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Ontogenesis and ontogenetic structure of cenotic populations of *Eremurus anisopterus* (Asphodelaceae) in the Kyzylkum desert (Uzbekistan)

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ABSTRACT

New information about ontogenesis and ontogenetic structure of cenotic populations of the rarest endemic of Kyzylkum mountains *Eremurus anisopterus* (Kar. & Kir.) Regel is presented. Plant communities with participation of cenopopulations of the studied species are characterized. Duration of ontogenesis in natural conditions lasts more than 20 years. The vegetation cycle of *E. anisopterus* under Kyzylkum desert conditions lasts about five months, from March to July. The study showed that in different ecological and cenotic conditions of the Kyzylkum desert the *E. anisopterus* cenopopulations are normal but incomplete. Cenopulations in both studied plant communities (*Eremerus*–sagebrush and *Eremurus*–*Peganum*) are young. The ontogenetic spectrum is left-handed and coincides with the characteristic one. This, in general, reflects the biological features of *E. anisopterus* and indicates the stable state of the Kuldjuktau population of the species.

Keywords: *Eremurus anisopterus*, ephemeroid, Kyzylkum desert, Kuldjuktau, ontogenesis, ontogenetic structure, cenopopulation

РЕЗЮМЕ

Рахимова Т., Рахимова Н.К. Онтогенез и онтогенетическая структура ценотических популяций *Eremurus anisopterus* (Asphodelaceae) в условиях пустыни Кызылкум (Узбекистан). Представлены новые сведения об онтогенезе и онтогенетической структуре ценопопуляций редчайшего эндемика останцовых гор Кызылкума *Eremurus anisopterus* (Kar. & Kir.) Regel. Дана характеристика растительных сообществ с участием ценопопуляций этого вида. Продолжительность онтогенеза в естественных условиях длится более 20 лет. Вегетационный цикл *E. anisopterus* в условиях пустыни Кызылкум длится около пяти месяцев – с марта по июль. Исследование показало, что в разных эколого-ценотических условиях пустыни Кызылкум изученные ценопопуляции *E. anisopterus* нормальные, но неполночленные. Ценопопуляции в составе изученных растительных сообществ (эремерусово-полынном и эремурусово-адраспановом) – молодые. Онтогенетический спектр – левосторонний, совпадает с характерным. Это, в целом, отражает биологические особенности *E. anisopterus* и свидетельствует о стабильном состоянии кульджуктауской популяции вида.

Ключевые слова: *Eremurus anisopterus*, эфемероид, пустыня Кызылкум, Кульджуктау, онтогенез, онтогенетическая структура, ценопопуляция

The assessment of the status of rare, vulnerable species is based on the study of the current status of their cenotic populations. Special attention is paid to identifying the ontogenetic structure and analyzing a number of organismal and population traits. Based on the totality of all these traits, the ecological and phytocenotic optimums of species are established, which are of great importance in preserving their natural populations. In recent years, due to global climate change, and directly with the desiccation of the Aral Sea, noticeable changes in the structure of populations of both edificatory and rare elements of the flora, are observed (Shomurodov 2018). These changes are expressed in the absence of separate age groups or multivergence of the ontogenetic structure of the cenopopulation, which are the result of irregularity of seed regeneration. Today, along with systematic, genetic, and molecular studies, population studies are carried out widely in the world (Päivi et al. 2009, Schwartz et al. 2013, Ren et al. 2014, Rakhimova et al. 2021).

The study of rare and endemic species is among the priority tasks in the field of botany, which is due to the increasing relevance and significance of the problem of studying and preserving biodiversity. The most promising method of studying rare and endemic plant species is the study of their natural populations. Since 2012, employees of the Institute of Botany of the Academy of Sciences of the Republic of Uzbekistan have been conducting studies on assessment of the state of cenotic populations of rare and endangered plant species included in the first edition of the Red Book of Uzbekistan (Pratov 1998). A number of articles were published based on the results of studies of plant cenopopulations (Akhmedov et al. 2015, 2016, Shomurodov et al. 2015, Saribaeva & Shomurodov 2017). The aim of the work was to study the ontogenesis and ontogenetic structure of cenopopulations of a rare endemic of Kyzylkum, *Eremurus anisopterus*.

