						(1,2,7,16,19, 20,21)
67	Saxifragaceae	*Saxifraga luteoviridis*				x			x	x					x	x	x	x	x						(1,2,7,16,19, 20,21)
68	Saxifragaceae	*Saxifraga moschata*				x		x		x					x	x	x	x	x	x					(1,2,7,16,19, 20,21)
69	Saxifragaceae	*Saxifraga paniculata* subsp. *cartilaginea*				x				x		x	x	x	x	x	x	x	x						(1,2,7,16,19, 20,21)
70	Saxifragaceae	*Saxifraga paniculata* subsp. *paniculata*				x				x		x	x	x	x	x	x	x	x						(1,2,7,16,19, 20,21)
71	Saxifragaceae	*Saxifraga rotundifolia*				x		x		x		x	x	x	x	x			x					x	(1,2,7,16,19, 20,21)
72	Saxifragaceae	*Saxifraga sancta*				x				x					x				x						(1,2,7,16,19, 20,21)
73	Saxifragaceae	*Saxifraga sempervivum*				x				x						x			x						(1,2,7,16,19, 20,21)
74	Saxifragaceae	*Saxifraga sibirica* subsp. *sibirica*				x				x		x	x	x	x	x	x	x	x		x				(1,2,7,16,19, 20,21)
75	Saxifragaceae	*Saxifraga sibirica* subsp. *mollis*				x			x	x	x		x	x	x	x	x	x	x		x				(1,2,7,16,19, 20,21)
76	Saxifragaceae	*Saxifraga sibthorpii*		x					x			x	x	x	x	x			x		x				(1,2,7,16,19, 20,21)
77	Saxifragaceae	*Saxifraga tridactylites*		x				x	x	x	x	x	x	x	x	x			x						(1,2,7,16,19, 20,21)
78	Crassulaceae	*Sedum acre*				x				x	x		x	x	x				x						(1,2,7,16,19, 20,21)
79	Crassulaceae	*Sedum aetnense*		x					x			x	x	x	x	x			x						(1,2,7,16,19, 20,21)
80	Crassulaceae	*Sedum album*				x			x	x	x	x	x	x	x	x			x						(1,2,7,16,19, 20,21,28)
81	Crassulaceae	*Sedum alpestre*				x				x					x	x	x		x						(1,2,7,16,19, 20,21)
82	Crassulaceae	*Sedum amplexicaule subsp. tenuifolium*				x			x			x							x					x	(1,2,7,16,19, 20,21)
83	Crassulaceae	*Sedum annuum*			x						x				x	x	x	x	x	x					(1,2,7,16,19, 20,21)
84	Crassulaceae	*Sedum atratum*		x				x		x					x	x	x		x						(16,32)
85	Crassulaceae	*Sedum assyriacum*		x							x		x	x	x					x					(1,2,7,16,19, 20,21)
86	Crassulaceae	*Sedum caespitosum*		x							x	x	x										x		(1,2,16,19,20,21)
87	Crassulaceae	*Sedum cepaea*			x				x	x	x			x	x									x	(1,2,7,16,19, 20,21)

