Ontogenetic structure of cenopopulations of Allium pskemense (Amaryllidaceae) in Uzbekistan

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Introduction

Due to the growing anthropogenic impact on the ecosystem, there is a need of conducting studies to identify and preserve biological diversity. Great attention needs to be paid to rare communities and species inside them, and also species growing at the border of their ranges (Zaogolnova, 1994). Ontogenetic structure is one of significant parameters of population; this side of the structural organization provides the ability of a population system to support itself and determines its resistance. Analysis of ontogenetic structure of plants provides knowledge of the further state of populations of species (Osmanova & Zhivotovsky, 2020). Studies oriented at evaluating current statuses of plant populations, preserving them in different conditions in situ, ex situ, quas in situ, providing stability of populations of rare species, composing lists of them and preserving species whose natural ranges are contracting as a result of various factors, are conducted by scientists of many scientific institutions all around the world (Volis et al., 2010; Yang, 2013; Li et al., 2015). Evaluation of current statuses of populations based on the population-ontogenetic approach is of great value for solving tasks of rational use, preservation, reproduction and support of populations (Smirnova et al., 1976). Currently, the population-ontogenetic method of studies in botany and ecology has become broadly implemented, since it based not only on visual evaluations, but takes into account different parameters that characterize the development of plants in the conditions of a plant community. In particular, an important feature of each cenopopulation is its ontogenetic spectrum (distribution of individuals by ontogenetic conditions) (Osmanova & Zhivotovsky, 2020).

Currently, the problem of rational use of natural resources and preservation of their biodiversity can be solved based on detailed studies of biology of species and peculiarities of their population organization in different-type cenoses.

Allium L. is one of the largest genera of the Amaryllidaceae family, comprising around 1,100 species, distributed all around the globe (Li et al., 2010; Govaerts et al., 2021). The primary center of evolution of the genus spans across Iran-Turan biogeographic region, and Mediterranean basin and the western part of North America are considered as secondary centers of biodiversity (Friesen et al., 2006). Currently, the problem of sustainable use of natural resources and preservation of their biodiversity may be solved based on detailed studies of biology of species and peculiarities of their population organization in coenenoses of various types (Zhijie et al., 2019; Kik et al., 2021). Among wild-growing medicinal plants, special place belongs to Allium L. of Amaryllidaceae family, which unites perennial and biennial plants with bulbs and rhizomes with a specific strong smell and taste. Central Asia is one of the largest centers of contemporary diversity of species and forms of wild-growing onion (Yusupov et al., 2020; Pandey et al., 2021). All species of the genus are of great agricultural interest as ornamental, edible, vitamin-containing and honey-bearing, medicinal and fodder plants (Yousaf et al., 2004, 2012; Ding et al., 2016).

Since Ancient Times, the peoples of the Central Asia have been consuming wild onions that are broadly distributed in almost all altitude belts—beginning from the hot Kyzylkum and Karakum deserts to the high Tian Shan and Pamir-Alay mountains. The conducted studies indicated that the population of the Central Asia has been using only some species, including Allium pskemense, A. stoveronii, garlic, A. oschaninii, and others (Aldoseeva et al., 2016). The first reports about using onions dates back 6 thou years (Block, 2010; Iksanova & Xovrin, 2011). In many countries, 6 species of onion are cultivated. However, which of the 6 species of section Phyllodolon Prokh. growing in natural conditions of Central Asia and Iran is the closest wild relative of the cultivated bulb onion (Allium cepa L.) is still a subject of discussion (Gurushidze, 2007). In the mountains of the Western Tian Shan, locals of Uzbekistan, Kazakhstan and Kyrgyzstan value one of the closest relatives of cultivated onion – Allium pskemense B. Fedtsch. Comparative analysis of wild Phyllodolon Prokh. species included in the section revealed that according to many morpho-