MATERIAL AND METHODS

Eremurus anisopterus is a 35–40 cm tall perennial herbaceous plant with a shortened rhizome, radially and spindle-shaped roots. Leaves narrowly linear, outer, 10–12 mm wide. The raceme is broadly cylindrical, 18–20 cm long. The bracts are narrow-triangular, long-stemmed, up to 2 cm long. The lower pedicels are 3–4 cm long. Perianth leaflets with 1 vein, light pink. Stamens uneven, shorter than the perianth leaflets. Capsule globular, 15–20 mm in diameter, seeds oblique. Blossoms in April–May; bears fruit in May. It occurs in the foothills of the Tamdytau, Kuldjuktau and Aktau Mountains (Navoi Region). In 1998, it was listed in the Red Book of the Republic of Uzbekistan (1998).

Geobotanical descriptions of plant communities, in which the studied species were found, were made according to the generally accepted methodology (Lavrenko & Korchagin 1964). Latin names of plant species are given according to Plants of the World Online (https://powo.science.kew.org/). The Plant Identifier of Central Asia (1968-1993) was used to identify plant species.

Identification of age states in ontogenesis was performed according to Rabotnov (1950). An individual was taken as a counting unit. When characterizing the population structure, we relied on the idea of a characteristic ontogenetic spectrum (Zaugolnova 1994).

Transects 10 m in length were established, each transect was divided into 1 m^2 plots. Four types of spectra are distinguished according to the character of ontogenetic group distribution: left-handed, centered, right-handed, and bimodal. The characteristic spectrum depends on the biological features of the species.

Assessment of the state of rare species populations was made on the basis of ideas about the characteristic ontogenetic spectrum according to the classifications of Uranov & Smirnova (1969) and "delta-omega" by Zhivotovsky (2001). To construct a map of the location of the studied cenopopulations of the studied species, the coordinates of locations were imported into the geographic information system ESRI ArcGIS ArcView v.10.0 (http://www.esri.com/ru-ru/arcgis/products/arcgis-pro).

RESULTS AND DISCUSSION

The genus *Eremurus* L. (Asphodelaceae Juss.) includes over 60 species mainly distributed in Central Asia, Afghanistan, Iran and in the mountains from the Crimea and the Caucasus to the Altai and Himalayas (Naderi et al. 2014). In Central Asia, 49 species of the genus occur, of which 5 species are distributed in Kyzylkum (*E. inderiensis* (Stev.) Regel, *E. anisopterus* (Kar. et Kir.) Regel, *E. ammophilus* Vved., *E. luteus* Baker and *E. korolkowii* Regel). The latter is a narrow endemic species of the Southwestern Kyzylkum mountains (Khasanov 2015). According to Kamelin (1973), the southern part of Mountain Central Asia is one of the centers of origin of the genus *Eremurus*, in connection with which many regional floras have a great diversity of *Eremurus* species (Beshko 2000).

In 2018, we investigated 2 cenotic populations of *E. anisopterus* growing in different ecological and cenotic conditions (Figs 1, 2).

The first cenotic population was recorded in the mottles in the southern foothill plain of Kuldjuktau (40°72'99'N 63°73'37'E) at an altitude of 390 m above sea level. *Artemisia diffusa* and *Eremurus anisopterus* dominate the plant community and cover 14 % or less. At the same time the density of individuals of the studied species per 10 m^2 is 4 %. The soil is sandy loam. 27 species of vascular plants belonging to different biomorphs are found in this community type. Due to favorable spring conditions, annual grasses prevail in the community.

The second cenopopulation was studied as part of an *Eremurus–Peganum* community growing east of the Churuk village (40°40'13'N 63°47'56'E) at an altitude of 309 m above sea level. The topography is flat, the soil is sandy loam and gravel, the soil is compacted by animals. The dominant community species are *Eremurus anisopterus* and *Peganum harmala*. The total herb cover does not exceed 19 %, the share of the studied species in it is 6 %. The species composition of the communities is composed of 32 species of vascular plants, most of which belong to herbaceous plants (Table 1).

Ontogenetic periods and age states

Three main periods and 6 age states of *E. anisopterus* were identified and described: in the virginile (pregenerative) period – juvenile (j), virginile (v); in the generative period – young generative (g1), middle-aged generative (g2), aging (g3) generative; in the postgenerative period – senile (s) age state (Fig. 3). At the time of the study we were unable to find the seedlings of *E. anisopterus*.