Table 1. *Continued*

Çizelge 1. *Devamı*

	Family	Species	Endemic	Life form				Leaf hairiness	Phyto geography			Altitude							Habitat						References*
				Herbaceous annual	Herbaceous biennial	Herbaceous perennial	Herbaceous monocarpic		Mediterrenian	Europe-Siberian	Irano-Turanian	0-500 m	500-1.000 m	1.000-1.500 m	1.500-2.000 m	2.000-2.500 m	2.500-3.000 m	3.000< m	Rocky areas	Moist grassy areas	Wetlands (Sweet)	Seaside (Salt)	Open areas	Forest areas	
88	Crassulaceae	*Sedum confertiflorum*		X					X	X	X	X	X	X	X	X			X						(1,2,7,16,19, 20,21,28)
89	Crassulaceae	*Sedum dasyphyllum*				X			X	X					X				X						(1,2,7,16,19, 20,21)
90	Crassulaceae	*Sedum eriocarpum subsp. caricum*	E	X					X			X	X						X						(1,2,7,16,19, 20,21)
91	Crassulaceae	*Sedum eriocarpum* subsp. *orientale*		X					X			X	X						X						(2,7,16,19,20,21)
92	Crassulaceae	*Sedum ermenekensis*									X				X				X					X	(3,16,19,20,21)
93	Crassulaceae	*Sedum euxinum*	E			X				X					X	X	X		X						(1,2,7,16,19, 20,21)
94	Crassulaceae	*Sedum gracile*				X				X					X	X	X	X	X						(1,2,7,16,19, 20,21)
95	Crassulaceae	*Sedum grisebachii* var. *grisebachii*				X				X		X	X											X	(1,2,7,16,19, 20,21)
96	Crassulaceae	*Sedum hispanicum* var. *semi glabrum*				X					X				X	X	X		X						(1,2,16,19,20,21)
97	Crassulaceae	*Sedum hispanicum* var. *hispanicum*				X					X	X	X	X	X	X			X						(1,2,7,16,19, 20,21,29)
98	Crassulaceae	*Sedum hispanicum* var. *planifolium*	E			X					X			X	X				X						(1,2,16,19,20,21)
99	Crassulaceae	*Sedum ince*	E	X							X			X	X				X						(1,2,7,16,19, 20,21)
100	Crassulaceae	*Sedum inconspicuum*	E	X							X					X			X						(1,2,7,16,19, 20,21)
101	Crassulaceae	*Sedum koyuncui*							X					X										X	(9,16,19,20,21)
102	Crassulaceae	*Sedum litoreum* var. *creticum*		X					X			X							X						(1,2,16,19,20,21, 29)
103	Crassulaceae	*Sedum litoreum* var. *litoreum*		X					X			X							X						(1,2,7,16,19, 20,21,29)
104	Crassulaceae	*Sedum lydium*	E			X			X	X		X	X	X						X					(1,2,7,16,19, 20,21,28)
105	Crassulaceae	*Sedum magellense*				X			X	X	X				X	X			X						(1,2,7,16,19, 20,21,29)
106	Crassulaceae	*Sedum microcarpum*		X							X	X							X						(1,2,7,16,19, 20,21,29)
107	Crassulaceae	*Sedum nanum*		X							X			X	X	X	X			X	X				(1,2,7,16,19, 20,21,29)
108	Crassulaceae	*Sedum ochroleucum subsp. ochroleucum*				X				X		X	X						X						(1,2,7,16,19, 20,21)
109	Crassulaceae	*Sedum optusifolium*				X				X	X	X	X	X	X	X			X						(28,29)
110	Crassulaceae	*Sedum pallidum* var. *bitynicum*				X				X		X	X	X	X				X					X	(1,2,7,16,19, 20,21,29)
111	Crassulaceae	*Sedum pallidum var. pallidum*				X				X		X	X	X	X				X					X	(1,2,7,16,19, 20,21,29)
112	Crassulaceae	*Sedum pilosum*				X				X				X	X	X			X						(28,29)
113	Crassulaceae	*Sedum rubens*				X			X	X	X	X	X	X					X					X	(1,2,7,16,19, 20,21,29)
114	Crassulaceae	*Sedum samium subsp. micranthum*	E	X					X				X	X					X					X	(1,2,7,16,19, 20,21)
115	Crassulaceae	*Sedum samium subsp. samium*		X					X				X	X					X	X					(1,2,7,16,19, 20,21)
116	Crassulaceae	*Sedum sediforme*				X			X	X		X	X						X						(1,2,7,16,19, 20,21,28,29)
117	Crassulaceae	*Sedum sempervivoides*			X						X			X	X	X	X		X						(28,29,31)
118	Crassulaceae	*Sedum steudelii*		X					X	X	X		X	X	X				X						(1,2,7,16,19, 20,21,29)
119	Crassulaceae	*Sedum stellatum*				X			X			X	X						X						(28,29)

