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Ontogenetic Structure of Coenopopulations of *Tulipa kaufmanniana* Regel (Liliaceae) in Uzbekistan

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Abstract Wild tulip species of the Western Tien-Shan have attracted attention of scientists and people, loving the beauties of nature, from the immemorial. The article discusses the current state of *Tulipa kaufmanniana* Regel coenopopulations located in the Uzbek part of the Western Tien Shan (Uzbekistan). *Tulipa kaufmanniana* has a wider altitudinal spread. It is found in the upper sub-mountain regions as far as the upland on all ranges of the western Tien-Shan. It shows unique polymorphism in nature. This species is endemic to the western Tien Shan. The studies were carried out on the Chatkal, Ugam, Kurama ridges of the Western Tien Shan. During 2021-2023 years, the current state of 8 coenopopulations (CP) was assessed on the basis of organismal and population characteristics. The age structure of the species was studied with division into 5 stages (*juvenile*, *immature*, *virginal*, *generative*, and *senile*). According to the demographic indicators of coenopopulations, the density per 1 m^2 was 0.85–16.65 individuals, and the ecological density was 2.12–18.07. Classification of age groups and their effectiveness according to A. A. Uranov and O. S. Smirnova (1969) shows that the types of coenopopulations are transient (CP 1, 3, 4, 5, 6, 8) and mature (CP 2, 7). It blooms from the end of March through the beginning of May, and bears fruit in June-July. Limiting factors: picking of flowers and economic use of territory. Measures of protection: protected in the Chatkal and Ugam-Chatkal state biosphere reserves and the Ugam-Chatkal national park. It is necessary to control the state of populations, to forbid picking of flowers, and to search for ornamental forms and their reproduction in cultivation. Wild tulips differ from cultured varieties by resistance to diseases as well as drought and frost-tolerance. However, our love of tulips is unable to prevent reduction of size and area of tulip population which decrease rapidly every year. The results obtained are used to monitor and preserve rare plants.

Keywords *Tulipa kaufmanniana* Regel, Endemic, Coenopopulation, Demographic Structure, Western Tien Shan, Uzbekistan

1. Introduction

The genus *Tulipa* L. is one of the largest genera in the family Liliaceae Juss. It has a huge habitat that extends across the all of Eurasia, from Portugal and northern regions of Africa on the west to the southern Japan islands on the east [1].

In recent years, climate change and temperature patterns, vegetation population, and phenology have been affected [2-4]. The assessment of the state of rare and endangered species in many countries of the world is based on the study of the current state of their coenotic populations [5-8]. At the same time, special attention is paid to the determination

of their ontogenetic structure and the analysis of organismal and population characteristics [9-12]. The set of traits is formed in the ecological-phytocenotic optimum of the species and is important for the preservation of natural populations. To assess the state of coenopopulations of rare and endemic plants, it is important to evaluate the age index, efficiency index, and delta-omega analysis [11]. In recent years, there has been a negative impact of the transformation of plants in arid regions on the organismal and population characteristics of coenopopulations. Species of the Tulipaceae family, common in the Western Tien Shan, are no exception to such processes [13, 14]. These species include *Tulipa kaufmanniana* Regel [14].

Central Asia is the center of origin of the genus *Tulipa* L. and the region with the highest species diversity [14]. Here, the presence of four foci of the historical composition of the formation of species of this genus was revealed. One of them is located in the deserts of Central Asia, and the other in the highlands [15-17]. The Pamir-Alai Range is recognized as the third focus, and the fourth is in the hills and mountains of the Western Tien Shan and stands out for its uniqueness [18]. Among scientists there are different views on the origin of the genus. According to V.I. Taliev [19] and Z.P. Bochantseva [18], the genus *Tulipa* L. originated on the shores of the Tethys, an ancient sea in the center of modern Eurasia. Tulips that grew on the shores of the ancient sea were distinguished by a large number of flowers and large leaves. As a result of the retreat of the sea, tulips, like many plants, have adapted to adverse mountain conditions, lost "extra" leaves and reduced the number of flowers.