Many plants of the Allium genus are economically valuable as vegetables. For example, Asian countries are the largest producers of wild Allium pskemense B. Fedtsch. Ontogenetic spectrum – a sensitive population indicator of changes in the environment – has been noted as useful in recording the age condition of plants. The study focused on the ontogenetic structure of five cenopopulations of A. pskemense; revealing that the examined cenopopulations growing in different ecological-coenotic environmental conditions are normal, and mainly incomplete, i.e. do not include all age groups. Their ontogenetic spectrum was left-sided, and only the coenotic populations 2, 4, 5 coincided with the characteristic spectrum. Depending on ecological-phytocoenotic living conditions, density of individuals in the studied communities ranged 1.75 to 4.50 ind./m², whereas the ecological density was within 2.00 to 5.29 ind./m². The research determined that the ontogenetic spectrum shifted to the centered type temporarily due to the uneven processes of the development. Similarities of biological features (long mature generative condition, prevalence of mode of reproduction by seeds, low viability of young individuals) of individuals of this species in various locations, type of cenopopulation, characteristic actual ontogenetic spectra indicate stable conditions for the studied CPs in forbs-Ziziphora-shrub (cenopopulation 5) communities in Uzbekistan.

Keywords: food; endemic; effective density; demographics; age structure; Tian Shan.

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logic-biologic features the closest species to the cultivated onion is Allium pskemense. As is known, the onion has a complex of advantages – valuable nutrients, vitamins, honey, medicinal and technical properties and is used as ornamental plant (Sharifi-Rad et al., 2016). Since the old times, the onion has been prepared by locals, leading to significant exhaustion of its reserves in the wild (Baytulin et al., 2012). Traditional utilization of A. pskemense as an edible plant has reduced its resources in Uzbekistan. Bulbs of A. pskemense have a strong and sharp smell and taste and the green plants have a good taste (Budiarov et al., 2018). It belongs to sharp onions. In the national cuisine of the Kazakhs, the Kyrgyz, Uzbek, and Tajikistan Peoples, it is most often marinated (Baytulin et al., 2012). Characteristic of cenopopulations of A. pskemense give grounds to evaluate the current status of natural populations and predict their following development.

In CIS countries (Ukraine, Russia, Uzbekistan, Kazakhstan), the current status of cenopopulations according to organism and population features were evaluated in the studies by Cheryominshika (2004), Cheryominshika et al. (2021), Kovalenko et al. (2017, 2019), Rakhimova et al. (2020), Shomurodov et al. (2021) and others.

The objective of our work was to study the ontogenetic structure of cenopopulations of A. pskemense in the territory of Uzbekistan. The cenopopulations grow at the height of 1,511–2,051 m above sea level (Fig. 1).

**Materials and methods**

Allium pskemense is a perennial herbaceous rhizome-bulb plant. Bulbs come singular or in pairs, elongated-ovoid, on short rhizome, 4–6 cm wide, with red-brown thin skinlike integral membranes. The stem is thick, 50–100 (120) cm high, hollow, gently-swollen below the middle, gradually narrowed toward the top, and bears membranous sheathes at the base. Two-(three) cylindrical leaves, gradually narrowing toward the apex, tube-like, straight, 2–3 (3.5) cm wide, 2 (3) times shorter than the stem. The umbel is ball-like, dense, multiflorous. It has to be noted that this species has very important biologic properties, lasting from early spring to late autumn, and has large bulbs. It grows in cracks in rocks and stony places (Vvedensky, 1935, 1941). It was described in 1905 by B. Fedchenko. Type: Uzbekistan, the valley of Pskem River near Pskem qishlaq, 09.08.1897). Endemic to the western Tian Shan (Sennikov et al., 2016).

