Advances in Biology & Earth Sciences
Vol.9, No.2, 2024, pp.301-309
https://doi.org/10.62476/abes9301

CHOROLOGICAL ANALYSIS AND PHENOLOGICAL OBSERVATIONS OF SOMESPECIES OF THE FAMILY *CRASSULACEAE* J.ST.-HIL. IN THE LESSER CAUCASUS OF AZERBAIJAN

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Abstract. Research has been carried out in some characteristic areas of Azerbaijan in recent years. The results of the chorological analyses showed that species of the *Crassulacea* in Irano-Turanian province, are distributed in two or three territories of this province. The results of phenologicalobservations and morphometric parameters indicate that all species have successfully passed through all stages of development. The sequence of seasonal changes in the same community is repeated from year to year, but the timing of the phases and individual details are different. As a result of the study of phenological features, the plants with the earliest start of vegetation,as well as early flowering and fruiting were identified. *P. stolonifer*, and *S. acre* are the plants with the earliest beginning of vegetation, as well as early flowering and fruiting. Fruits of plantsof the *Crassulaceae* genus ripen in July. 1 species of hare cabbage (*Sedum acre*) is found onlyin the Lesser Caucasus, two species (*S. hispanicum, S. pentapetalum* Boriss.) are foundthroughout Azerbaijan, 6 species (*Prometheum pilosum, Phedimus spurius, Sedum gracile, S. pallidum, S.annum, Petrosedum subulatum*) in the territory of the Greater and Lesser Caucasus, Nakhichevan (*Diabar*), Lankaran, one species (*Phedimus stoloniferum*) of the Greater Caucasus, the Lesser Caucasus, Lankaran, one species (*Sedum tenellum*) in the territory of theGreater Caucasus, the Lesser Caucasus, Lankaran, one species (*Sedum album*) in the Lesser Caucasus, in Nakhichevan, 1 species (*Prometheum sempervivoides*) distributed in the regions of Nakhichevan, Lesser Caucasus, Lankaran.

Keywords: *phenoindicators, phytocenoses, chorology, flowering phase, environmental factors.*

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Received: *4 May 2024;* ***Accepted:*** *14 July 2024;* ***Published:*** *2 August 2024.*

1. Introduction

The article presents the results of a chorological analysis of 14 species of the *Crassulaceae* family, distributed in the Lesser Caucasus, and identifies their geographical elements. We also carried out phenological observations and studied the main morphometric indicators for 3 species of the family *Crassulacea* growing in different conditions: *Petrosedum subulatum* C.A.Mey. Boiss., *Phedimus stolonifer* S.G. Gmel., *Sedum acre* L. The net photosynthetic productivity of species during the flowering phase was also studied. A special place is occupied by trees, most of which have high

How to cite (APA):
Akbarova, Ch., Mammadova A. (2024). Chorological analysis and phenological observations of some species of the family *Crassulaceae* J.St.-Hil. in the Lesser Caucasus of Azerbaijan. *Advances in Biology & Earth Sciences, 9*(2), 301-309 https://doi.org/10.62476/abes9301

ornamental qualities and resistance to damaging abiotic and biotic environmental factors, which opens wide opportunities for their use in landscaping. Flora as a system of populations of all plant species inhabiting a given area has its structure at the intralandscape level. For the natural flora of any ecologically and floristically peculiar subdivision of a landscape, the concept of partial flora was introduced. Phenological observations of plants are influenced by several factors. One important factor is temperature, as plants respond to changes in temperature by initiating or delaying certain phenological events. Another factor is precipitation, as the availability of water plays a vital role in the timing of plant growth and flowering. Day length also affects plant phenology, with longer days triggering certain stages of plant development. Additionally, biotic factors such as pollinators and herbivores can influence phenological patterns. Understanding these factors is crucial for accurately predicting and assessing the impact of climate change on plant phenology. This knowledge can also inform conservation and management strategies to mitigate potential negative effects on plant communities. The beauty of their appearance allows them to be used in landscape design. The genus was processed by Karyagin. Azerbaijan consists of 4 provinces (Atropatan, Caucasus, Hyrkan, and Turan) located in two floristic regions, where the elements of the Mediterranean and Irano-Turanian are combined. Of these, the Caucasian 5 (Guba, Caspian, Gobustan, Shamakhi, Lesser Caucasus), Atropatan 2 (Nakhichevan, Diabar), Hirkan 1 (Talysh), Turan 2 (Eastern Caucasus, Absheron) are botanical and geographical regions, which have a more extensive area and are constantly developing (Ipatov & Kirikova, 1993; Nanieva, 2014; Dafni, 1992; Flora of Azerbaijan, 1953). The phenological features of 3 species have been studied and analyzed in detail according to generally accepted methods. Phenological observations of plants are an indispensable part of the process of studying plants. This helps to reveal the ecological and physiological variability of plants. Phenological observations provide material on the degree of growth of phytocenoses. The question arises: is it necessary to study the phenology of plant communities or individual representatives. To understand the seasonal development of the nature of a particular year, researchers are helped by bright, noticeable seasonal phenomena – phenoindicators, the onset of which should be perceived as a signal for the start of work of a certain type. In developed countries, in particular the United States, phenological information is the subject of business. Farmers buy annual crop forecast reports (Gadzhiev, 1990; Goncharova, 2020; 5. Gusev, 2004; Portenier, 2001; Lakin, 1990).