T. kaufmanniana Regel is also considered the wild relative of cultural plants. Central Asia is famous as a center of diversity of apples, pears, onion, tulips, spinach, carrot, and other crops. Therefore, Vavilov defined Central Asia as one of the original centers of cultivated plants in different stages [20, 21]. The plants in question have been the subject of much research on their populations for several years [22-25]. Coenopopulations of *T. kaufmanniana* Regel have not been studied.

2. Materials and Methods

Tulipa kaufmanniana grows singly or in small groups in the basins (Table 1) of the rivers Pskom, Ugam, Akhangaron, Chatkal (Uzbekistan, Kazakhstan, Kyrgyzstan) (Figure 1). It grows on stony soils from foothills to highlands [18]. Due to the fact that this species has the most polymorphic properties, Dutch breeders have developed many varieties based on it. This species is one of the sharply declining species in the Western Tien Shan [26, 27]. The plant blooms in March-April. This species is included in the Red Book of the Republic of Uzbekistan under the status of 3 – reducing species [27].

Table 1. Location of coenopopulations

№	Latitude	Longitude	h
1	41,261199	69,810075	1233
2	41,523963	70,026421	1658
3	41,656101	69,757669	1151
4	41,695445	69,946044	872
5	41,643577	69,746428	973
6	41,079035	70,301311	1120
7	41,115961	70,501712	1840
8	41,557762	70,104795	929

In phytocoenoses with the participation of the species, geobotanical descriptions were carried out according to generally accepted methods on areas of 100 m^2 [28, 29]. When identifying species and their life forms, a 10-volume Key to Plants of Central Asia [30] was used.

Plant names are given in accordance with the online databases Plants of the World Online [31] and Global Biodiversity Information Facility (GBIF) [32]. The structure of coenopopulations has been studied by conventional methods. For this, at least 3 transects were identified in each coenopopulation of the species [33]. The ontogenetic structure of coenopopulations is determined by the ratio of different ontogenetic states in the coenopopulation. Individuals of a species are taken as a unit.

The description of the population structure was based on the concept of the characteristic ontogenetic spectrum of the species [34]. According to the nature of the distribution, ontogenetic groups were divided into 4 spectra: left-sided, centered, right-sided and bimodal. The characteristic spectrum of a species was determined by its biological properties. Descriptions of coenopopulations were carried out according to the classifications of A.A. Uranov and O.V. Smirnova [35]. The species distribution map was compiled using ArcGIS 10.6.1. When organizing living collections of species, planting material was planted on a specially designated site in the Tashkent Botanical Garden. A living collection of plants has also been established in this regard in the Botanical Garden. In recent years, a lot of effective research has been carried out in this direction [36-45].

Figure 1. *Tulipa kaufmanniana* in different coenopopulations (CP)

During the study, 8 coenopopulations were identified with the participation of *T. kaufmanniana*. These coenopopulations have been isolated from a variety of phytocoenotic-ecological environments. Tulips grow in different environmental conditions, from foothills up to snow-covered mountain tops, decorated by their multi-color region nature and bringing the people beauty and joy, especially in spring, when there is filled of single or grouped flowers or various tulip species in various colors: red, bright-yellow, yellow and red, red with blue border, fire-red etc. One may say surely, that wild tulips of Western Tien-Shan are the most beautiful plants among all the species of gild decorating grasses of flora of the Central Asia and bordering countries (Figure 2).

