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The current state of the cenopopulations of *Adonis tianschanica* (Adolf) Lipsch. (Ranunculaceae) in Southeast Kazakhstan

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Abstract. *Kulymbet K, Mukhitdinov N, Kubentayev S, Tynybayeva K, Tastanbekova A, Kurmanbayeva M, Gafforov Y, Kaparbay R, Zhumagul M. 2023. The current state of the cenopopulations of* Adonis tianschanica *(Adolf) Lipsch. (Ranunculaceae) in Southeast Kazakhstan. Biodiversitas 24: 4359-4372. Adonis tianschanica* (Adolf) Lipsch. is a rare, sub-endemic species growing in the Tien Shan mountains with declining numbers, making it listed in the Red Book of Kazakhstan. The aim of the study is to investigate the distribution and abundance of *A. tianschanica* cenopopopulations (CP) in its natural habitats in southeastern Kazakhstan as well as assess soil characteristics, biological and arealogical features, including the ontogenetic structure of cenopopopulations. Five cenopopulations (CP) of *A. tianschanica* were identified, namely two CPs in Ketmen Ridge (Kegen Pass), two CPs in Dzungarian Alatau (Tekeli Gorge) and one CP in Terskey Alatau (Saryzhaz). Vegetation data were collected using the traditional methods of field geobotanical studies based on the ecological-physiognomic approach.Plant communities having dominant species from a single ecobiomorph and ecologically related species groups.. We complemented the population analysis with a soil properties map compiled from existing cartographic and available literature. The results of this study indicated the low number of *A. tianschanica* individuals in all CPs, which is likely due to the biological characteristics of the species (i.e. low seed production and seedling recruitment and the lack of vegetative regeneration) as well as environmental factors, and anthropogenic impact, mainly grazing with. We found that the total number of individuals of *A. tianschanica* in the five cenopopulations was 106 individuals. The average density of the species varied from 1.3 to 3.1 plants/m^2 with CP2 being the highest and CP5 the lowest. The five cenopopulations were classified based on the absolute maxima of ontogenetic groups. There were two maxima in the age composition of individuals in CPs 3 and 4: the first (18.8-42.1%) was a group of vegetative plants (v), and the second (21.1-50.0%) was a group of young generative plants (g1). The natural state of the habitat of this cenopopulation can be explained as more favorable than others. In CP2, the absolute maximum corresponded to vegetative plants group (v) (37.0%). In CP5, young generative individuals (g1) and mature generative (g2) predominated (from 30.8% to 38.4%). In terms of age composition, the state of *A. tianschanica* cenopopulations is considered relatively satisfactory but demonstrated a low level of abundance. It has been established that the state of the species populations in the studied regions is affected by soil conditions, changes in climatic conditions and anthropogenic impact.

Keywords: *Adonanthe*, age composition, cenopopulation, Northern Tien Shan, soil, Subendemic

INTRODUCTION

Ranunculaceae, which is distributed almost all over the world, is considered one of the essential families of ancient angiosperms. It contains 43 genera and 2346 species (Christenhusz et al. 2016). *Adonis* L. is a genus of the Ranunculaceae family. This genus comprises approximately 40 species of annual and perennial plants, which are widely distributed in southwestern Asia and Europe, northern Africa, and the Mediterranean region (Dong et al. 2017; Orhan et al. 2017; Hossein-Pour et al. 2019; Karahan et al. 2022). The aerial part of the species plant contains organic compounds, alkaloids, glycosides, saponins, nitrogenous compounds, carotenoids, flavonoids acid and vitamins (Mohadjerani et al. 2014; Yin et al. 2014; Baek et al. 2015; Kubo et al. 2015; Zhang et al. 2015). It is used as a cardiotonic agent (Maham and Sarrafzadeh-Rezaei 2014; Dong 2015). *Adonis* is rich in various classes of bioactive metabolites and has been used in European and Chinese folk medicine for their cardiac-enhancing effects (Shang et al. 2019). Also, species of the genus *Adonis* have antiangiogenic, cytotoxic, antibacterial, antioxidant, acaricidal and anti-inflammatory activity and have a positive effect on the central nervous system (Shang et al. 2013; Mohadjerani et al. 2014; Shikov et al. 2014; Yang et al. 2015; Kubo et al. 2015; George et al. 2017; Shang et al.

2017; Aziz et al. 2018; Guo et al. 2018; Kim et al. 2018). The plants of this genus were historically employed for decorative purposes in some areas due to the beauty of the flower.regions (Shang et al. 2019).

There are eight species of *Adonis* growing in Kazakhstan (Abdulina 1999; POWO 2023): *Adonis apennina* L., *Adonis villosa* Ledeb., *Adonis tianschanica*, *Adonis chrysocyathus* Hook.f. & Thomson, *Adonis vernalis* L., *Adonis volgensis* Steven ex DC., *Adonis scrobiculata* subsp. *scrobiculata*, *Adonis aestivalis* L. of which five species (*A. villosa, A. tianschanica, A. chrysocyathus, A. vernalis, A. volgensis*) are included in the Red Book of Kazakhstan (Red Book of Kazakhstan 2014). Previous studies on *Adonis* were mostly restricted to morphological, ecological, palynological, cytological analyses and genetic diversity in various regions of the world (Dong and Sung 2013; Erfanzadeh et al. 2013; Kubentayev et al. 2019; Mitrenina 2022). *A. tianschanica* is a rhizomatous perennial herb. During the flowering stage, it reaches up to 45 cm in height. Its leaves are scaly. At the beginning of the growing season, shoots and leaves are strongly hairy, while in the fruiting stage, they are almost naked. Flowers are solitary, 3.5-5 cm in diameter, located at the shoots' ends. Petals are lemon-yellow and uneven. The fruit is a nutlet; the seeds are 3-4 mm long and 2-3 mm wide, finely wrinkled (WFO 2023).

The Northern Tien Shan is a large mountain system, including the Ketmen, Zailiysky Alatau, Kungei Alatau, and the northern slopes of the Terskey Alatau, Talas Alatau (Mackenzie et al. 2018). The ranges of the northern Tien Shan (Ketmen, Zailiysky, Kungei Alatau) are characterized by high plant biodiversity and belt distribution of vegetation (Gemejiyeva et al. 2019). In this regard, knowledge about the ecological and botanical features, ecological confinement and distribution, binding to a certain altitudinal belt of the resource species of the northern Tien Shan mountain system is interesting both in theoretical and practical terms since the basic information of these features depends on the sustainable use and conservation of biodiversity (Tojibaev et al. 2020).

In terms of biodiversity conservation, protection is not only focused on individual species but also on a number of unique plant communities. Their diversity and sustainability are important conditions for creating an optimal environment for biological productivity. A small part of the communities are protected to some extent in nature reserves, but there is no general list of reference data for endangered and rare plant communities, which indicates that their protection is critical for further conservation. A number of them are of particular interest as standards for a stable ratio of species. Since very narrow ranges of geographical distribution are sometimes found in plant communities, accidental death can lead to their loss in the wild. These rare and endangered species can only be saved through enhanced measures to protect their communities (Raven et al. 2011).

Adonis tianschanica is a rare Central Asian species with a limited habitat isolated in the Tien Shan mountain system (Poshkurlat 2000). The main distribution area of the species is in Kazakhstan: in the Kyrgyz Alatau (in the upper reaches of the Talas River), on the ridges of the Kungei Alatau (in the valley of the Chonkemin River), on the ridges of the Tereskei, Dzungarian and Zailiysky Alatau and on the spurs of the Ketmen ridge. The eastern border of the species' habitat is in China, in the northern parts of Xinjiang Province, while the southwestern border of its habitat is in Kyrgyzstan. Population numbers of the species are intensively decreasing, and there is a real threat of degradation of *A. tianschanica* populations up to complete extinction of the species in some areas of Kazakhstan. It is now necessary to assess the current status of the species populations in the main growth areas of the species. Therefore, the aim of the work is to study the distribution and number of populations of *A. tianschanica* in its natural habitats in Dzungarian Alatau, Kazakhstan, and to investigate the soil characteristics, biological and arealogical features, including the ontogenetic structure of its populations.