A. pskemense is included in the Red Book of Uzbekistan as rare species for the Republic with fragmented range (Khassanov, 2019). A. pskemense mainly occurs in forb communities. The status of A. pskemense in the studied areas varies and to a high degree depends on orthography, abiotic and anthropogenic factors. It is a typical petrophyte. However, despite that, it grows in small groups on moister north and northeast slopes. A. pskemense is distinct for its tolerance to drought and freezing conditions, high adaptability to soil conditions and resistance to diseases. However, the seeds of this onion often become infested by pests (Pratov & Yuldashev, 2009).

The onions occupy a variety of positions in the phytocoenosis. They can dominate or be subordinate in a phytocoenosis (Cheremushkina, 2004). Geobotanic descriptions were made for all the communities where the population structure of species had been studied according to the generally accepted methods on 100 m² plots (Lavrenko & Korchagin, 1964).

The ontogenetic structure of cenopopulation employed was studied using generally accepted methods (Urano, 1975; Smirnova et al., 1976; Zhivotovsky, 2001; Zlobin et al., 2013). Transects measuring 1 m in width and 5–10 m in length were divided into test plots of 1 m² where the ontogenetic status of every individual was assessed.

To determine the ontogenetic status of the species, we used herbarium samples collected during the field studies and the results of previous studies of this species. Ontogenetic spectrum of the cenopopulations (henceforth CPs) was determined as the ratio of plants of different ontogenetic status, expressed as a percentage of the overall number of individuals (Smirnova et al., 1976).

We characterized the population structure based on the knowledge of the characteristic ontogenetic spectrum (Zaugolnova, 1994). According to the pattern of distribution of ontogenetic groups, 4 types of the spectrum are distinguished: left-sided, centered, right-sided and biomodal. The characteristic spectrum depends on biological specifics of the species. Characteristic type of CP range was determined according to Zaugolnova (1994). To characterize the CPs, we used demographic parameters of indices of age and efficiency (Urano, 1975; Zhivotovsky, 2001). They were analyzed in Delta-Omega software, kindly provided by L. A. Zhivotovsky. The type of cenopopulation was determined according to Delta-Omega classification of Zhytovtovsky (2001). Delta (A) is age index (Urano, 1975) that is used to evaluate the age level of a cenopopulation at each moment of time, and omega (ω) reflects the efficiency of plant of i-genetic condition (value of “pressure” on energy resources of the environment, expressed in shares of pressure imposed by plants of middle-age genera-
The bulb does not form. After the cotyledon dies, the plant becomes juvenile type. The first cenopopulation was found near Lashkerek – a mountain gisheiq in the ravine of the Say of the same name – the left tributary of the Ohangaron, which starts from the western slopes of the Qurama Range (40.892062 N, 70.223536 E, h = 1917). Herbaceous cover of the area comprises forb-juniper forests. Projectile cover of the grass stand where the studied cenopopulation grows was 55–60%, the share of the studied species in it accounted for 2%. Botanical composition comprised 28 species of vascular plants, where perennials dominated.

The next cenopopulation was distinguished near Sijjak village. Sijjak is in the valley of mountain river Pskem, its right-bank part, hemmed in by the Ugam Range. Currently, Sijjak is in the northwest bank of the Chavrik water reservoir (41.718108 N, 70.021405 E, h = 1712). Herbaceous cover is composed of forb-shrub communities. General projective cover of the grass stand was 40–45%. The botanical composition of the community included 27 flowering plants. Most *A. pskemense* individuals were found in this particular cenopopulation, accounting for 3% (Table 1).

We carried out analysis of higher plants in 5 cenopopulations. Species composition of the community was 71 species, including trees – 6, shrubs – 7, subshrubs – 2, perennials – 49, biennials – 2 and annuals – 5 (Table 2). The characteristic spectrum of the species was left-sided. There were two types of ontogenetic structure of the studied cenopopulations of *A. pskemense*: centered (cenopopulations 1, 3) and left-sided (cenopopulations 2, 4, 5). Inferring from the species’ biology, the characteristic ontogenetic spectrum of cenopopulations of this species would be left-sided type peaking with pre-generative individuals (Fig. 2).