Table 1. *Continued*

Çizelge 1. *Devamı*

	Family	Species	Endemic	Life form				Leaf hairiness	Phyto geography			Altitude							Habitat						References*
				Herbaceous annual	Herbaceous biennial	Herbaceous perennial	Herbaceous monocarpic		Mediterrenian	Europe-Siberian	Irano-Turanian	0-500 m	500-1.000 m	1.000-1.500 m	1.500-2.000 m	2.000-2.500 m	2.500-3.000 m	3.000< m	Rocky areas	Moist grassy areas	Wetlands (Sweet)	Seaside (Salt)	Open areas	Forest areas	
120	Crassulaceae	*Sedum stoloniferum*				X		X		X	X		X	X						X					(28,29)
121	Crassulaceae	*Sedum subulatum*				X				X	X			X	X	X	X	X	X						(1,2,7,16,19, 20,21,29)
122	Crassulaceae	*Sedum spurium*				X				X			X	X	X	X	X		X						(28,29,31,32)
123	Crassulaceae	*Sedum telephium*				X				X	X				X	X	X		X					X	(28,29,31)
124	Crassulaceae	*Sedum tenellum*				X			X	X	X				X	X	X	X	X						(1,2,7,16,19, 20,21)
125	Crassulaceae	*Sedum ursi*	E			X			X					X	X	X	X		X						(1,2,7,16,19, 20,21)
126	Crassulaceae	*Sedum urvillei*				X			X	X	X	X	X	X					X						(1,2,7,16,18, 19,20,21,29)
127	Crassulaceae	*Sempervivum armenum* var. *armenum*	E			X		X		X	X				X	X	X	X	X						(1,2,7,16,18, 19,20,21,30)
128	Crassulaceae	*Sempervivum armenum* var. *insigne*	E			X		X		X	X				X	X	X	X	X						(1,2,7,16,18, 19,20,21,30)
129	Crassulaceae	*Sempervivum artvinense*				X		X		X						X			X						(1,2,7,16,19, 20,21,30)
130	Crassulaceae	*Sempervivum brevipilum*	E			X		X			X			X					X						(1,2,7,16,18, 19,20,21,30)
131	Crassulaceae	*Sempervivum davisii*				X		X		X	X		X	X	X	X			X						(1,2,7,16,18, 19,20,21,30)
132	Crassulaceae	*Sempervivum ekimii*	E			X		X		X				X	X	X	X	X	X						(4.6,7,16,18, 19,20,21)
133	Crassulaceae	*Sempervivum feigeanum*	E					X		X		X	X						X						(7,16,18,19, 20,21)
134	Crassulaceae	*Sempervivum furseorum*	E			X		X		X					X	X			X						(1,2,16,18,19,20, 21,30)
135	Crassulaceae	*Sempervivum gillianii*	E			X		X		X					X	X	X		X						(1,2,7,16,18, 19,20,21,30)
136	Crassulaceae	*Sempervivum glabrifolium*	E			X		X		X		X	X						X						(1,2,7,16,18, 19,20,21,30)
137	Crassulaceae	*Sempervivum glabrifolium* subsp. *glabrifolium*	E					X			X							X	X						(7,16,18,19,20,21 ,30)
138	Crassulaceae	*Sempervivum globiferum* subsp. *aghricum*	E			X		X			X						X		X						(1,2,7,16,19, 20,21,30)
139	Crassulaceae	*Sempervivum herfriedianum*	E					X		X		X	X	X	X				X						(7,16,19,20,21)
140	Crassulaceae	*Sempervivum ispartae*	E			X		X	X					X					X						(1,2,7,16,18, 19,20,21,30)
141	Crassulaceae	*Sempervivum minus*	E	X				X		X			X	X	X	X	X		X						(7,15,16,18,19,20 ,21)
142	Crassulaceae	*Sempervivum minus var. glabrum*	E			X		X		X			X	X	X				X						(1,2,7,16,19, 20,21,30)
143	Crassulaceae	*Sempervivum minus var. minus*	E			X		X		X			X	X	X				X						(1,2,7,16,19, 20,21,30)
144	Crassulaceae	*Sempervivum montanum*				X		X		X					X	X	X		X						(32,33)
145	Crassulaceae	*Sempervivum pisidicum*	E			X			X					X	X	X			X						(1,2,7,16,18, 19,20,21,30)
146	Crassulaceae	*Sempervivum sosnowskyi*				X		X		X						X			X						(6,7,9,16,18, 19,20,21,22)
147	Crassulaceae	*Sempervivum staintonii*	E			X		X		X					X				X						(1,2,7,16,18, 19,20,21,30)
148	Crassulaceae	*Sempervivum transcaucasicum*				X		X		X							X		X						(1,2,7,10,16, 18,19,20,21)
149	Crassulaceae	*Umbilicus chloranthus*				X			X			X							X						(1,2,7,16,18, 19,20,21)
150	Crassulaceae	*Umbilicus erectus*				X			X	X	X		X	X	X	X			X						(1,2,7,16,19, 20,21)
151	Crassulaceae	*Umbilicus horizontalis var. horizontalis*				X			X			X	X						X					X	(1,2,7,16,19, 20,21)