MATERIALS AND METHODS

Study area and period

This study was conducted in Dzungarian Alatau, The Terskey Alatau Ridge and Ketmen Ridge. Dzungarian Alatau is located in the eastern and southeastern parts of Kazakhstan (Bakhtaulova et al. 2022). The Dzungarian Alatau, which lies between 44 and 46° N, is not a single ridge but an entire mountain system, which consists of several, but mainly of two parallel, high mountain ranges: the northern and the southern (Kenzhebaeva et al. 2014). The Dzungarian Alatau is characterized by a sharply continental climate with large variations of seasonal and daily temperatures, very low precipitation (in the plain a little more than 300 mm per year, in the mountains up to 400 mm) and dry summers (Vilesov 2018). Relative humidity during the day is about 50% (about 60% in the mountains), and at night, about 60% (about 80% in the mountains) (Panyushkina et al. 2017). The Terskey Alatau Ridge is asymmetrical, with a short, gentle southern slope and a long northern one. It has temperate continental climate. The annual rainfall is 800-1000 mm, and at the foot is 150-300 mm (Zapparov et al. 2021). Ketmen Ridge, one of the medium-altitude ranges, is located in the eastern part of the Tien Shan. The climate is sharply continental and mountainous (Akmatov et al. 2021).

In southeastern Kazakhstan three different soil belts occur: a low-mountain steppe belt of mountain chestnut soils and mountain chernozems; a mid-mountain meadow-forest belt of leached and podzolized mountain chernozems, brown and dark gray mountain forest soils; high mountain meadow belt with mountain meadow and mountain meadow steppe soils (Pachikin et al. 2014).

The object of current research work is the species *A. tianschanica*, common in South-East Kazakhstan. The research work was carried out in the period from April to May 2020 and 2022. In the study, 5 cenopopulations (CP) of *A. tianschanica* were identified, namely two CPs in Ketmen Ridge (Kegen Pass), two CPs in Dzungarian Alatau (Tekeli Gorge) and 1 CP in Terskey Alatau (Saryzhaz) (Figure 1).

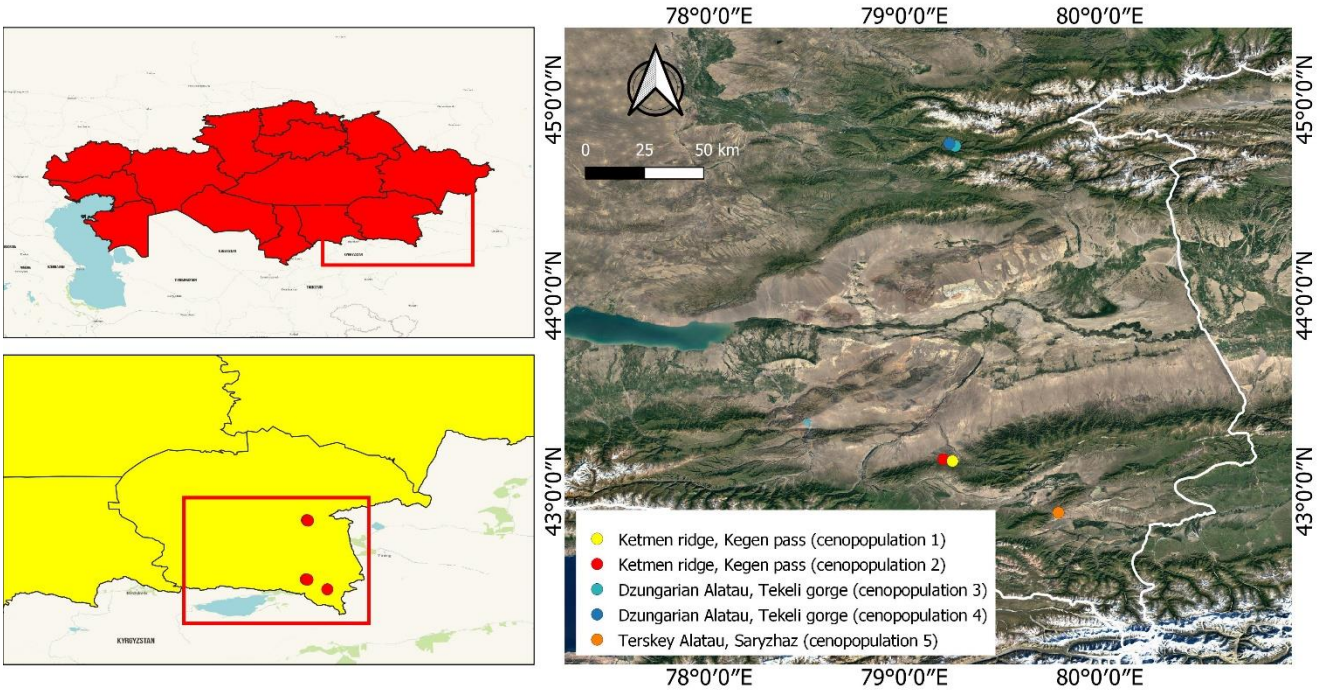

Figure 1. Map of the study area showing the distribution area of *Adonis tianschanica* in southeastern Kazakhstan

Field survey and laboratory methods

The study was carried out according to generally accepted methods for studying cenopopulations. To identify the phytocenotic features of *A. tianschanica* populations, the traditional methods of field geobotanical studies were performed using the ecological-physiognomic approach. The ecological and physiognomic types combined plant communities with dominant species from only one ecobiomorph and ecologically associated species groups. When describing cenopopulations, the classification is based on the absolute maxima of ontogenetic groups (Mukhitdinov et al. 2014). In distinguishing the age composition, the following classification of Uranov (1969) was used: p-sprouts; j-juveniles, im-immature; v-virginal and young vegetative; g_1-young generative; g_2-middle or mature generative; g_3-aging generative; ss-subsenile; s-senile; wi-wilted individuals (Ydyrys et al. 2013). The density of the cenopopulation was estimated by the number of individuals per one-meter square. Attention was paid to the average density, i.e. the number of individuals per unit of the total area.

Using unique description forms, the populations were described. 15 study sites were set up in each population, each measuring 10 × 10 meters (100 m^2). 75 sites altogether were considered. In order to pinpoint the location, the GPS device recorded the community boundaries' marginal points. The form was initially filled out with general information, such as the description number, geographic location, date, coordinates, height, site size, and photo number. Following this, the main sections listed below are reflected in the form: The name of the vegetation type based on dominating species; the community's floral composition with a note on species occurrence. We chose a piece of the reconstruction of a homogeneous contour to do this using GPS.In the course of fieldwork, only 5 soil profiles were laid in those places where cenopopulations were found. For physical and chemical analysis of the soil, 19 samples were taken, and each sample was analyzed in 3 repetitions. All these soil samples were grouped into 3 soil types according to the morphological characteristics and chemical properties of the soils. The following chemical compositions of soils were determined: total humus-according to ST RK ISO34477-2019, CO_2-according to GOST 26425-85, total nitrogen-according to GOST 26107-84, total phosphorus, potassium - according to GOST 26261-84, pH indicator - according to GOST 26423 -85, trace elements Zn, Cu, Fe, Mn - according to GOST 27262-87, granulometric composition - according to GOST 12536-2014.

The soil map was compiled based on some of the existing cartographic and reference materials from previously published data. The existing soil map of Kazakhstan at a scale of 1:2500000 (National Atl. 2010) was used as the basis for the map. Distribution maps of *A. tianschanica* and soil maps were prepared using ArcGIS.

Statistical data analysis

Pearson's correlation was performed using the R statistical platform to analyze morphological parameters between populations (R-Studio Team 2020).

RESULTS AND DISCUSSIONS

Soil analysis

This study conducted an assessment of the soil condition, including the morphological characteristics and the chemical

composition. We found that CP1-2 have the soil type of the leached mountain chernozem (Ketmen Ridge, Kegen Pass), CP3-4 have the mountain-meadow-steppe soil type (Dzhungarsky Alatau, Tekeli Gorge), and CP5 has to the southern mountain chernozem (Terskey Alatau, tract Saryzhaz) (Figure 2).