We conducted a chorological analysis and research on the onset of vegetation stages of some representatives of the Crassulaceae families, which are widespread in the territory of Azerbaijan (specifically in the region of the Lesser Caucasus). Arboretums and botanical gardens are currently engaged in the search, conservation, and study of plant genetic resources to effectively utilize the biodiversity potential of species, forms, and varieties. The study of soil and floristic complexes is the most important task in the way of preservation of natural monuments of Azerbaijan. Our analyses of the spectrum of biomorphological groups showed that the leading species in the flora of the study area are herbaceous perennials - 66.67%. These life forms are most adapted to endure the unfavourable climatic conditions of the steppe (Babayev *et al*., 2019). Phenological studies conducted in different geographic locations may reveal variations in plant responses to environmental cues. This information is valuable for understanding regional differences in plant phenology. Certain plant species may serve as phenological indicators for broader ecological changes. Researchers might identify key species that can be

monitored to assess ecosystem health. Analysis of phenological data may reveal correlations between the timing of plant events and climate variables. This could include temperature, precipitation, and photoperiod, helping researchers understand how climate influences plant phenology. The results of phenology research on plants can vary widely based on the specific objectives of the study, the plant species investigated, and the environmental context.

2. Materials and Methods

Phenological phases of plants represent different stages in their life cycle that are influenced by seasonal and environmental factors. The timing of these phases can be affected by factors such as temperature, day length, and precipitation. Here are some common phenological phases observed in plants: Budburst (leaf bud expansion), flowering, fruiting, leaf abscission, root growth and etc. For research, a chorological analysis of species of the family Crassulaceae D.C in the Lesser Caucasus was carried out (Flora of Azerbaijan, 1950, IV, 267-268) and phenological phases of species distributed in the Northern Lesser Caucasus, and morphometric characteristics during the flowering period. Based on Portenier's system, the geographical elements of chorological analysis of species with different geographical ranges have been determined (Sukachev, 1990; Moza & Bhatnagar, 2007; Golubev, 1962; Hasanova, 2021). Understanding and monitoring these phenological phases is crucial for various reasons, including assessing the impact of climate change, predicting crop yields, and studying plant ecology. Researchers, farmers, and citizen scientists often engage in phenological observations to gather data and gain insights into the dynamics of plant life cycles (Beideman, 1974; Grossheim, 1950; Portenier, 2000; 2001).