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The high numbers of juvenile individuals are explained by the long life expectancy of plants in this ontogenetic condition compared with the rest of the pre-generative groups. For cenopopulation 2, absolute values were seen for juvenile individuals (51.6%). This variant of the spectrum is formed during abundant bulb-bearing and in places with regular precipitations. Drastic decrease in the number of immature individuals in forbs-Artemisia-shrub community is associated with loss of fragile plants as a result of trampling by cattle. In cenopopulation 4, absolute values were seen for juvenile individuals (49.7%). Ontogenetic spectrum for cenopopulation 5 is two-peaked. Peaks occur for juvenile (24.4%) and virginile individuals (26.6%). The high share of juvenile individuals in this cenopopulation is related to effective seed reproduction, as well as with longer life expectancy of this ontogenetic condition in drier locations. Furthermore, the described cenopopulation was located on pebbled soil of southern bank of the Zindan Say (Ugom-Chatqol Range). Year-round regular pasturing of cattle impedes free development of young seedlings. This is also indicated by absence of juvenile and immature individuals in 4 cenopopulations.
Table 2

| Plant names                  | Characteristics of herbaceous communities with Allium pse Slovenense |
|------------------------------|---------------------------------------------------------------------|
| Vicia sativa                 | Life form: herb.                                                     |
| Geranium divaricatum         | Life form: shrub.                                                   |
| Asperuginoides axillaris      | Life form: shrub.                                                   |
| Papaver sp.                  | Life form: herb.                                                     |
| Erigeron acris               | Life form: shrub.                                                   |
| Tragopogon capitatus         | Life form: herb.                                                     |
| Heracleum lehmannianum       | Life form: shrub.                                                   |
| Calamagrostis alajica        | Life form: shrub.                                                   |
| Allium atrosanguineum        | Life form: herb.                                                     |
| Ixiolirion tataricum         | Life form: shrub.                                                   |
| B. calystegia sepium         | Life form: shrub.                                                   |
| Bupleurum exaltatum          | Life form: shrub.                                                   |
| Hedysarum angrenicum         | Life form: herb.                                                     |
| Oxytropis albovillosa        | Life form: herb.                                                     |
| Gontsch.                     | Life form: shrub.                                                   |
| Koenigia coriaria            | Life form: herb.                                                     |
| Stellaria rwasica            | Life form: shrub.                                                   |
| Salvia sclarea               | Life form: herb.                                                     |
| Poa sp.                      | Life form: herb.                                                     |
| Tulipa bifloriformis         | Life form: herb.                                                     |
| Eremurus sp.                 | Life form: herb.                                                     |
| Rubus caesius                | Life form: herb.                                                     |
| Juglans sp.                  | Life form: herb.                                                     |
| C. pse Slovenense             | Life form: herb.                                                     |

In left-sided cenopopulations, immature individuals accounted for 6.4–17.7% and in four cenopopulations, immature individuals were almost absent. Of all the studied cenopopulations, only the fifth cenopopulation was complete, comprising all age groups, indicating a uniform course of longer life cycle of plants. Centered spectrum is a spectrum where the maximum is observed (cenopopulation 1, 3) for middle-aged generative plants (g2). In those cenopopulations, the share of total generative individuels equaled 58.5–72.9%. This is related to gradual increase in life expectancy of individuals in the generative period and highest rate of elimination of juvenile and immature individuals, which depend on weather conditions and phyto-eco-environment condition. Cenopopulations 1 and 3 were incomplete, absence of juvenile individuals in this cenopopulation was associated with weather variability affecting the germination.