On the Ketmen Ridge (Kegen Pass) with soil type of leached mountain chernozem, the humus content in the upper 0-10 cm layer was high, amounting to 7.64%; decreased to 0.35%, the soil is highly supplied with humus. The content of nutrients depends on the content of humus in the soil. These elements on the studied soils varied as follows: total nitrogen within 0.49-0.112%, phosphorus within 0.2-0.176%, and potassium within 2.335-2.758%. The soil is characterized by high nitrogen content, medium phosphorus content and high potassium content. The content of gross potassium in the arable layer of soils is 0.5-3.0%.

According to the mechanical composition, the soil up to 30 cm is medium loamy, the layers from 30 to 50 cm are heavy loamy, and from 50 cm to 70 cm again medium loamy. The reaction of the soil environment (pH) was strongly alkaline, ranging from 7.86 to 8.36. The content of CO_2 ranged from 0.73-9.84. With an increase in the depth of the cut, the indicators of these parameters increased (Figure 3). The absorbed bases ranged from 0.26 to 26.95 meq. per 100 g of soil. The absorbed bases were dominated by Ca and Mg. The soil has an increased and high absorption capacity. The content of gross trace elements was within the following limits: Zn 49.6-7.2 mg/kg, Cu 14-20.8 mg/kg, Mn 317.2-663.6 mg/kg, Fe 29700-49320 mg/kg. The contents of all considered trace elements were below the maximum allowable concentration for their gross forms in the soil (Table 1).

The results above suggest that the soil is fertile rich with humus and nutrients and has high absorption capacity. The content of nutrients is naturally higher in the upper horizons as compared to lower horizons.

In the Dzungarian Alatau, Tekeli gorge, with soil type of mountain meadow-steppe, has a high content of humus (0-50 cm); in the upper 0-10 cm layer, the humus content was high and amounted to 9.81%, on the 10-30 cm horizon the humus decreased to humus decreases further with depth to a low degree (1.02%). Nutrients were also high, fluctuating as follows: nitrogen within 0.126-0.616%, phosphorus within 0.088-0.212%, potassium within 2.44-2.969%. According to the mechanical composition, the soil is classified as heavy loamy up to 30 cm and medium loamy from 30 to 50 cm (Gorbyleva 2000).

The reaction of the soil environment (pH) was strongly alkaline (7.43-8.28). The content of CO_2 increased to a high level with increasing depth and within the range of 0.66-9.28. The absorbed bases ranged from 4.50 to 7.07 mg - is equivalent to per 100 g of soil were in very low to low ranges (Figure 4). The amount of absorbed Ca and Mg were noted to be predominant within absorbed bases.

The content of gross trace elements was investigated within this range: Zn 64-162.4 mg/kg, Cu 18-22.8 mg/kg, Mn 278.8-581.6 mg/kg, Fe 20700-25260 mg/kg. An excess of the MAC of zinc up to 2.9 times was noted; for the rest of the microelements, the indicators did not go beyond the MAC (Table 1).

Mountain chernozem southern soils, which occur in Teriskey Alatau are distinguished due to a rich supply of humus in the 0-30 cm layer. The humus content on this horizon was 9.13%, slightly decreasing on the second half-meter horizon (30-50 cm) to 4.32% (average). Accordingly, the nutrient elements of the soil were high in content and fluctuated within the following limits: gross nitrogen 0.36-0.54%, phosphorus 0.17-0.21%, potassium 2.96-3.07%. The gross content of potassium often exceeds the content of nitrogen and phosphorus and is determined by the particle size distribution. Clay and loamy soils are especially rich in potassium, where the content reaches 2-3%. According to the mechanical composition, the soil up to 30 cm is medium loamy, and from 30 cm to 50 cm it is heavy loamy.

Table 1. Chemical characteristics of soils (n=3) in Southeast Kazakhstan

Depth of sample (cm)	Microelements (mg/kg)				Soil nutrition elements (%)		
	Zn	Cu	Mn	Fe	N	P_20_5	K_2O
Leached mountain chernozem							
0-10	72.2±3.5	20.8±2.2	663.6±16.4	49320±360	0.490±0.06	0.200±0.02	2.758±0.2
10-30	77.2±4.5	18.4±2.0	517.2±15.8	35600±290	0.350±0.02	0.176±0.02	2.652±0.1
30-50	52.8±3.4	14.4±1.6	317.2±12.5	29700±270	0.112±0.01	0.152±0.01	2.387±0.2
50-70	49.6±3.4	14.0±1.5	295.2±11.6	35320±340	0.056±0.01	0.152±0.01	2.335±0.1
Mountain meadow-steppe							
0-10	162.4±10.2	22.0±2.2	581.6±15.3	25260±270	0.616±0.07	0.212±0.02	2.969±0.2
10-20	75.6±4.5	22.8±2.2	366.8±12.4	20700±240	0.378±0.02	0.188±0.02	2.652±0.2
20-30	64.0±4.5	18.0±2.0	278.8±11.4	21760±260	0.196±0.01	0.188±0.02	2.546±0.2
30-50	73.6±4.5	18.4±2.0	302.8±12.5	22400±240	0.126±0.01	0.088±0.01	2.440±0.1
Southern mountain chernozem							
0-10	74.4±4.5	21.6±2.2	546.4±14.6	32520±340	0.546±0.06	0.212±0.03	3.075±0.3
10-30	78.8±4.5	20.0±2.2	392.0±12.2	18000±220	0.406±0.04	0.176±0.01	3.022±0.2
30-50	57.2±4.5	16.4±1.8	237.6±11.0	26500±270	0.364±0.04	0.176±0.01	2.969±0.2

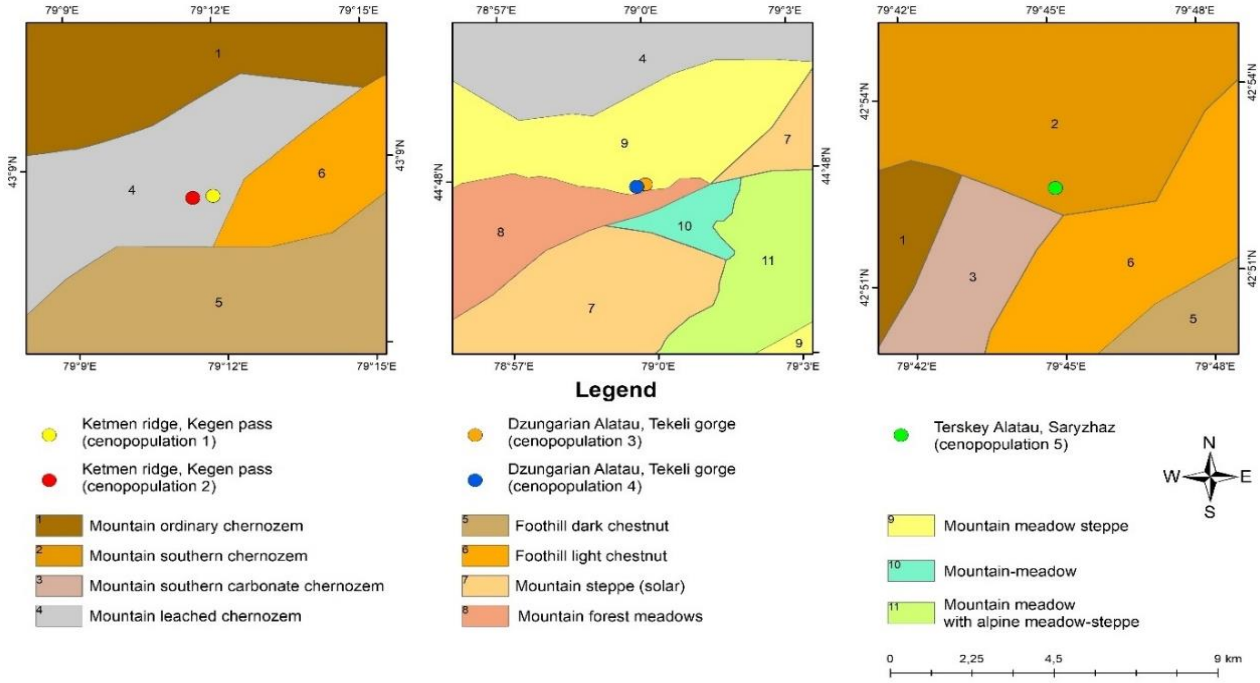

Figure 2. Soil map of the study area in Southeast Kazakhstan with scale of 1:90000