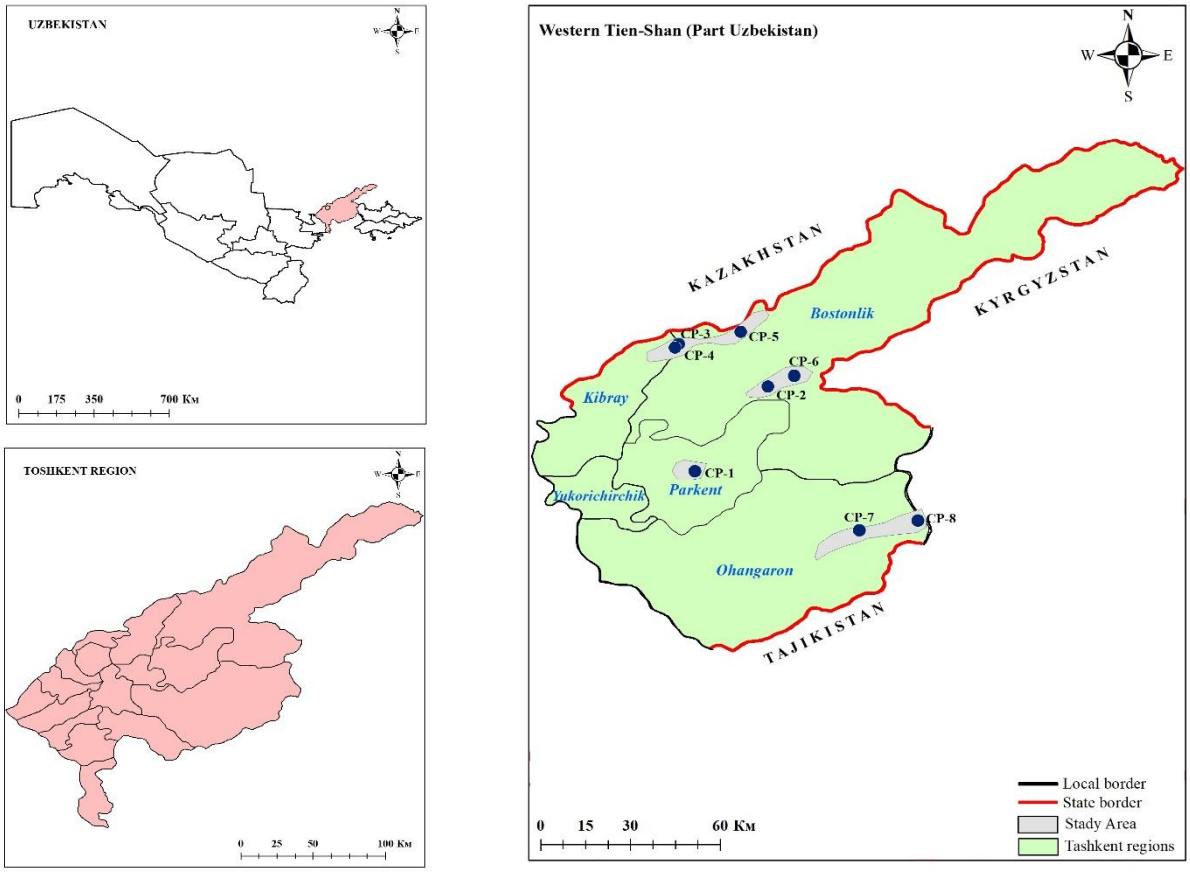

Figure 2. Map of the study area

3. Results and Discussion

Research has been conducted in a variety of environmental environments. In recent years, there has been much international research [40, 41]. In these regions, the influence of various anthropogenic factors was observed. In these coenopopulations, 61 species of higher plants have been identified. The first coenopopulation is located on the hills around the village of Ulugbek, Parkent district, Tashkent region (N 41.261199 E 69.810075, h-1233). The vegetation of the territory is represented by the eremurus-bush community. The soil consists of large gravels. This coenopopulation is dominated by *Prunus amygdalus* and *Eremurus regelii*.

The second coenopopulation is located in the Chimgansay of the Bostanlyk district (N 41.523963, E 70.026420 h-1658). The vegetation of the territory is represented by a forb-bush-juniper community. The soil is shallow, stony-gravelly. The degree of vegetation cover of the soil is 45-50%. *Juniperus seravschanica* and *Prangos pabularia* dominate here.