Table 1. *Continued*

Çizelge 1. *Devamı*

	Family	Species	Endemic	Life form				Leaf hairiness	Phyto geography			Altitude							Habitat						References*
				Herbaceous annual	Herbaceous biennial	Herbaceous perennial	Herbaceous monocarpic		Mediterrenian	Europe-Siberian	Irano-Turanian	0-500 m	500-1.000 m	1.000-1.500 m	1.500-2.000 m	2.000-2.500 m	2.500-3.000 m	3.000< m	Rocky areas	Moist grassy areas	Wetlands (Sweet)	Seaside (Salt)	Open areas	Forest areas	
152	Crassulaceae	*Umbilicus horizontalis var. intermedius*				x			x			x	x						x					x	(1,2,7,16,19, 20,21)
153	Crassulaceae	*Umbilicus intermedius*				x			x		x	x	x						x	x					(7,16,18,19,20,21)
154	Crassulaceae	*Umbilicus luteus*			x				x	x	x	x	x	x					x						(1,2,7,16,19, 20,21)
155	Crassulaceae	*Umbilicus parviflorus*				x			x			x							x						(1,2,7,16,18, 19,20,21)
156	Crassulaceae	*Umbilicus rupestris*				x			x	x		x	x						x						(1,2,7,16,18, 19,20,21)
157	Crassulaceae	*Umbilicus tropaeolifolius*				x			x	x		x	x						x						(1,2,7,16,18, 19,20,21)

* 1= Davis, 1965-85; 2=TUBİVES, 2004; 3= Ozhatay & Kültür, 2006; 4= Karaer & Celep, 2008; 5= Vladimirov et al., 2008; 6= Ozhatay et al., 2011; 7= Güner et al., 2012; 8= Minareci et al., 2012; 9= Ozhatay et al., 2013; 10= Thiede, 2017; 11= Uludag et al., 2017; 12= Bozyel et al., 2021; 13= Şükran & Abamor Bahar, 2022; 14= Ozhatay et al., 2022; 15= [CSFN, 2023]; 16= [KEW, 2023]; 17= [JSTOR, 2023]; 18= [S&S, 2023]; 19= [SL, 2023]; 20= [PT, 2023]; 21= [OP, 2023]; 22= Karaer et al., 2010; 23= [IDA, 2023]; 24= Suehs et al., 2004; 25= Stancu & Stancu, 2003; 26= Daşkın et al., 2006; 27= Uotila et al., 2012; 28= Bilgili & Karahan, 2011; 29= Karahan et al., 2006; 30= Karahan, 2004; Karahan & Angın, 2008; 31= Karahan & Yılmaz, 2001; 32 Wagner & Larcher, 1981.

The succulent species examined within the scope of the study are 94 herbaceous perennials, 36 are herbaceous annuals, 6 are herbaceous biennials and 5 have monocarpic (Table 1) life forms. Within the scope of the study, 157 succulent taxa were identified in 3 phytogeographic regions in Türkiye. Of these taxa, 97 belong to the Euro-Siberian, 73 to the Mediterranean, and 63 to the Iranian Turanian phytogeography (Table 1). The largest number of taxa was found to be in the Euro-Siberian phytogeography. Besides, some taxa can be found in more than one phytogeographic region. For example, there are 39 taxa in the Mediterranean and Euro-Siberian phytogeography, 33 taxa in the Euro-Siberian and Iranian Turanian phytogeography, 25 taxa in the Mediterranean and Iran Turanian phytogeography, and 21 taxa in three phytogeography.