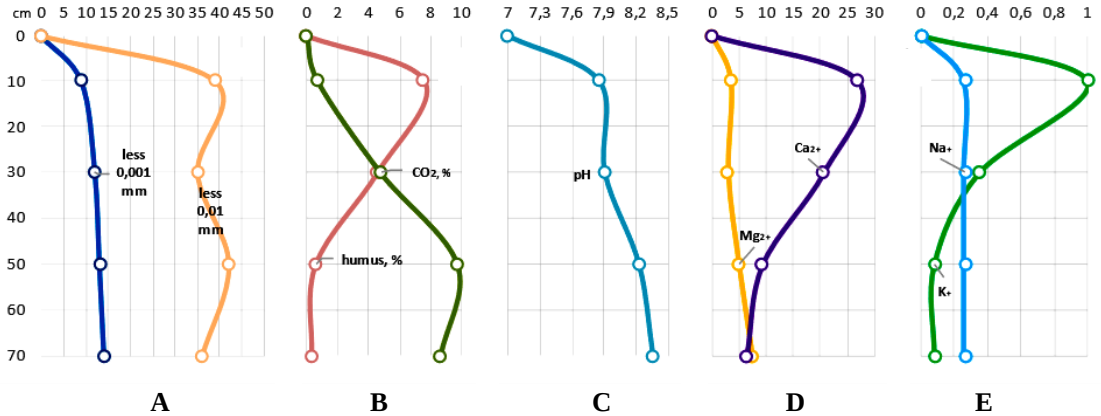

Figure 3. Analytical characteristics of leached mountain chernozem**:** A. Granulometric composition, fractions, %; B. Humus, %. CO_2 carbonates, %; C. pH; D. Exchange bases Ca_{2+}, Mg_{2+}; E. Na_+, K_+, mmol (eq.)/g

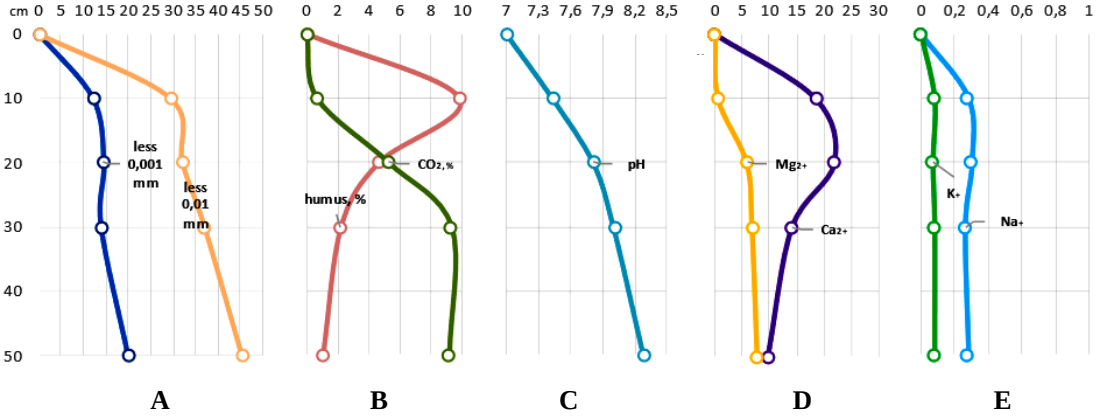

Figure 4. Analytical characteristics of mountain meadow-steppe: A. Granulometric composition, fractions, %; B. Humus, %. CO_2 carbonates, %; C. pH; D. Exchange bases Ca_{2+}, Mg_{2+}; E. Na_+, K_+, mmol (eq.)/g

The soil pH was strongly alkaline, ranging from 7.1 to 7.96. The content of CO_2 was in the range of 0.45-6.11 increased in the lower horizons. The soil belongs to the group with a very high absorption capacity, i.e., the content of absorbed bases is more than 30 meq. per 100 grams of soil. The contents of absorbed bases varied within 30.12-34.63 mg - is equivalent to per 100g of soil (Figure 5). Absorbed Ca and Mg predominated in the composition of the absorbed bases.

The chemical properties of soil in the studied area are presented in Table 1. The content of gross trace elements was within the following limits: Zn 57.2-78.8 mg/kg, Cu 16.4-21.6 mg/kg, Mn 237.6-546.4 mg/kg, Fe 18000-32520 mg/kg (Table 1). Of the studied trace elements, the zinc content exceeded the MAC by 0.6 times, and the rest of the microelements were below the MAC.

Area distribution of *Adonis tianschanica*

Based on the results of the revision of the herbarium collections AA, MW and, the review of the literature and the data of our own field studies, the general distribution of *A. tianschanica* was studied (Table 2, Figure 6). Based on the results, it has been noted that the species is distributed in three countries: (i) the Republic of Kazakhstan within the Almaty region on the ridges of Dzhungarsky Alatau, Zailiysky-Kungei Alatau, Ketmen-Terskey Alatau (Kolbintsev 2014; Otradnykh et al. 2015); (ii) Kyrgyzstan in the Issyk-Kul region on the ridges of the Kyrgyz and Kungei Alatau (Pimenov et al. 1995); (iii) People's Republic of China, Xinjiang (Catalogue of Life 2023; Flora of China 2018).

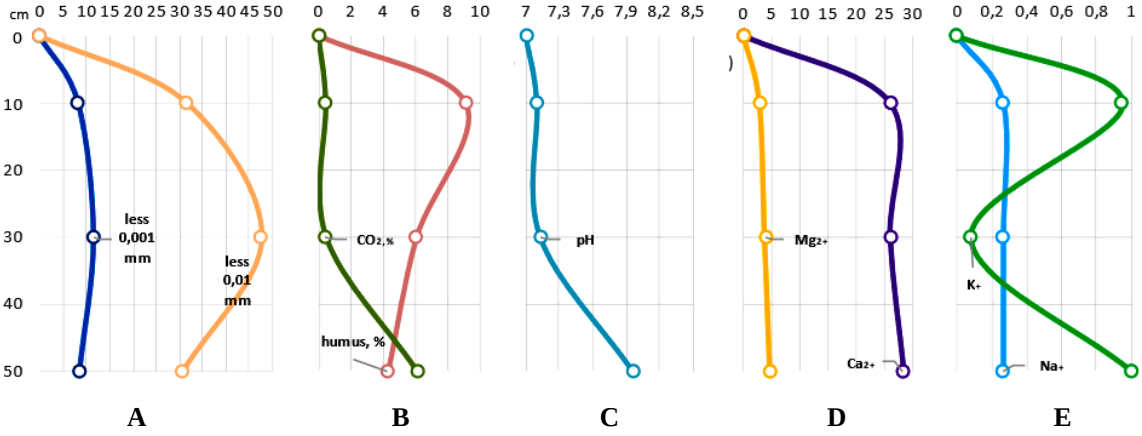

Figure 5. Analytical characteristics of mountain southern chernozem: A. Granulometric composition, fractions, %; B. Humus, %. CO_2 carbonates, %; C. pH; D. Exchange bases Ca_{2+}, Mg_{2+}; E. Na_+, K_+, mmol (eq.)/g