The latter is likely associated with intense cattle grazing, because the cenopopulation grows near inhabited settlements, the inhabitants of which are usually graze their cattle in the area. The second important reason for the absence of juvenile individuals in the cenopopulation is desiccation and their being blown away by the wind during the study period, as is often seen in desert conditions. In the spectrum, a gradual increase was seen in the share of a certain ontogenetic group compared with the previous, which is likely associated with increase in life expectancy of plants living in the following conditions and decrease in mortality of individuals. The ontogenetic spectra of cenopopulations (cenopopulations 1, 3) do not coincide with the characteristic one. Absence of juveniles is an artifact. The latter was associated with the late period of the vegetative season during which we were collecting material, when juvenile plants were dormant and were impossible to find without thorough excavations. On the one hand, it was related to precipitations that wash young fragile individuals off during spring and intense grazing, and on the other hand – irregularity of seed reproduction. This species is known to be broadly used by the locals as an edible plant. This does not allow the plants to develop potential seeds every year. In those cenopopulations, germination of the individuals living in tree and shrub communities are not always successful (Fig. 2).

Discussion

Relatively high projective cover and shading because of dense overgrowth by high shrubs and subshrubs would significantly improve the germination of seeds and survivability of young fragile individuals. The small amount of senile individuals in the cenopopulations is explained by many biotic and abiotic factors. Minimum values of post-generative fraction (ss) are related to last rates of ontogenesis in old generative ontogenetic condition and mortality of individuals. The share of senile individuals did not exceed 8.1%. The greatest share of senile individuals was recorded in cenopopulation 3. Low parameters in ontogenetic range of senile individuals are among the biological peculiarities of onions.

Comparing A. pse Slovenense cenopopulations in different ecological-generating living conditions revealed that averaged range was centered, double-peak with high share of virginitie and generative (gg) individuals. The averaged ontogenetic range does not correspond to the characteristic. This is explained by the high extent of elimination of young fragile individuals as a result of temporary watercourses. Another important factor in the low share of young individuals in the studied cenopopulations is intense cattle grazing. Because of the broad spread of ephemeral and ephemeral plants, actively consumed by all kinds of cattle, local cattle farmers actively use highland pastures in early spring for cattle grazing. This affects the structures of populations of early-vegetating plants, including A. pse Slovenense. Another reason for the biormality of averaged ontogenetic spectrum of A. pse Slovenense is their germination in large stones in stoney-detritus soils. Germination rate of seeds in such conditions is not always successful (Fig. 3). Density of individuals in cenopopulations was analyzed for their multi-year dynamics. Depending on ecological-phyto-eco-environment living conditions, population density in the studied communities varied 1.40 to 4.50 ind./m², and ecological density – 1.75 to 5.29 ind./m². Comparative analysis of the parameters of the general number of individuals and their density revealed that those parameters were high in the Zandin Say population (cenopopulation 5) compared with Urung’och (cenopopulation 3) and Nunai (cenopopulation 4). Effectively density of the population was 0.57 to 1.75 (Table 3).

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Fig. 2. Ontogenetic spectra of *Allium pskemense* cenopopulations.

We also compared indices of recreation (\(I_b\)) and aging (\(I_c\)), reflecting dynamic processes in cenopopulation. In the cenopopulations, the index of recreation was 0.36 to 2.69. The ageing index in all cenopopulations was close to zero, due to the fact that most individuals die in old generative condition. A similar biological peculiarity is characteristic for most onion plants (Baranova, 1999).

Ontogenetic structure was evaluated by Uranov (1975) who proposed age index “delta” (\(\Delta\)). This parameter is based on an account of energy metabolized by the plant by the start of the next ontogenetic condition. At the same time, “weight” is the share of each ontogenetic condition. In 2001, L. A. Zhyvotovsky added omega (\(\omega\)) to this evaluation, which may be considered as mean energy effectiveness or energy pressure on the environment imposed by an “ordinary” plant. Comparison of two indexes led to development of delta-omega classification that allowed – based on two-dimensional approach – to divide cenopopulations into young, adult, and old. This classification corresponds to the criterion of absolute maximum in case of single-peaked ontogenetic distributions. Furthermore, delta-omega classification takes into account the case of formation of two maxima in the studied cenopopulation, and therefore, distinguishes a new type of cenopopulation – transitional. A distinctive feature of such cenopopulations is simultaneous presence of significant share of young (younger \(g_2\)), as well as old (older \(g_3\)) plants. However, this principle of classification does not allow one to determine the subsequent fate of transitional cenopopulations, specifically – directions toward becoming younger or ageing.