Among the phytogeographic regions examined within the scope of the study, in the Mediterranean: the Mediterranean climate, in European Siberia: A temperate oceanic climate and in Iran Turan phytogeographical region: The hard Continental climate type is observed. Most of the succulent taxa examined in the study area are located in the Alpine Belt (2000m <). However, there are many taxa that can grow at sea level. Leaf hairiness is a defense mechanism developed by plants to reduce water loss by transpiration and is considered a sign of drought resistance. While the leaves of 45 taxa are hairy, the leaves of 112 taxa are hairless. Habitat research was conducted for 157 taxa examined. The 123 succulent taxa studied can live in rocky areas (Table 1) and in very shallow soils. These taxa are the most advantageous taxa for use in roof gardens. After the rocky areas, the most taxa are moist grassy areas (20 taxa), forest areas (19 taxa), wetlands (13 taxa), and open areas (12 taxa). The habitat with the least number of taxa is the seaside (5 taxa). Taxa distributed by the sea are the most suitable species for use in dune areas. In addition, these taxa are highly resistant to high salt and drought.

Besides, some species can live simultaneously in different habitats. Within the scope of the study, 13 taxa can grow in rocky areas and forest areas, and 8 taxa can grow in rocky areas and moist grassy areas (Table 1). In addition, *Saxifraga carpetana* subsp. *graeca* species is the only taxon that can grow in rocky areas, moist grassy areas, seasides, and open areas. Finally, the endemism status of the examined succulent taxa was determined. 38 of the 157 succulent taxa identified are endemic. Of endemic taxa; 17 of them *Sempervivum* spp. genera, 8 of them *Sedum* spp. genera, 1 of them *Saxifraga* spp. genera, 6 of

them *Rosularia* spp. genera and 6 of them *Prometheum* spp. belongs to the genera (Table 1). The genera with the highest endemism rate are *Sempervivum* spp.

Succulent Plants for cool Climates in Türkiye

Among the succulents examined within the scope of the study, 97 taxa were identified that can grow in cool (Temperate-Ocean) climates. As seen from Table 1, the most succulent taxa in Türkiye are grown in the cool climate zone. The 26 examined *Saxifraga* spp. among 23 taxa, 23 *Sempervivum* spp. among 17 taxa, 49 *Sedum* spp. among 26 taxa, 10 *Prometheum* spp. among 5 taxa, 9 *Umbilicus* spp. among 4 taxa and 16 *Rosularia* spp. 3 taxa grow in cool climates. Based on these data, *Saxifraga* spp. and *Sempervivum* spp. genera grow better in cold climates when *Rosularia* spp. can be assumed that the genera do not develop well in cool climates under Turkish conditions. *Saxifraga* spp. the genera 21 of 26 taxa can grow in rocky and shallow soils and 18 taxa develop at altitudes above 2000 m. This information means that *Saxifraga* spp. can potentially be used in green roof applications in cool areas. Among the examined taxa, only the *Saxifraga artvinensis* taxon is endemic among the *Saxifraga* spp. genera which are common in Türkiye. Hairiness is generally an adaptation developed by plant species adapted to warm climates (Moles et al., 2020). However, Little et al. (2016), it has been determined that hairiness provides protection to the plant not only in arid climates but also in cool climates. When the genera *Saxifraga* spp. was examined, it was determined that only 8 taxa were hairy among 26 taxa. In line with this information, it can be stated that the use of *Saxifraga* spp. is more appropriate for green roofs to be designed in cool climates in Türkiye.

Another cool climate succulent plant genera is *Sempervivum* ssp. *Sempervivum* genera is the member of Crassulaceae family and native for Europe and Asia continents. This genus exist both arid regions (Karahan, 2004). The genera *Sempervivum* spp, it is seen that all 22 taxa grow in rocky and shallow soils. When the altitude values are examined, 11 of 22 taxa show growth at an altitude above 2000 m. In addition, *Sempervivum* spp is highly resistant to temperature extremes, strong sun exposure, and drought. *Sempervivum* spp. is a preferred genus in green roof and xeriscape landscaping applications (Carey et al., 2009; Karahan, 2004). It is known that the soil requirements of the genera *Sempervivum* spp. are also very low (Zaharia, 2012). Monteiro et al. (2017), it was determined that the most frequently used plants on green roofs, *Sedum* spp., had better environmental cooling and substrate insulation potential than *Sempervivum* spp. The most striking feature of the genera *Sempervivum* ssp. is its endemism. Of the 22 taxa examined, 17 are endemic. This corresponds to an endemism rate of 77,2%. It has already been mentioned that hairiness is an adaptation developed by plant species that have adapted to both hot and cold climates. However, according to a study by Wang et al. (2022), hairy leaves are seen in drier climates, while hairless leaves are seen in more humid climates. When the genera *Sempervivum* spp. was examined, it was seen that only *Sempervivum pisidicum* taxa were not hairy out of 22 taxa. In addition, when the hairiness, phytogeography, altitude, and habitat areas were compared diagonally, it was determined that all 10 *Sempervivum* spp. genera were hairy, growing in cold climates, growing at altitudes above 2000 m, and all of them growing in rocky areas. In line with this information, studies on *Sempervivum* spp. species, which has a very high endemism rate, should be increased and its ability to grow in other climates should be examined in more detail. In addition, its use on green roof should be expanded.