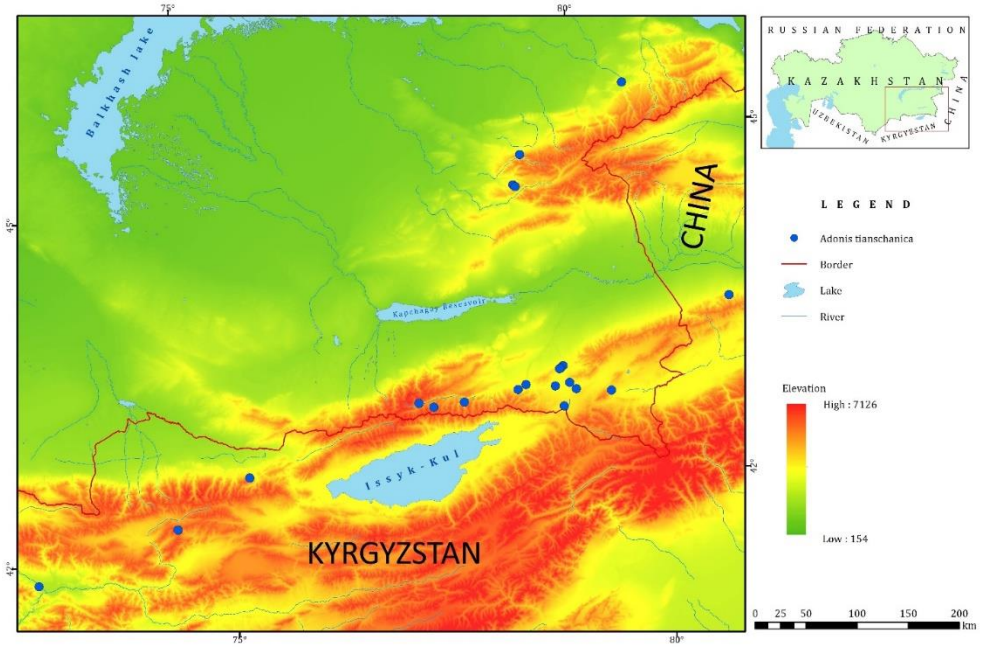

Figure 6. Geographical distribution of *Adonis tianschanica*

Table 2. The studied samples and literature sources on the study of the distribution of *Adonis tianschanica*

*Country	Ridge	Location	Coordinates		Date of collection, publication	The author of the collection	Herbarium (H), Observation (O), Literature (L)	The collection identifier
KZ	Dzungarian Alatau	The western spurs of the Dzungarian Alatau, the Katurkin Mountains. Upper reaches of the Karagaily river.	45.039865	79.141697	1959-05-27	Goloskokov V.P.	H	AA
KZ	Dzungarian Alatau	Dzungarian Alatau. Lepsinsky district	45.513642	80.551538	1940-05-24	Poliakov P.P.	H	AA
KZ	Kungei Alatau	Kungei Alatau. SV mountain slopes above the Kurmekty river.	43.035894	77.448746	1942-05-15	Lazarenko A.S.	H	AA
KZ	Kungei Alatau	The eastern tip of the Kungei Alatau ridge, the valley of the Karkara River, the hills along the Irisu River 3 km from the highway to Kegen.	42.810289	79.1590322	1966-06-01	Boryaev K.	H	AA
KZ	Kungei Alatau	The eastern spurs of the Kungei Alatau ridge, hills and foothills along the Irsu River.	42.984750	77.989450	1975-06-03	Lushpa O.U.	H	AA
KZ	Kungei Alatau	Kungei Alatau, Kurmekty, slopes of Yu-in the exposition	43.020023	78.647386	1942-05-04	Lazarenko A.S.	H	AA
KZ	Ketmen ridge	The area of the middle course of the Kegen River. The western tip of the Sholadyr Mountains.	43.005073	79.272291	1946-08-15	Rubtsov, N.I. Stepanova E.F.	H	AA
KZ	Kungei Alatau	East. the extremity of xp. Kungei Alatau, dol. Karkara River, along the Irisu River 3 - 4 km from the ford across the Karkara River.	42.995345	79.096056	1966-06-01	Boryaev K.	H	AA
KZ	Kyrgyz Alatau	Kyrgyz Alatau ridge, tract. Toguz bulak (in the interfluve of Alamedin and Issyk-Ata).	43.026745	78.696777	1976-05-12	Karmysheva N.H.	H	AA
KZ	Ketmen ridge	East of the Tien Shan, Kegen River basin	42.989636	79.305158	1969-06	Poshkurlat A.	H	MW
KZ	Ketmen ridge	North Tien Shan, Ketmen ridge, Kegen lane, sub-alpine belt, height about 2000 m num. April 28, 2014	43.144722	79.196944	2014-04-28	Kolbintsev V.	O	Kolbintsev 2014
KG	Talas Alatau	Uzun Akhmat Ridge	41.829957	72.720830	1979	Pakhomova M.G.	L	Pakhomova 1972
KZ	Kungei Alatau	In the Kurobe Gorge of the Kungei Alatau ridge	42.982550	77.617299	2015	Otradnykh, I.G. Shedina, I.A. Kokoreva, I.I.	L	Otradnykh et al. 2015
KG	Kyrgyz Alatau	Kyrgyz Alatau ridge, Shamsi River basin, on gravelly slopes	42.586075	75.329421	1995-07-30	Pimenov, M.G. Klyuykov, E.V. Lazkov, G.A.	H	Pimenov et al. 1995
CN	Eastern Tien Shan	Slopes; ca. 1900 m. W Xinjiang.	43.502778	81.349722	2018	Flora of China 6: 389-391.	L	Flora of China 2018
KZ	Ketmen ridge	Ketmen ridge, Kegen pass	43.143417	79.196194	2020	Kulymbet, K.K. Abidkulova K.T.	H	AA
KZ	Ketmen ridge	Ketmen ridge, Kegen pass	43.143444	79.189389	2020	Kulymbet, K.K. Abidkulova K.T.	H	AA
KZ	Dzungarian Alatau	Dzungarian Alatau, Tekeli gorge	44.796444	78.994694	2020	Kulymbet, K.K. Abidkulova K.T.	H	AA
KZ	Dzungarian Alatau	Dzungarian Alatau, Tekeli gorge	44.796167	78.992778	2020	Kulymbet, K.K. Abidkulova K.T.	H	AA
KZ	Terskey Alatau	Terskey Alatau, Saryzhaz	42.874194	79.749556	2020	Kulymbet, K.K. Abidkulova K.T.	H	AA

Phytocenotic characteristics of cenopopulations and biological features of *A. tianschanica*

To study the phytocenotic characteristics of the cenopopulations of *A. tianschanica* and its biological characteristics, the age spectrum, numbers, habitat, morphological features, dominants and related species were studied within the community. In the study area, 5 cenopopulations of the species were examined (Figure 1). To assess the state of the CP, the following basic parameters were chosen as organ traits: plant height (cm); diameter south/north (cm); diameter east/west (cm); number of flowers (pcs); flowers length (cm); number of shoots (pcs); shoot length (cm) (Table 3, Figure 7); share of young individuals (j-v, %); share of generative individuals (g_1-g_3, %); share of old individuals (ss-s, %) (Table 4).