Evaluation of age (\(\Delta - \delta\)) and efficiency (\(\omega - \omega\)) of cenopopulations revealed that the studied cenopopulations were maturing (cenopopulations 1, 4), young (cenopopulations 2, 5) and mature (cenopopulation 3, Fig. 4).

**Table 3**

Demographic characteristics of *Allium pskemense* cenopopulation

| No. | \(I_b\) | \(I_c\) | \(\Delta\) | \(\omega\) | \(P_{est}\) ind/m² | effective density, ind/m² | overall number of individuals | Types of cenopopulations |
|-----|--------|--------|----------|--------|----------------|------------------------|-----------------------------|--------------------------|
| 1   | 1.13   | 0      | 0.32     | 0.71   | 2.41           | 2.05                   | 1.40                        | maturing                 |
| 2   | 0.40   | 0      | 0.16     | 0.37   | 1.93           | 1.55                   | 0.57                        | young                    |
| 3   | 2.69   | 0.08   | 0.44     | 0.75   | 2.05           | 1.85                   | 1.38                        | mature                   |
| 4   | 0.99   | 0      | 0.26     | 0.63   | 1.75           | 1.40                   | 0.88                        | maturing                 |
| 5   | 0.36   | 0.04   | 0.19     | 0.39   | 5.29           | 4.50                   | 1.75                        | young                    |

Note: \(I_b\) – restoration index; \(I_c\) – ageing index; \(\Delta\) – age index; \(\omega\) – efficiency index, \(P_{est}\) – ecological density.
The conducted study of 5 cenopopulations of the rare species *A. pskemense* revealed that the status of the populations is satisfactory. The study indicated that in different ecological-sozological living conditions, the examined populations were normal, mostly incomplete. Individuals do not undergo all the stages of ontogenesis and are in the worst conditions. Absence of certain ontogenetic groups in cenopopulations was related to ecological-phytocoenotic condition of germination and cattle grazing level. Absence of senile age groups in certain cases is explained by species’ biology and successional conditions of cenopopulations. The spectra of some of the populations (with centered spectrum) did not coincide with the characteristic one. Prevalence of pre-generative individuals in them determines the examined cenopopulations as young. This is explained by loss of most individuals in the generative period of ontogenesis. Overall density in the cenopopulations of *A. pskemense* varied 2.00–5.29 ind./m². Status of *A. pskemense* indicated that anthropogenic factors decreased the number and range of populations. Consequently, serious measures should be taken to preserve the species’ distribution and create the gene fund of natural populations of *A. pskemense*. A collection of the gene fund of natural populations of *A. pskemense* has been made.

Therefore, for the study object, the demographic characteristics of cenopopulations (number and density of individuals) depended on many factors, including: peculiarities of species’ biology, life form of plants and way of reproduction, types of self-support of cenopopulations, ecological-phytocoenotic environment and height above sea level, presence of anthropogenic pressure, vital strategy of species and its competitiveness. Maps have been created that depict the spread of cenopopulations, which we can recommend as initial materials for performing long-term monitoring studies of the status of the examined cenopopulations. Thus, the study indicated that anthropogenic factors decreased the number and range of *A. pskemense*. Therefore, serious measures should be taken to preserve the natural thickets.

In the territory of Tashkent Botanical Garden named after F. Rusanov in *ex situ* conditions, a collection of the gene fund of natural populations of *A. pskemense* has been made.

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