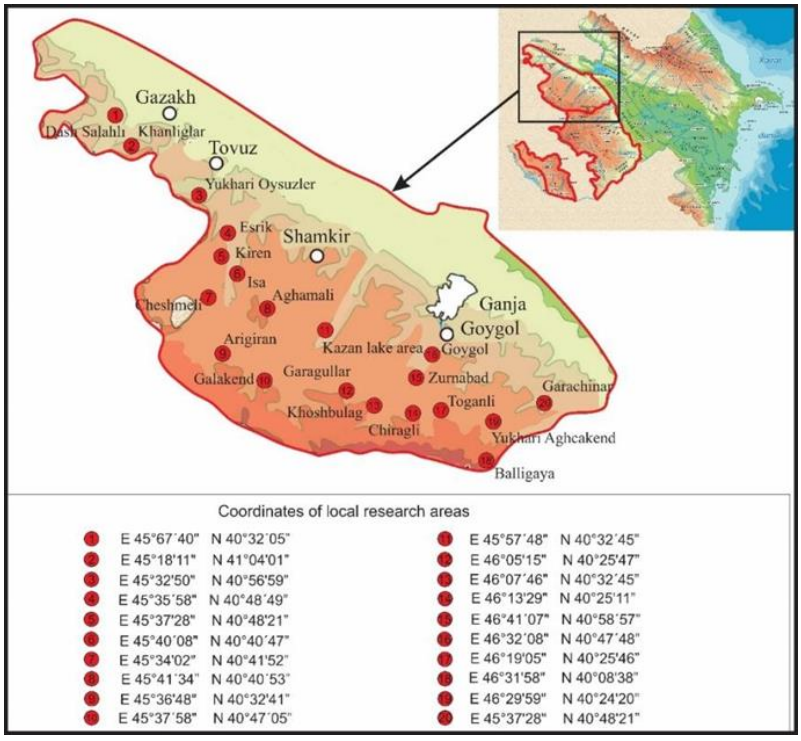

Figure 1. Local taxa aggregation sites

3. Results and Discussion

Studies have shown that 1 species of hare cabbage (*Sedum acre*) is found only in the Lesser Caucasus, two species (*S. hispanicum, S. pentapetalum* Boriss.) are found throughout Azerbaijan, 6 species (*Prometheum pilosum, Phedimus spurius, Sedum gracile, S. pallidum, S.annum, Petrosedum subulatum*) in the territory of the Greater and Lesser Caucasus, Nakhichevan (Diabar), Lankaran, one species (*Phedimus stoloniferum*) of the Greater Caucasus, the Lesser Caucasus, Lankaran, one species (*Sedum tenellum*) in the territory of the Greater Caucasus, the Lesser Caucasus, Lankaran, one species (*Sedum album*) in the Lesser Caucasus, in Nakhichevan, 1 species (*Prometheum sempervivoides*) distributed in the regions of Nakhichevan, Lesser Caucasus, Lankaran.

Common species

1. Circumboreal Element – The natural range of most species included in this element encompasses most of the Old and New Worlds.

Sedum album is distributed in the high-mountain, middle and upper mountain belts, rocky and rocky places at an altitude of 1000-1800 meters above sea level Boreal species.

2. Euro – Caucasian element (Caucaso-European). The natural habitat includes the Caucasian-European subregion of the Circumboreal Region. The species common here are not common in other botanical-geographical areas.

Sedum acre – it is found in the middle mountain belt at altitude, on dry, sandy slopes at an altitude of 1300 meters above sea level.

3. Caucasian element (element Caucasian). These species are boreal. It includes not only elements of the Caucasian flora, but also plants of the surrounding territories. Especially the Euxine province, the Main Caucasian Range, and the Eucaucasia are real endemics.

Sedum gracile- at altitude occurs scattered on gravel slopes and rocks in the upper forests of the alpine and subalpine belts at an altitude of 1200-2500 m above sea level.

Hemicryptophyte.

Sedum tenellum grows on rocky and gravelly slopes in the alpine and subalpine belts at an altitude of 1600-3000 meters above sea level.

Phedimus spurius- spreads in the subalpine and alpine belts, on open rocky slopes, in juniper forest at an altitude of 1200-3000 meters above sea level.

4. Euxinic Element

Sedum annum - It is distributed in the middle and upper belt in rocky rocks and on rocky outcrops at an altitude of more than 700 meters above sea level.

Ancient Mediterranean Species

5. Mediterranean Element. The species included here are distributed in 2 or more botanical- geographical areas in vegetation formations.

Sedum hispanicum - in the subalpine belt on dry, open, gravelly and rocky areas at an altitude of 2400 meters above sea level.

6. The element Irano-Turanian. These species belong to the ancient Mediterranean species. Species belonging to the Iranian-Turanian province are distributed in 2 or more territories of this province.

***Petrosedum subulatum* (C.A. Mey.) Boiss**. occurs in the middle and upper belts on rocky, gravelly slopes, and rocks, as part of vegetation such as freegan, sometimes in forests at an altitude of 1000-1800 meters above sea level.

***Prometheum pilosum* M. Bieb**. is distributed on the rocks of the middle and upper mountain belt at an altitude of 1000-1800 meters above sea level.