The CP1 was located in the Ketmen Ridge, Kegen Pass (Figure 1). Dominant species in a community where *A. tianschanica* occur, including *Artemisia frigida, Festuca valesiaca, Tulipa brachystemon* and *Artemisia vulgaris*. It has altitude of 1955-1956 m a.s.l., exposure of east, slope, temperature of -30°C, and total projective cover of 50-60%. Associated species recorded were *Eremostachys speciosa, Helictotrichon desertorum, Oxytropis ochroleuca, Stipa orientalis, Carex stenophylloides, Erysimum hieracifolium, Phlomis pratensis, A. tianschanica, Erysimum altaicum, Lappula macrocarpa, Potentilla conferta, Ligularia narynensis* and *Artemisia dracunculus.*

Figure 7. The flowering of *Adonis tianschanica* in Dzungarian Alatau, Tekeli Gorge, Southeast Kazakhstan

Table 3. Morphometric and quantitative indicators of *Adonis tianschanica* in Southeast Kazakhstan

Parameter		Cenopopulation (CP)				
		1	2	3	4	5
Height of generative individuals at the time of flowering (cm)	M	13	8.8	23.6	27.5	15.1
	SD	0.3	1.3	2.01	2.3	1.2
Diameter of the bush (cm)	M	11.1	6.64	14.2	16.5	9.9
	SD	1.03	0.03	1.7	1.3	1.5
Number of flowers per individual (pcs)	M	12.0	8.0	5.0	3.0	2.0
	SD	1.03	0.5	0.3	0.6	0.5
Number of shoots per individual (pcs)	M	18.0	13.0	6.0	5.0	3.0
	SD	1.6	1.3	0.3	0.5	0.5
Shoot length (cm)	M	16.0	8.0	30.0	25.0	18.0
	SD	1.1	1.5	2.1	1.6	1.3
Number of adults per 1 square meter (pcs)	M	0.3	0.16	0.2	0.2	0.3
	SD	0.002	0.001	0.001	0.001	0.002
Number of shoots per individual (pcs)	M	9	8.3	4.2	4	8.2
	SD	1.0	1.1	0.3	0.3	1.1

Table 4. Distribution of the number of *Adonis tianschanica* individuals by age groups

Location (Cenopulation)	Number of individuals, plants (n=10)									Total
	p	j	im	v	g_1	g_2	g_3	ss	s	
Ketmen Ridge (CP1)	-	-	-	10	8	8	-	1	-	27
Ketmen Ridge (CP2)	-	-	2	5	8	12	4	-	-	31
Dzungarian Alatau (CP3)	-	-	-	3	8	3	-	-	2	16
Dzungarian Alatau (CP4)	-	-	-	8	4	7	-	-	-	19
Terskey Alatau (CP5)	-	-	-	4	5	4	-	-	-	13
Average	-	-	0.4	6.0	6.6	6.8	0.8	0.2	0.4	21

The CP2 was located on the Ketmen Ridge, Kegen Pass (Figure 1). Dominant species in a community involving *A. tianschanica* included *C. stenophylloides, F. valesiaca, O. ochroleuca* and *A. frigida*. It has an elevation of 2032-2033 m a.s.l, exposure of northeast, slope, temperature of -10-15°C, and total projective cover of 80-100%. Associated species were *Leontopodium fedtschenkoanum, Saussurea caespitans, Pulsatilla campanella, Cerastium bungeanum, P. conferta, Goniolimon orthocladum, Androsace sericea, E. speciosa, Taraxacum pseudoalpinum, A. tianschanica, P. pratensis, A. dracunculus, Potentilla nervosa, Macroappulais semeni, H. desertorum* and *Dracocephalum integrifolium.*

The CP3 was examined in the Tekeli Gorge, Dzungarian Alatau (Figure 1). Dominant species in a community involving *A. tianschanica* included *Ligularia macrophylla, Rosa acicularis, Ferula kelleri* and *Eremurus altaicus.* It has an elevation of 2043-2044 m a.s.l., exposure of southeast, slope, temperature of -50°C, and total projective cover of 90-95%; The vegetation cover is dense with associated species, including *Rheum wittrockii, Galium verum, T. brachystemon, Primula macrocalyx, Polygala hibrida, Origanum vulgare, A. vulgaris, E. altaicus, Paeonia intermedia, Iris bloudowii, A. tianschanica, L. narynensis, Thalictrum foetidum* and *Polygonum scabrum.*

The CP4 was found in the Tekeli Gorge, Dzungarian Alatau (Figure 1). Dominant species in a community involving *A. tianschanica* were *Pedicularis semenowii, Berberis sphaerocarpa, R. acicularis* and *A. dracunculus*. It has elevation of 2040-2042 m a.s.l., exposure of southeast, slope, temperature of -50°C and total projective cover of 90%. The associated species included *Rosa spinosissima, L. narynensis, P. hibrida, Centaurea iberica, P. macrocalyx, E. altaicus, Potentilla orientalis, Lonicera karelinii, Juniperus sibirica, Frangula alnus, E. altaicum, Galium saurense, Euphorbia latifolia, Rheum witrockii* and *Myosotis witrockii.*

The CP5 was studied in Terskey Alatau, Saryzhaz tract (Figure 1). Dominant species in a community involving *A. Tianschanica* were *A. vulgaris, F. valesiaca, D. integrifolium* and *A. dracunculus*. It has altitude of 2154-2155 m a.s.l., exposure of southeast, slope, temperature of -30°C, and total projective cover of 40-50%. Associated species recorded were *E. speciosa, Agropyron cristatum, A. frigida, E. hieracifolium, H. desertorum, P. semenowii, Linaria vulgaris, Ribes heterotrichum, Scutellaria przewalskii, P. pratensis, Linum corymbulosum, Jurinea lanipes, Patrinia intermedia, Lonicera altmanii, S. orientalis* and *G. verum.*

Due to the presence of dominant *A. tianschanica*, CP1 and CP2 had the highest density of individuals, with an average 2.7-3.1 plants/m^2. In CP3, CP4 and CP5, the average plant density was 1.6 plants/m^2, 1.9 plants/m^2 and 1.3 plants/m^2, respectively. The total number of *A. tianschanica* individuals in all surveyed CPs was 106 individuals, including 27 individuals in CP1, 31 individuals in CP2, 16 individuals in CP3, 19 individuals in CP4, and 13 individuals in CP5. The Morphometric and quantitative indicators of *A. tianschanica* in the examined CPs are shown in Table 3. The height of generative individuals at the time

of flowering was CP3 (26.86 cm)>CP4(26.79 cm)>CP5 (14.55 cm)>CP1 (11.24 cm)>CP2 (9.01 cm), while flower length was CP3 (17.88 cm)>CP4 (16.37 cm)>CP5 (9.32 cm)>CP1 (8.11 cm)>CP2 (7.29 cm) and number of adults per 1 m^2 was CP2 (0.48 cm)>CP1(0.36 cm)>CP3 (0.28 cm)>CP4 (0.26 cm)>CP5 (0.22 cm).

The height of generative individuals at flowering, number of adults per 1 m^2 , number of shoots per individual and bush diameter were selected for correlation analysis to test the significance of differences between cenopopopulations. According to correlation analysis between populations by morphological traits, a weak negative correlation was observed between CP1 and CP2, CP1 and CP3 by height of generative individuals. A weak positive correlation was observed between CP1 and CP4 on the number of adults per 1 m^2. A weak negative correlation was also observed between population CP5 with CP1 and CP2 for this trait. A strong negative correlation between CP1 and CP2 was observed for bush diameter (Figure 8).

In order to establish how the groups of traits of the generative sphere of *A. tianschanica* plants correlate with each other, we conducted a correlation analysis on morphological parameters (Figure 9). Pearson correlation evaluation in all conditions showed that the mean value of the height of individuals at the time of flowering was positively correlated with the number of shoots per individual and bush diameter in CP1, CP2, and CP5. In the fourth cenopopulation, the height of individuals at flowering was negatively correlated with the number of shoots per individual. In addition, the number of shoots per individual was negatively correlated with bush diameter. Interestingly, the height of generative individuals at the time of flowering had the highest correlation value with bush diameter, Tr04 = 0.75. For traits such as number of shoots and bush diameter, a positive correlation was observed in CP1 and CP5. The results of the analysis showed that the correlation coefficient R between generative structure cenopopopulations was 100%, which is statistically significant (P<0.05). This indicates that the development of generative organs largely depends on nutrient elements in the development of vegetative structures, as the maximum development of vegetative organs allows the successful development of the generative organs of plants.

Strong positive correlations were observed between the height of generative individuals, number of shoots per individual, and between bush diameter and height of generative shoots. A large number of strong positive correlations were found in CP1 and CP5. These cenopopulations are located in mountain massifs, where species are in rather favorable growing conditions. The majority of CPs are characterized by average correlations between traits. CPs 2, 3 and 4 are characterized by a very small number of correlations. The lowest correlation coefficients are characteristic of populations growing under unfavorable weather conditions. In case of changes and deterioration of habitat conditions, the average degree of correlation may decrease, which may indicate an adaptive response of plants.