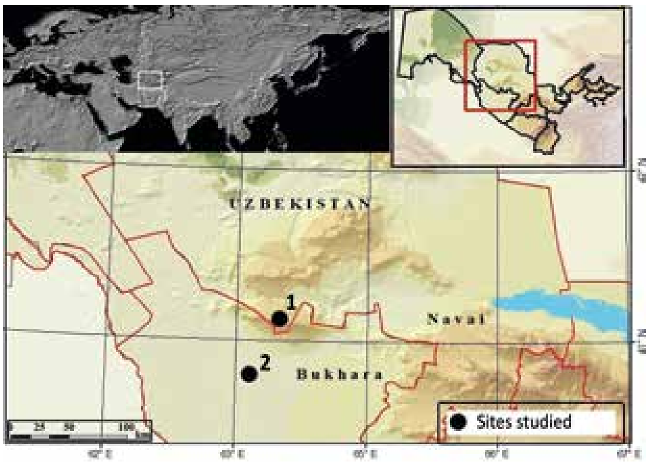

Figure 1 Distribution map of the studied cenopopopulations of *Eremurus anisopterus* (Kar. & Kir.) Regel

Figure 2 General view of *Eremurus anisopterus* and its cenopopulation (photo by N.K. Rakhimova, 04.15.2018)

Table 1. List of plant community species with *Eremurus anisopterus* for cenopopunations 1 (CP 1) and 2 (CP 2). '+' means presence, '-' – absence.

Species	Life form	Species cover, %	
		CP 1	CP 2
Xylosalsola arbuscula (Pall.) Tzvelev	shrub	+	1
Astragalus villosissimus Bunge	shrub	-	1
Nanophyton erinaceum (Pall.) Bunge	shrub	+	-
Artemisia diffusa Krasch.ex Poljakov	subshrub	7	3
Artemisia turanica Krasch.	subshrub	1	-
Acanthophyllum pungens (Bunge) Boiss.	subshrub	+	-
Acanthophyllum cyrtostegium Vved.	subshrub	-	+
Halothamnus subaphyllus (C.A. Mey.) Botsch.	subshrub	-	+
Eremurus anisopterus Kar. & Kir.) Regel	perennial	4	6
Ferula assa-foetida L.	perennial	1	-
Fritillaria karelinii (Fisch. ex D. Don) Baker	perennial	+	+
Tulipa lehmanniana Merckl.	perennial	+	+
Tulipa biflora Pall.	perennial	+	+
Poa bulbosa L.	perennial	+	+
Carex pachystylis J. Gay.	perennial	+	+
Peganum harmala L.	perennial	+	8
Ixiolirion tataricum (Pall.) Schult. & Schult. f.	perennial	+	+
Rheum turkestanicum Janisch.	perennial	+	-
Carex physodes M. Bieb.	perennial	+	-
Cousinia hamadae Juz.	perennial	+	-
Convolvulus hamadae (Vved.) V. Petrov	perennial	-	+
Colchicum robustum (Bunge) Stef.	perennial	-	+
Holosteum umbellatum subsp. glutinosum (M. Bieb.) Nyman	annual	+	+
Lallemantia royleana (Benth.) Benth.	annual	+	+
Climacoptera lanata (Pall.) Botsch.	annual	+	-
Leptaleum filifolium (Willd.) DC.	annual	+	-
Delphinium leptocarpum (Nevski) Nevski	annual	+	-
Ceratocarpus arenarius L.	annual	+	-
Rochelia bungei Trautv.	annual	+	-
Astragalus ammophilus Kar. &Kir.	annual	+	-
Valerianella triplaris Boiss. & Buhse	annual	+	-
Euphorbia inderiensis Less. ex Kar. & Kir.	annual	+	-
Papaver pavoninum Schrenk	annual	-	+
Koelpinia linearis Pall.	annual	-	+
Arnebia decumbens (Vent.) Coss. &Kralik	annual	-	+
Ceratocephala testiculata (Crantz) Besser	annual	-	+
Veronica capillipes Nevski	annual	-	+
Goldbachia laevigata DC.	annual	-	+
Meniocus linifolius (Stephan ex Willd.) DC.	annual	-	+
Amberboa turanica Iljin	annual	-	+
Ziziphora tenuior L.	annual	-	+
Caroxylon scleranthum (C.A. Mey.) Akhani & Roalson	annual	-	+
Astragalus bakaliensis Bunge	annual	-	+
Astragalus arpilobus subsp. hauarensis (Boiss.) Podlech	annual	-	+
Astragalus campylorhynchus Fisch. & C.A. Mey.	annual	-	+
Cuminum setifolium (Boiss.) Koso-Pol.	annual	-	+
Nonea caspica (Willd.) G. Don	annual	-	+

According to Butnik (2007), seeds germinate underground. One cotyledon at germination with its upper end remains in the seed. The root and the first leaf break sperm derma through. Only the lower part of the cotyledon, which forms the sheath, protrudes.