The third coenopopulation is located on the territory of the Aktash sanatorium, Bostanlyk district (N 41.656101 E 69.757669, h-1151). The vegetation of the territory is represented by a forb-almond community. The degree of vegetation cover of the soil is 20-25%. The soil consists of steep gravel beds. The botanical composition is not very rich. Only 11 species were identified in this coenopopulation. The dominant species are *Prunus amygdalus* and *Rumex pamiricus*.

The fourth coenopopulation is located in the Aktash (Kengsay) region (N 41.643577, E 69.746428 h-973). The vegetation of the territory is represented by a forb-bush community. The soil is rocky. The degree of vegetation cover of the soil is 35-40%. The dominant species in this coenopopulation are *Salix blakii* and *Ephedra equisetina*.

The fifth coenopopulation is located on a rocky-rubbly slope near the village of Khumson, Bostanlyk region (N 41.695445, E 69.946044 h-872). The vegetation of the territory is represented by a forb-eremurus community. The main dominant species is *Eremurus regelii*. The degree of vegetation cover of the soil is 15-20%.

The sixth coenopopulation is located on the southern slopes surrounding the Obirakhmat area (N 41.557762, E 70.104795, h-929). The vegetation of the territory is represented by a forb-bush community. The degree of vegetation cover of the soil is 20-25%. The botanical composition of the region is not very rich. The number of species is 12. The dominant species are *Prunus amygdalus* and *Carex melanantha*.

The seventh coenopopulation is located on the territory of Airisay, Akhangaron district, Tashkent region (N 41079035, E 70301311, h-1120). The vegetation of the territory is represented by ferula-eremurus community. In

this coenopopulation, 18 species were identified. The soil consists of large gravels. The degree of vegetation cover of the soil is 35-40%. The dominant species are *Prunus petunnikowii* and *Ferula angreni*.

The eighth coenopopulation is located on the territory of Duansay of the Kamchik pass (N 41.115961, E 70.501712 h-1840). The vegetation of the territory is represented by a ferula-bush community. The soil is coarse-grained stones. In this coenopopulation, 14 species of higher plants were identified. The degree of vegetation cover of the soil is 22-25%. The dominant species are *Spiraea hypericifolia* and *Eremurus regelii* (Table 2).