***Sedum stoloniferum* S.G. Gmel**. is distributed in the lower and middle mountain belt, in forests and shrubs at an altitude of up to 1500 meters above sea level.

Table 1. Geographical elements of chorological analysis of some species of the *Crassulaceae* family

Chorotype	Number of taxa	Percentage of species	Plants
Circumboreal	1	7.7%	*Sedum album*
Euro-Caucasian	1	7.7%	*Sedum acre*
Caucasian	3	23.1%	*Sedum gracile* *Sedum tenellum* *Phedimus spurius*
Euxinic	1	7.7%	*Sedum annum*
Mediterranean		7.7%	*Sedum hispanicum*
Irano-Turanian		46.1%	*Petrosedum subulatum* *Prometheum pilosum Phedimus stoloniferum Prometheum sempervivoidesSedum pallidum* *Sedum pentapetalum*

S.pallidum M. Bieb. It is distributed at an altitude of 500-2500 meters, from plain to high-mountain belt, on rocky slopes, in forests, and in riverbeds from 500 to 2500 meters above sea level. *S. pentapetalum* A. Bor. is distributed in clayey, rocky places of the lower mountain belt at an altitude of 500-800 meters above sea level. *Prometheum sempervivoides* Fisch. in M.B. above 700 m it is distributed in the middle and upper belt of mountains, on rocky and gravelly slopes. After the results of the chorological analysis, we selected 3 species of the Tolstyaceae family, growing in different conditions, as objects of study: *Sedum subulatum* (C.A.M.) Boiss, *Sedum stolonifer* S.G. Gmel., *Sedum acre* L. The characteristic appearance of representatives of the *Crassulaceae* family is reflected in the name of the family. The word "Crassus" means "fat" in Latin. The fleshy, succulent stems and leaves make up a notable feature of this family. These species are perennials. In the flora of Azerbaijan, we found these species in the village of Khoshbulag in the Dashkesen region. Plants were found in mountain- meadow and free ganoid types of vegetation in the lower, middle, and upper mountain belt at an altitude of 1000-1800 m above sea level. The ornamental nature of the plants is given by the leaves of various shapes and colours. Phenological observations made it possible to establish that the beginning of flower stalk regrowth was in June. Sedum styloides showed early regrowth of the peduncle relative to other herbaceous plants of the phytocenoses in the third decade of May. The regrowth of the peduncle lasted from 5 days to 19 days.

Table 2. Phenological observations of seasonal development of representatives of the family Crassulaceae (Average for 2021-2023)

Plant taxa	Early Appearance	Full Appearance	Budding	Beginning of flowering	Mass flowering	End offlowering	Beginning of fruit ripening	Massripening of fruits
Petrosedum subulatum	09.04	30.05	14.06	05.07	20.07	25.07	31.07	07.08
Phedimus stolonifer	15.04	15.06	06.07	30.07	05.08	15.08	25.08	10.09
Sedum acre	17.04	10.06	04.07	20.08	29.08	25.09	30.09	07.11

Figure 2. Overview of the studied species of the *Crassulaceae* family. *Petrosedum subulatum, Ohedimus stolonifera, Sedum acre* L.

Flowering of *P. subulatum* was completed in the first decade of August. The most sensitive to dampness is the shoot-bearing sedum. All species and varieties are drought-tolerant. Plants do not tolerate shade well, stretch out, and lose their compact shape and bright color. Therefore, it is better to place them in well-lit areas. Dry, poor, sandy, neutral, or slightly alkaline soils are preferred. If the soil contains a lot of nutrients, their color becomes less bright, and they winter worse. Prospects were determined by the success of all phenophases and were based on a complex of decorative, economic and biological characteristics. All species produced mature seeds 23 to 31 days after flowering. The duration of flowering in other species varied from 15 days (sedum) to 35 days (sedum). S. styloides stand in culture, and do not require any other measures against excess moisture than good drainage. As can be seen from Table 2, budding in *P. subulatum* begins in June, in *P. stolonifer* and *Sedum acre* in July. The flowering phase was observed in *Sedum styloides* at the end of May, lasting a little less than a month. Sedum also bloomed for about twenty days in August. The longest flowering duration was observed in *Sedum causticus* for more than a month August-September. From phenological observations, some peculiarities should be highlighted. For example, the sedum loses its lower leaves during flowering. Thus, the economic interest of this member of the family *Crassulaceae* after the flowering phase, it is not present due to the lack of green mass. The rest of the studied plants, as perennials, retain green ground parts even in winter. The most complete form of the plant is preserved by the caustic stonecrop. We also noted that for all the considered members of the *Crassulaceae* family. The most