Juvenile plant. In the middle of April of the first year of growth, the first leaf appeared, 6–8 cm long and 1–2 mm wide. A sheath 0.5 cm long is formed in the lower part. The storing root (root-tuber) is brown with base diameter 3–5 mm, 2–2.5 cm long, the thickened root is 2.5–3 cm from the soil surface. In the middle of April of the second year of growth, there is 1 green leaf, 10 to 20 cm long, 1–2 mm wide. The leaf base is covered with filmy white sheaths. The leaf sheath is 1–4 cm long and 0.5–0.7 cm wide. One thickened root is 5–6 cm deep from the soil surface, with a base diameter of up to 0.5 mm. Most juvenile individuals produce two leaves, 18–24 cm long and 2–3 mm wide. The leaf sheath is 4–5 cm long and 0.5–1.0 cm wide. Two or three thickened roots up to 5–6 cm long and 4–5 mm wide are formed, arranged horizontally. Duration of juvenile age is 1–4 years.

Young virginal plants of the third and fourth years of growth develop 4–6 leaves each, 20–28 cm long and 0.4–0.5 cm wide. Leaf sheaths are retained. The number of living thickened roots increases to 4–5. They are 6–9 cm long and 5–6 mm wide. Thickened roots die off every year. In this age state, the number of dead thickened roots is up to 15–18 pcs. Some specimens have up to 11–16 leaves, they are 26–28 cm long and 0.4–0.5 cm wide. Until the generative period, only leaves grow in virginal plants. Duration of this age state is 3–6 years depending on weather and other conditions.

Young generative plants (g1). Leaves reach 25–30 cm in length and 0.5–0.6 cm in width. Number of dead thickened roots reach 20–25 pcs. Young generative individuals have 7–9 live thickened roots. Live thickened roots are 10–11 cm long, oriented horizontally, 8–9 mm in diameter. The leaf base is covered with numerous white filmy leaves. In April, only one generative shoot appeared in young generative plants. Total length of a generative shoot is 25–30 cm, and generative organs (inflorescences) were formed with a height of 15–18 cm. Number of flowers on one generative shoot is 15–25 pcs. Flowers are pink, consist of 6 petals. Petals are 1–1.5 cm long and 0.3–0.6 mm wide. The duration of the stage is 5–9 years.

Mid-age generative plants (g2). In this age state the height of a generative shoot reaches 40–65 cm. The length of the generative part (inflorescence) is 30–40 cm. The number of leaves increases to 30–40 pcs, their width 0.5–0.8 cm. There is only one generative shoot with 35–75 flowers on the bush. The capsule contains up to 15 oblique-winged seeds, 7–10 mm long and 4–5 mm wide. At a depth of 5–6–8 cm there are up to 11 thickened roots, 13–16 cm long, with a diameter of 8–10 mm at the base. There are 20–30 dead roots departing from the rhizome, 15–20 cm long. In *E. anisopterus* the number of leaves increases with age, but the thickened roots die off every year and new ones appear, and there is an increase in the last year leaves. The duration of the stage is 6–15 years.

Aging generative individuals (g3). At this age, no increase in the number of thickened roots is observed, but the number of leaves increases to 20–25, i.e. each *E. anisopterus* bush has its own limit of thickened root formation. In the lower part of the generative stem there is its dead part with the remains of old thickened roots. The

Figure 3 Ontogeny of *Eremurus anisopterus*: j – juvenile; v – virginal; g1 – young generative; g2 – middle age generative; g3 – ageing generative; s – senile

bud is covered with bases of dead leaves and leaflets, the outer layers of which are brown, the inner ones are filmy, white. At this age, the generative shoot reaches 25–35 cm in length; the inflorescence is up to 15 cm long; the number of flowers is 18–20. The number of live thickened roots in most bushes is up to 3, their length 6–8 cm, width 0.8–1.0 cm. The duration of the stage is 14–20 years.

Senile period. The number of leaves decreases. Their length reaches up to 15–20 cm. Generative shoots are not formed. The whole plant from the bottom is covered with last year's dried leaves. All thickened roots die off. Only one root remains alive. The dead roots are up to 10–15 cm long, with up to 15 of them. Duration of the plant senile period in the Kyzylkum desert conditions, depending on weather conditions, from 18–21 years and on.