Table 2. Floristic composition of coenopopulations of *Tulipa kaufmanniana*

Species name	Life form	Abundance, %							
		1	2	3	4	5	6	7	8
Juniperus seravschanica Kom.	Tree	+	3	-	-	-	-	-	-
Prunus amygdalus Batsch	Tree	3	-	2	-	-	4	-	1
Salix blakii Goerz	Tree	-	-	-	+	-	-	-	-
Ephedra equisetina Bunge	Bush	-	1	-	+	-	-	-	-
Prunus petunnikowii (Litv.) Rehder	Bush	-	-	-	-	1	-	+	-
Prunus spinosissima (Bunge) Franch.	Bush	-	+	-	-	-	+	-	4
Rosa canina L.	Bush	-	-	-	3	-	-	-	-
Rosa webbiana Wall.	Bush	-	-	-	2	-	-	-	-
Spiraea hypericifolia L.	Bush	-	-	+	-	-	-	-	1
Ziziphora clinopodioides Lam.	Shrub	-	-	-	+	-	-	-	-
Ziziphora pedicellata Pazij & Vved.	Shrub	4	-	-	-	-	-	-	-
Allium eriocoleum Vved.	Perennial	-	-	-	-	1	-	-	-
Allium aflatunense B. Fedtsch.	Perennial	-	-	+	-	+	-	-	-
Allium atrosanguineum var. *fedschenkoanum* (Regel) G.H.Zhu & Turland	Perennial	-	+	-	-	-	-	-	-
Allium griffithianum Boiss.	Perennial	-	1	-	-	-	+	+	-
Anemone petiolulosa Juz.	Perennial	-	1	+	-	-	1	-	+
Anemone tschernaewii Regel	Perennial	-	+	-	+	-	-	-	-
Arctium dolichophyllum (Kult.) S.López Romasch., Susanna & N.Garcia	Perennial	-	+	-	-	-	-	-	+
Bupleurum exaltatum M.Bieb.	Perennial	-	-	-	-	-	-	+	-
Calamagrostis epigejos (L.) Roth	Perennial	-	+	-	-	-	-	-	-
Carex melanantha C.A.Mey.	Perennial	-	1	-	-	-	+	+	-
Cousinia angrenii Juz.	Perennial	-	-	-	-	-	-	+	-
Crocus alatavicus Regel & Semen.	Perennial	-	-	-	+	-	-	-	-
Elwendia angreni (Korovin) Pimenov & Kljuykov	Perennial	-	-	-	-	-	-	+	-
Eremurus fuscus (O.Fedtsch.) Vved.	Perennial	+	-	-	-	-	-	-	+
Eremurus regelii Vved.	Perennial	2	+	-	1	1	+	-	+
Eremurus robustus (Regel) Regel	Perennial	+	+	+	-	-	2	-	-
Ferula angreni Korovin	Perennial	-	-	-	-	-	-	+	-
Ferula diversivittata Regel &Schmalh.	Perennial	-	-	+	-	-	+	-	-
Ferula prangifolia Korovin	Perennial	-	+	-	-	-	-	-	-
Gagea chomutovae (Pascher) Pascher	Perennial	-	-	-	-	+	+	-	-
Gagea dschungarica Regel	Perennial	-	-	-	-	+	-	-	-

Table 2 Continued

Geranium linearilobum DC.	Perennial	-	-	-	-	-	-	+	-
Iris halophila var. *sogdiana* (Bunge) Skeels	Perennial	-	-	-	-	+	-	-	-
Iris korolkowii Regel	Perennial	-	-	-	-	+	-	-	-
Ixiolirion tataricum (Pall.) Schult. & Schult.f.	Perennial	-	-	1	+	+	1	1	-
Mediasia macrophylla (Regel et Schmalh.) Pimenov	Perennial	-	-	-	-	-	2	-	-
Mentha arvensis L.	Perennial	-	-	+	-	-	-	+	-
Mentha longifolia var. *asiatica* (Boriss.) Rech.f.	Perennial	-	+	-	+	+	-	-	+
Origanum vulgare subsp. *gracile* (K.Koch) Ietsw.	Perennial	3	-	-	-	-	-	-	-
Phleum alpinum L.	Perennial	-	+	-	-	-	-	-	-
Phlomis regelii Popov	Perennial	-	-	-	-	+	-	-	-
Phlomis sewerzowii Regel	Perennial	-	-	+	-	+	-	-	-
Phlomoides ostrowskiana (Regel) Adylov, Kamelin & Makhm.	Perennial	-	-	-	-	-	-	+	-
Phragmites australis (Cav.) Trin. ex Steud.	Perennial	-	+	-	+	-	-	-	-
Poa bulbosa L.	Perennial	+	-	+	-	-	+	-	+
Prangos pabularia Lindl.	Perennial	-	+	-	-	-	-	-	-
Rhodiola kirilowii (Regel) Maxim.	Perennial	-	-	-	+	-	-	-	+
Rumex pamiricus Rech.fill.	Perennial	-	-	+	-	-	-	-	-
Salvia sclarea L.	Perennial	-	-	-	-	1	2	-	-
Salvia tianschanica Machm.	Perennial	-	-	-	-	+	-	-	-
Taraxacum juzepczukii Schischk.	Perennial	-	-	-	-	+	-	-	-
Taraxacum officinale Weber ex F.H.Wigg.	Perennial	-	-	+	-	-	+	+	-
Tulipa bifloriformis Vved.	Perennial	+	+	-	-	+	+	-	-
Tulipa kaufmanniana Regel	Perennial	1	2	1	1	2	2	1	2
Tulipa korolkowii Regel	Perennial	-	-	-	-	-	-	+	+
Ungernia sewerzowii (Regel) B.Fedtsch.	Perennial	-	+	-	-	-	-	-	-
Daucus carota L.	Biennial	-	+	-	-	+	-	+	-
Erodium cicutarium (L.) L'Hér.	Annual	-	-	-	+	-	-	+	-
Papaver pavoninum Schrenk	Annual	+	+	-	-	-	+	+	+
Turgenia latifolia (L.) Hoffm.	Annual	-	+	-	-	+	-	+	+