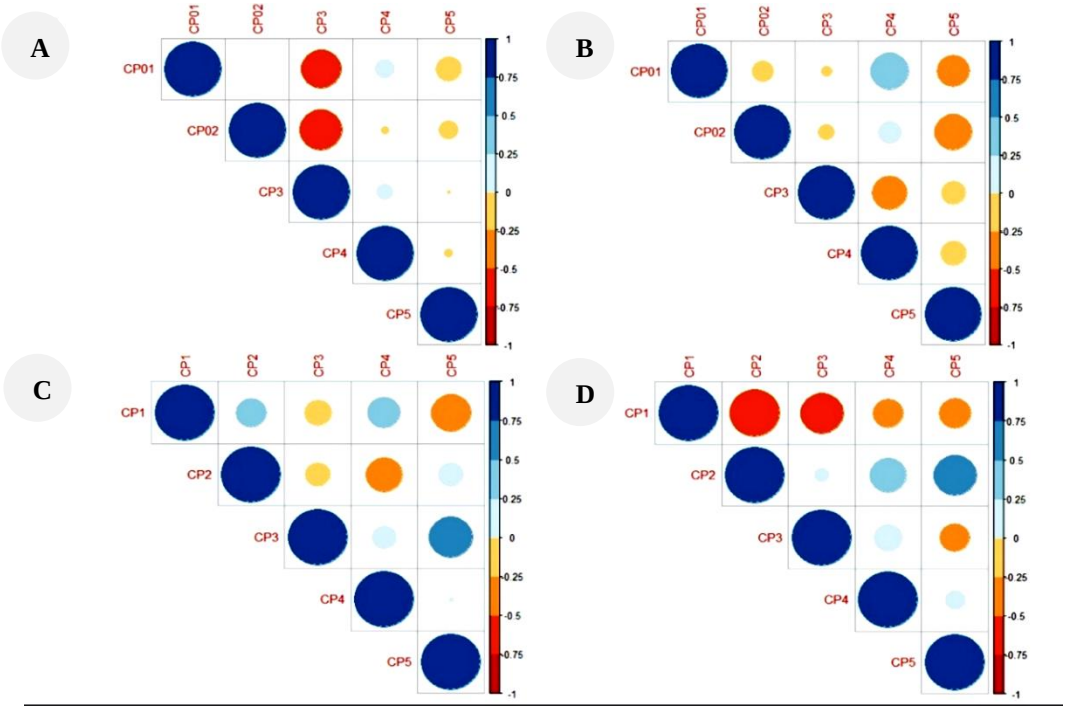

Figure 8. Correlation analysis of morphometric parameter between cenopopulations: A. Height of generative individuals in flowering stage (cm.); B. Number of adults per 1 square meter; C. Number of shoots per individual (pcs); D. Diameter of the bush (cm). Correlations with P <0.05 are highlighted in color. The color indicates either a positive (blue) or negative (red) correlation

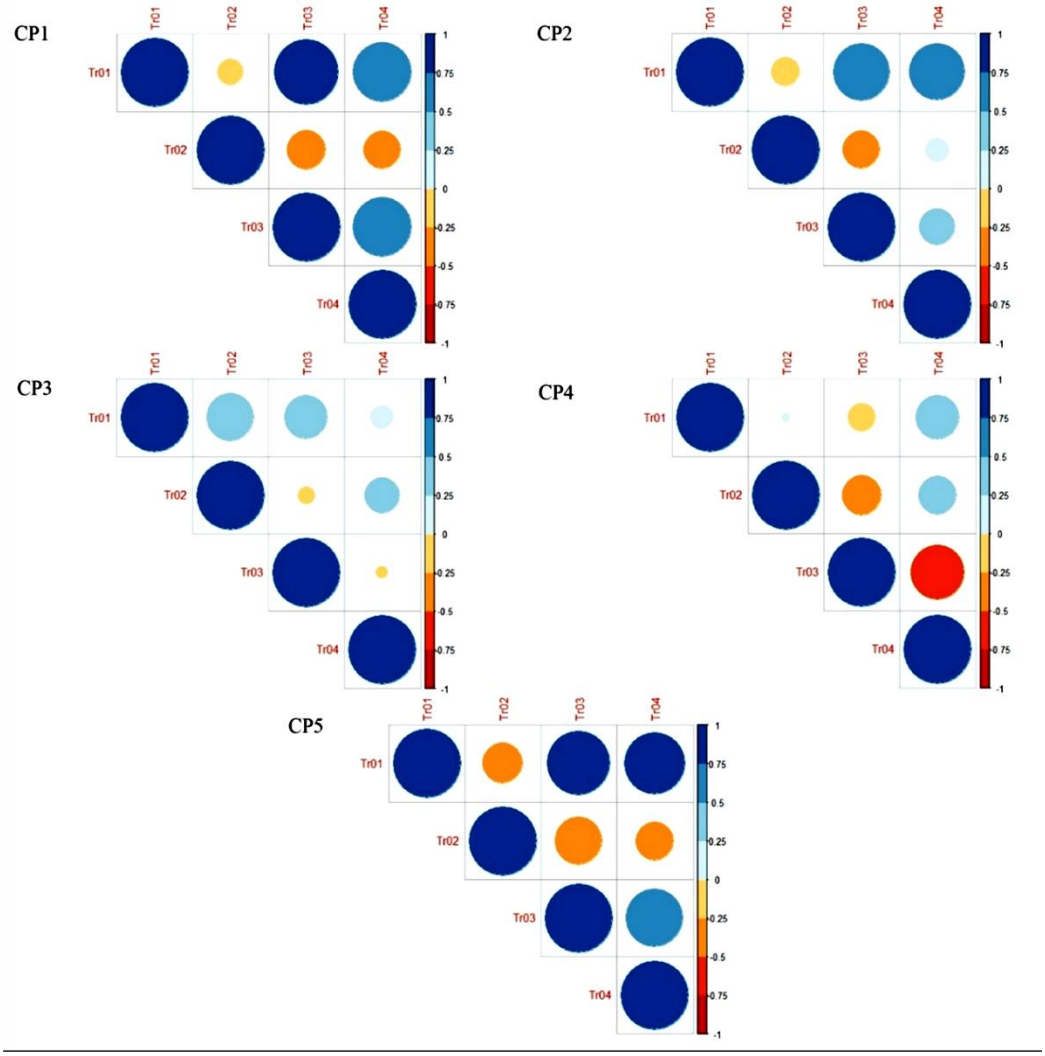

Figure 9. Correlation analysis of morphometric parameters and quantitative indicators of specimens within CP1-CP5 cenopopulations. Correlations with P <0.05 are highlighted. The color indicates either positive (blue) or negative (red) correlation. Notes: Tr01 = The height of generative individuals at the time of flowering (cm.); Tr02 = Number of adults per 1 m^2; Tr03 = The number of sprouts per specimen (pcs); Tr04 = Diameter of the bush (cm)

The distribution of the number of individuals by age groups in all CPs showed the following average indicators: the immature (im) with 0.4 individuals, virginal (v) with 6.0 individuals, generative (g_1) with 6.6 individuals; generative (g_2) with 6.8 individuals, generative (g_3) with 0.8 individuals, subsenile (ss) with 0.2 individuals, and senile (s) with 0.4 individuals (Table 4).

In CPs 1 and 4, the number of young individuals prevails (37% and 42%), which shows a good seed regeneration of the population. In CPs 2, 3 and 5, the proportion of generative individuals (38-50%) prevails. However, the proportion of young individuals in these CPs (16-30%) is sufficient to maintain the population. The number of pregenerative individuals in cenopopulations is noticeably low (p-im) and is characterized by vegetative individuals (v) (3.8-12.4%) (Table 5).

The results of this study indicate the low number of *A. tianschanica* individuals in all CPs, which is likely due to the biological characteristics of the species (low seed renewal and seed production) and the lack of vegetative propagation and environmental factors. The states of CP1 and CP2 are satisfactory, however, as grazing and trampling of plants by domestic animals are noted. There are cattle pastures on the Kegen pass. Also, the low number of individuals can be explained by constant winds on the open slopes of the CP.