Ontogenetic structure

In terms of species biology features (high seed productivity and seed germination), the characteristic spectrum of both cenopopulations of *E. anisopterus* should be considered left-handed (Fig. 4) and, according to the classification by Uranov & Smirnova (1969), are normal, incomplete.

In the ontogenetic spectrum of the first cenopopulation, the peak is noted on virginal individuals. The predominance of virginile individuals (48.27 %) in the cenopopulations is the result of intensive seed regeneration. The gradual increase in the number of individuals in the left part of the spectrum to the virginile age state and their decrease in the generative state down to the zero value in the right part of the spectrum indicates the successive state of this cenopopulation.

In the second cenopopulation, the peak in the spectrum falls on individuals of the young generative (g1) age state. The proportion of individuals of the young generative group here reaches 33.96 % (Fig. 4) The high rate of this fraction in the cenopopulation is due to the rapid rate of ontogenesis in the pregenerative age state and the high elimination of the young fraction as a result of intensive grazing. It should be noted that this cenopopulation grows in the vicinity of a settlement and the area is used year-round for grazing. The ontogenetic spectrum of this cenopopulation coincides with the characteristic and reflects the biological peculiarity of the species.

The density of individuals in the studied cenopopulations varies on average from 0.96 to 1.76 individuals per m^2, ecological density – from 2.07 to 2.40 individuals per m^2. Approximation of the recovery index to the one (0.91 and 0.96) in the studied cenopopulations indicates high seed regeneration. The zero value of the aging index, on the

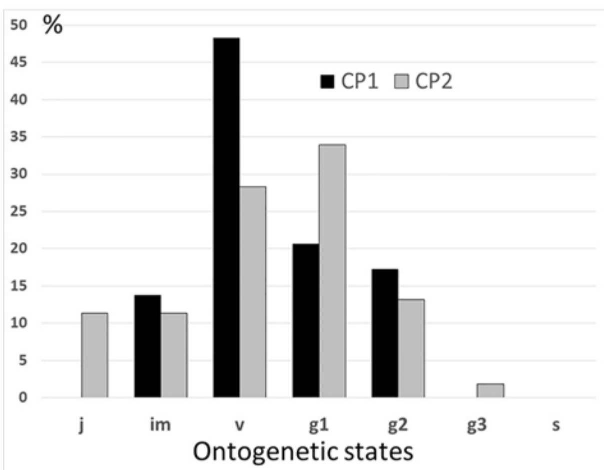

Figure 4 Ontogenetic spectra of *Eremurus anisopterus* in cenopopulations 1 (CP 1) and 2 (CP 2)

Table 2. Demographic characteristics of *Eremurus anisopterus*

Cenopopulation	Density of individuals/m², pcs	Ecological density of individuals/m², pcs	I_V	I_{ST}	Delta (Δ)	Omega (Ω)	Type CP
CP 1	0.96	2.07	0.92	0	0.20	0.56	young
CP 2	1.76	2.40	0.96	0	0.21	0.56	young

Note: Δ – index of age, Ω – index of efficiency, I_V – index of recovery, I_{ST} – index of ageing

one hand, is associated with the successional state of the cenopopulations and, on the other hand, with the death of most individuals in the old generative state (Table 2).

An assessment of the age (Δ) and efficiency (Ω) of the cenopopulations showed that both *E. anisopterus* cenopopulations were young (cenopopulation 1 Δ = 0.20, Ω = 0.56; and cenopopulation 2 Δ = 0.21, Ω = 0.56).

CONCLUSION

The study of ontogenesis shows that the total lifespan of *Eremurus anisopterus* in natural conditions lasts more than 20 years. In natural habitats, the species grows as part of sprawling sagebrush and mixed sagebrush formations in the foots of the residual mountains of Kyzylkum (predominantly Kuldjuktau). It is also widespread in degraded areas where *Peganum harmala* dominates. The ontogenetic spectrum of cenopopulations growing as part of *Eremurus*–sagebrush and *Eremurus–Peganum* communities is left-sided. The peak in the spectrum falls on virginile and young generative states, which indicates a good seed regeneration. This is also confirmed by the high value of the regeneration index. Self-maintenance of cenopopulations occurs solely due to seed regeneration. All the above-mentioned parameters indicate a stable state of the Kuldjuktau population of *Eremurus anisopterus*

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