The study of coenopopulations of *T. kaufmanniana* revealed two types of ontogenetic structure spectra: left-sided and centered spectra.

The left-sided spectrum is characteristic of representatives of the genus and was found in 62.5% of coenopopulations (CP 1, 3, 4, 5, 6, 8). In the left-hand spectrum, there were individuals from different ontogenetic states in various ratios. In addition to a number of ecological and phytocenotic factors, a greater number of individuals belonging to young fractions in coenopopulations were also associated with the biology of the species. The fact is that, like other representatives of the genus, *T. kaufmanniana* is a species with a high seed yield. According to the analysis of the obtained data, 220-450 seeds were formed in each middle-aged individual, which, in turn, had a direct impact on the restoration of the number of young fractions in the coenopopulation. Of course, the high germination of plant seeds in the field (25-30%) was also associated with this. In coenopopulations specific for the left-sided ontogenetic spectrum, a high proportion of juvenile and virginal individuals was noted (Figure 3).

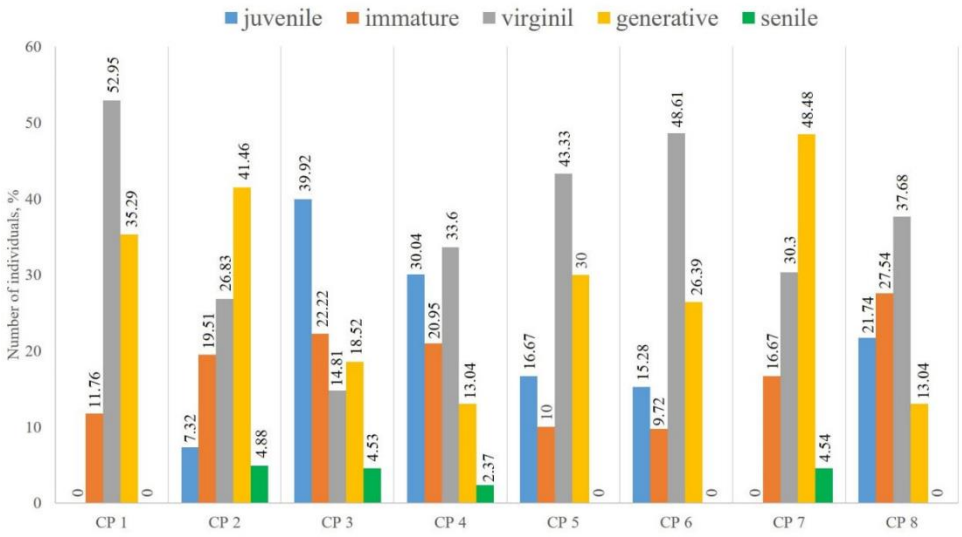

Figure 3. Ontogenetic structure of coenopopulations of *Tulipa kaufmanniana*

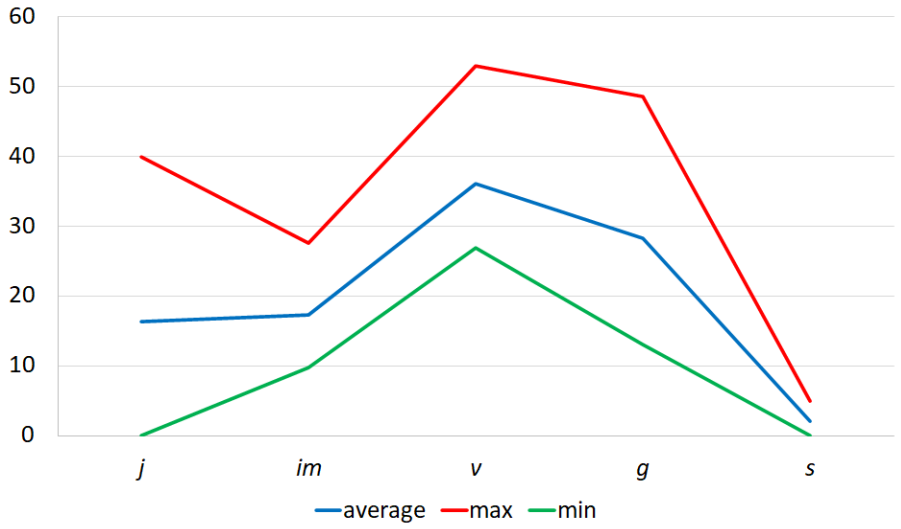

Figure 4. Average value of ontogenetic structure of coenopopulations of *Tulipa kaufmanniana*

The 2nd and 7th coenopopulations have a centered spectrum; the proportion of generative individuals in them was about 41.46–48.48%. The sharp increase in the proportion of generative individuals in the coenopopulation is partly due to the fact that this period of ontogeny lasts much longer than other periods. In addition, as a result of floods that occur in these coenopopulations in the spring, large plants are more likely to survive. Young leaves of the *T. kaufmanniana* are a favorite food of sheep and goats during this period, and young plants are trampled underfoot, which in turn also leads to the centralization of the coenopopulation spectrum.