productive phase of vegetation is the flowering phase, which is also known from literary sources. We also determined the main morphometric indicators of species: stem length, number of leaves, leaf area, and calculated the net productivity of photosynthesis of all species in the flowering phase, which is the most promising in terms of practical use. The accounting period was 31 days. The data obtained are shown in Table 3. This species bloomed with a distinctive carpet of bright yellow. Fruit ripening lasted from July 31st to August 7th, as well as from August 25th to September 10th and from September 30th to November 7th.

Table 3. Phenological parameters of plants in the flowering phase

Plants	**Stem length, (sm)**	**Number of leaves, pcs.**	**Leaf area (sm^2)**	**Stem length, (sm)**	**Number of leaves, pcs.**	**Leaf area (sm^2)**
	2022	**2023**	**2022**	**2023**	**2022**	**2023**
Petsubulatum	41,50±2,56	43,20±2,60	28,50±1,19	31,10±1,2	18,65±2,52	18,74±2,5
Pedimus stolonifer	31,20±2,244	31,90±2,18	14,30±0,80	15,20±1,3	36,16±6.07	36,19±6,1
Sedum acre	10,50±0,74	11,20±0,69	10,4± 0,89	10,6±0,83	1,22±0,16	1,21±0,13

Table 4. Timing of phenological phases of plant families

Species	**April**			**May**			**June**			**July**			**August**		
P. subulatum															
P. stolonifer															
S. acre															

	Flower bud swelling
	Budding
	Beginning of flowering - end of flowering
	Fruit setting
	Fruit ripening

Notation for phenospectra plotting

The dates of the beginning of leaf color change and leaf fall were observed from the third decade of July, the first decade of August, with a slight change in date and some dependence on weather conditions. The beginning of stable frosts usually coincided with the end of leaf fall. Table 4 shows the timing of leaf color change (Table 4). Budburst/Leafing Out: a) Record the date when buds on trees and shrubs begin to open or when leaves start emerging; b) Different plant species have specific triggers for budburst, often related to temperature and day length. Flowering: a) Note when plants produce flowers; b) Observe the color, size, and number of flowers; c) Some plants flower in response to temperature, day length, or other environmental cues. Fruiting: a) Document when fruits start developing on plants. b) Record the size, color, and number of fruits; c) Fruiting may be influenced by factors such as pollination success and temperature.

Table 4. Changes in the coloration of leaves of plants of the families

Species	May			June			July			August		
P. subulatum												
P. stolonifer												
S. acre												

As a result of the study of phenological features, the plants with the earliest start of vegetation,as well as early flowering and fruiting were identified. *P. stolonifer*, and *S. acre* are the plants with the earliest beginning of vegetation, as well as early flowering and fruiting. Fruits of plantsof the *Crassulaceae* genus ripen in July. According to the results of our observations, the beginning of vegetation in species was observed quite early, in the third decade of March. Weather conditions influenced the beginning of the flowering of species. In years with warm weather flowering of plants was observed early and, on the contrary, in years with cold weather - later. The dates of the beginning of leaf color change and leaf fall were observed from the third decade of July, the first decade of August, with a slight variation in date and some dependence on weather conditions. The beginning of stable frosts usually coincided with the beginning of stable frosts. All plant phenotypes were observed from April 2021 to October 2022, and then again from May 2022 to April 2023. The flowering period of all plants lasted 2-3 months. It took 18–20 days for the vegetative shoots to form flower buds, but it took only 12–15 days for the buds to burst. The ovary produces ripe fruits after 15–35 days of pollination. Ithas been found that on rainy days the flowering process, when the flower emerges from the bud, is delayed by an hour. Between 5 and 6 o'clock flowering occurs, and between 6 and 8 o'clock the flower opens. The average flower lifespan was 37.9±0.89 hours with a range of 35-40 hours.

4. Conclusions

The results of the chorological analyses showed that species of the Crassulacea in Irano-Turanian province, are distributed in two or three territories of this province. The results of phenological observations and morphometric parameters indicate that all species have successfully passed through all stages of development. The sequence of seasonal changes in the same community is repeated from year to year, but the timing of the phases and individual details are different.

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