There are two maxima in the age composition of individuals in CPs 3 and 4: the first (18.8-42.1%) is a group of vegetative plants (v), and the second (21.1-50.0%) is a group of young generative plants (g_1). The natural state of the habitat growing in this cenopopulation can be explained as more favorable than others (Figure 10).

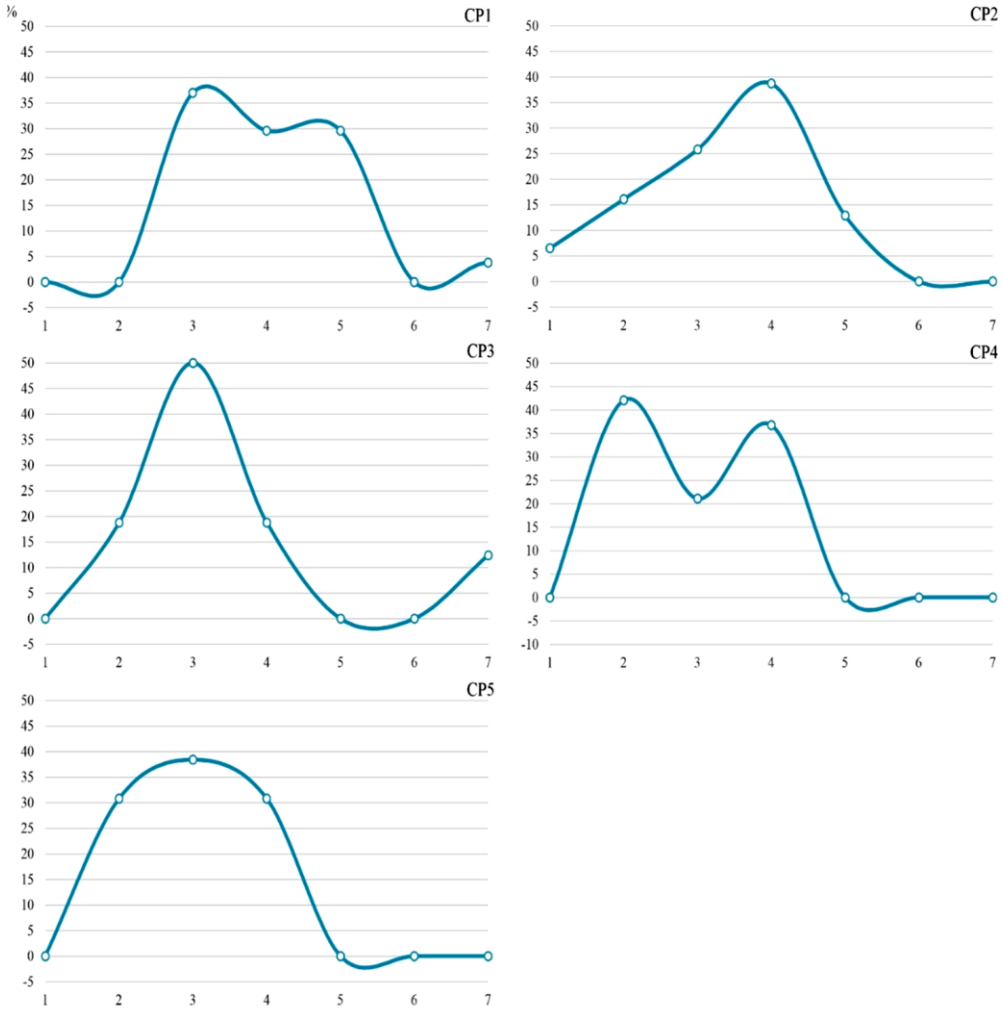

Figure 10. Age composition of *Adonis tianschanica* cenopopulations in percent (%) where the X axis shows the age group: 1. immature (im), 2. virginil (v), 3. young generative (g_1), 4. mature generative (g_2), 5. old generative (g_3), 6. subsenile (ss), 7. senile (s)

Table 5. Distribution of the proportion of age groups within the surveyed CPs

Parameter		Cenopopulation				
		1	2	3	4	5
Share of young individuals (j-v), %	M	30.0	14.1	16.8	40.1	29
	SD	2.1	1.1	1.3	2.3	2
Share of generative individuals (g1-g3), %	M	28.6	36	48	34	36
	SD	1.9	2.1	2.5	2.1	1.6
Share of old individuals (ss-s), %	M	3.8	-	11	-	-

In CP 5, generative individuals (g_1-g_2) predominate (from 30.8% to 38.4%). Aging generative (g_3), subsenile (ss), and senile (s) individuals are not found. The area of the cenopopulation is small and the position of the species in the cenopopulation is satisfactory. This cenopopulation is characterized by the lowest number of individuals. In CPs 1, 3, 4, 5 no individuals are found in the generative (g_3) state. Young generative (g_1) individuals predominate in almost all cenopopulations. Subsenile (ss) individuals were noted only in CP 1-3.8%, and senile (s) individuals existed in CP 3 - 12.4% (Figure 10).

Discussion

This study conducted a comprehensive assessment of the important state of *A. tianschanica* cenopopulations in Southeast Kazakhstan. In the studied areas, we observed 5 cenopopulations, in all of which we found a low number of A. *tianschanica* individuals. This is likely associated with low seed reproduction and the absence of vegetative reproduction, as well as with extreme growth conditions of the species. This study is consistent with the findings of the previous study (Medvegy et al. 2009). Chmura et al. (2012) stated that the age structure of the population affects the reproductive potential of plants. Seed germination of A. *tianschanica* is also affected by biological features and a short latent period. However, it has been examined that the height of the aerial parts of plants is proportional to the distance of seed distribution.

The total number of individuals of *A. tianschanica* in the five cenopopulations was 106 individuals. The average density of the species varied from 1.3 to 3.1 plants/m^2 with CP2 being the highest and CP5 the lowest. The complex cenotic characterization of five cenopopulations of A.

tianschanica revealed that all cenopopulation of the species of interest in the ontogenetic composition are almost complete. Young generative (g_1) individuals predominate in almost all cenopopulations, while juvenile seedlings were absent. Based on the literature, *Adonis* L. go through several phases of development during its life history (Chmura et al. 2012; Denisow et al. 2014). Most of the studied CP1 belong to the sagebrush-fescue plant association, CP2 is sedge-fescue-shrub-wormwood community, CP3 is the golden ray-shrub community, CP4 is lousewort-shrub community, and CP5 is sagebrush-fescue-snakehead community. According to the literature data, in populations with a predominance of cereal vegetation, it affects the development of juvenile plant seedlings (Mohammad et al. 2014). This is due to the low germination of seeds, as this is facilitated by the turfiness of the underlying surface. This is one of the forms of phytocentric interspecific competition. Our study highly correlates with the previous studies (Bożena et al. 2008).

Vegetation in the study area is mainly affected by soil varieties. In our studies, soil fertility was high in all selected areas. For example, in mountain-meadow-steppe soils, fertility is greater than in leached chernozems and in southern chernozems. Accordingly, the quantitative morphological indicators of different cenopopulation were different. In plant conservation, there is a strong relationship between soil and vegetation for the maintenance of biodiversity (Priscyla et al. 2016). It has been observed that the diversity and soil structure influence the life cycle of *A. Tianschanica*. Species composition can change, forming groups of indicator species for each, with inconspicuous differences in species richness (Assis et al. 2011; Guerra et al. 2013). The relationship between species, populations and ecosystems enhances resilience by providing sources of seeds, nutrients and biological heritage. Combining phenotypic plasticity, species range changes, and microevolution constitutes adaptive capability.Bernhardt and Leslie 2013).

In conclusion, information about the current state of cenopopulations of rare species is essential to know the prospects for their existence and to develop appropriate protection measures. In terms of age composition, the state of *A. tianschanica* cenopopulations is estimated as relatively satisfactory but demonstrates a low level of abundance and density. It has been established that the state of the cenopopulations of the species in the studied regions is affected by soil conditions and environmental factors.

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