Succulent Plants for warm Climates in Türkiye

Among the examined succulents, 72 taxa that can grow in warm (Mediterranean) climates were determined. In the Mediterranean phytogeography, 21 taxa among 49 *Sedum* spp., 6 taxa among 10 *Prometheum* spp., 11 taxa among 26 *Saxifraga* spp. and 9 taxa among 16 *Rosularia* spp. were found to grow in warm climates. In addition, *Umbilicus* spp. (9 taxa), *Mesembryanthemum* spp. (3 taxa) and *Crassula* spp. (2 taxa) were all grown in warm climates. Based on these data, it can be assumed that *Umbilicus* spp, *Mesembryanthemum* spp and *Crassula* spp grow better in warm climates. In addition, the genera *Rosularia* spp. is a genus adapted to warm climates. The genera *Umbilicus* spp. all of the 9 taxa

are in rocky and shallow soils, and all grow at altitudes below 1,000 m. Succulent species are generally plants adapted to shallow soils (Kirschner et al., 2021). Our country is among the water-poor countries in terms of water. In water-rich countries, more than 10,000 m^3 of water per person per year falls, while this amount is only 1,450 m^3 in Türkiye (Ismaeil & Sobaih 2022; Altay & Uslu 2022). In this context, also succulent taxa to be used especially in shallow and deep soils should be preferred in green roof and xeriscape landscape applications. According to the study by Takesh et al. (2019), the taxon *Umbilicus intermedius* is generally distributed worldwide, but it is more common in South Africa, the deserts of Israel, and Lebanon the mountains of Jordan and Saudi Arabia and in arid regions of Iran such as Ilam has been detected. In addition, no endemic taxa could be found among *Umbilicus* spp. When the hairiness status was examined, no hairiness was found in *Umbilicus* spp. Considering that *Umbilicus* spp. grows in rocky and shallow soils, generally develops at low altitudes, and adapts to warm climates, ıt can be said that it has a high potential to be used in extensive green roof to be designed in Türkiye. Another warm climate succulent genera is *Rosularia* spp. All 16 *Rosularia* spp. genera can grow in rocky and shallow soils and 9 out of 16 taxa thrive at altitudes below 1,000 m. In the examinations, it was determined that 6 of the *Rosularia* spp. genera were endemic. In addition, when the hairiness of *Rosularia* spp. genera were examined, it was determined that only 5 taxa were hairy. Considering all this information, *Rosularia* spp. is a genus that has the potential to be used in applications made on shallow soils such as green roofs. It can also be preferred in xeriscape landscaping applications. By using *Umbilicus* spp. and *Rosularia* spp. species naturally found in Türkiye, the amount of water consumption can be reduced, maintenance costs can be reduced, and it can be ensured that the taxa used are less affected by the environmental climatic conditions.

Succulent Plants for warm and cool climates in Türkiye

Within the scope of the study, the Irano-Turanian phytogeographic region (hard continental climate) reflects both warm and cool climate characteristics. Among the detected taxa, there are 63 taxa that can grow in harsh continental climates. Among the examined taxa, 11 taxa among 16 *Rosularia* spp., 10 taxa among 26 *Saxifraga* spp., and 25 taxa among 49 *Sedum* spp. were found to grow in both warm and cool climates. As a result of examination at these data, it was determined that *Rosularia* spp. and *Sedum* spp. genera show better growth in both warm and cool climates. *Sedum* spp. genera is a species that can adapt to both arid and cool conditions in Türkiye. Many taxa perform well against winter frosts, including *Sedum album*, *Sedum acre, Sedum reflexum* and *Sedum spurium* used on green roofs (Farrell et al., 2012). In a study by Klein and Coffman, (2015), it was found that in temperate climates, *Sedum* spp. outperforms North American naturally grown plant species in shallow roof soils. However, in a study conducted by Klein and Coffman (2015), it was mentioned that *Sedum* spp. genera should be used with caution when designing green roofs as they do not perform well in warm climates. The genera *Sedum* spp., 24 out of 49 taxa can grow in rocky and shallow soils. In a study by Dvorak & Volder (2010), the effect of soil depth on *Sedum* spp. species was evaluated. As a result of the study, it was seen that the *Sedum sarmentosum* species had the highest coverage among all soil depths. In addition, *Sedum floriferum, Sedum stefco* and *Sedum spurium* species were determined to be much more effective at 7 cm depth than 4 cm depth in terms of soil depth. Although the *Sedum* spp. genera has proven successful on shallow wide green roofs in many ecoregions, there is also confusion in some ecoregions. It has been observed in studies that *Sedum* spp. is exposed to root damage due to freezing (Chell et al., 2022). *Sedum* ssp. species are rosette-shaped plants that spread irregularly. *Sedum* ssp. genus is found not only in arid but also in semi-arid, tropical, subtropical and cool climate regions (Dvorak & Volder 2010; Demircan et al., 2006)**.** In the study conducted by Karahan & Yılmaz (2001), they determined the use of some succulent species such as *Euphorbia* ssp, *Sedum* ssp, and *Sempervivum* ssp, which are resistant to the ecological conditions of the Central Anatolia Region. When the altitude values of the genera *Sedum* spp. were examined, it was determined that there were 14 taxa below 1,000 m, and 16 taxa developed at an altitude above 2000 m. Only 8 taxa are endemic among the most common *Sedum* spp species among

succulent species in our country. When the hairiness status of Sedum spp. genera in Türkiye was examined, and no hairiness was found in the taxa. In line with this information, for green roofs to be designed in Türkiye, *Sedum* spp. is a versatile breed that can be used in extensive green roofs to be designed in both cool and warm climates.

Limitations of the Study

This study was conducted to determine the succulents that can be used in green roof in Türkiye, which has 3 phytogeographic regions and was determined as the study area, there are some limitations. For example, there have been difficulties in accessing herbariums for altitude, habitat, hairiness, and endemism detection. At this point, the web pages or checklists of the relevant universities were examined. To determine hairiness, the pictures on the herbarium and internet addresses were looked at. In addition, when examining the hairiness, only leaf hairiness was examined. In future studies, the hairiness of the plant on the stem and shoot should also be examined. The most important limitation of the study is that the subjects such as soil and water consumption could not be reached.

CONCLUSION

Within the scope of the study, family, endemism, life form, hairiness, phytogeography/climate, altitude, and habitats of 157 succulent taxa were determined. Then, using this information, the suitability of the plants for green roofs in cool climates, warm climates or both climates, and suitability was evaluated according to phytogeographic regions. In addition, habitat and hairiness conditions can help us to obtain information about the climate, soil, and water consumption of the habitat where the plants live. Altitude helps the climatic characteristics of the area where the plants live. When the results of the study were examined, it was determined that the use of 97 succulent taxa for cool climate regions was appropriate and among these taxa, *Saxifraga* spp. and *Sempervivum* spp. were found to be dense. In warm climate regions, *Umbilicus* spp. and *Rosularia* spp. genera were found to be dense among 72 succulent taxa. In addition, these taxa are genera that can be used in xeriscape landscape applications. As a result of the study, 63 taxa that can grow in both climatic regions were determined. Among these taxa, *Rosularia* spp. and *Sedum* spp. genera were found to be dense. In addition to helping with the correct planning and design studies for green roofs according to the climate, this study will contribute to the reduction of water consumption with natural succulent plant species that can be used in xeriscape landscapes in an important issue such as the water crisis, which has been on the agenda in recent years. Before green roof planning and design studies are carried out in Türkiye, succulent species should be selected according to the climate of the phytogeographic region. There is also a need for a working process with the university, relevant ministries, local governments, experts, and other stakeholders. Thanks to these arrangements, a green roof arrangement can be realized in terms of water, energy, and climate.

Data Availability

Data will be made available upon reasonable request.

Author Contributions*

Conception and design of the study: OA; sample collection: KE; analysis and interpretation of data: OA; visualization: OA; writing manuscript: OA, KE.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that there is no need for an ethics committee for this research.

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