In addition to the above factors, the recreational process also has a significant impact on the centralization of the spectra of the 2nd and 7th coenopopulations. These coenopopulations are located near settlements and on the side of busy roads.

In early spring, locals prefer to relax around the tulips and at the same time make bouquets of large *T. kaufmanniana* flowers. This, in turn, adversely affects the seed stock of *T. kaufmanniana* in the soil and leads to a sharp decrease in the number of young individuals in the coenopopulation. As a result of the analysis of ontogenetic structures in various ecological and phytocenotic conditions, the main ontogenetic structure of *T. kaufmanniana* was determined. It has a peak in virginal (33.5%) and generative (29.2%) individuals. The fact that the viability of these individuals is high, and their average value is greater than others indicates the relative stability of the studied coenopopulations. The average value of the ontogenetic structure of coenopopulations shows that they have a normal ratio of juvenile and immature individuals (Figure 4).

Table 3. Demographic indexes of coenopopulations of *Tulipa kaufmanniana*

CP No	Total number of individuals, pcs	Density of individuals, pcs ($1\ m^2$)	Ecological density, P_{ecol} ($1\ m^2$)	Recovery index, I_r	Aging index, I_a	Type of CP
CP 1	17	0.85	2.12	0.54	0.00	transient
CP 2	41	2.05	3.72	0.70	0.05	mature
CP 3	243	12.10	15.10	0.22	0.04	transient
CP 4	253	12.65	18.07	0.14	0.02	transient
CP 5	30	1.50	3.33	0.42	0.00	transient
CP 6	72	3.60	6.54	0.35	0.00	transient
CP 7	66	3.30	5.70	1.03	0.04	mature
CP 8	69	3.45	5.30	0.14	0.00	transient

A sharp difference in the total number of individuals in coenopopulations from each other was noted. In particular, if the highest number was 253 individuals, then the lowest was 17. The density of individuals per 1 m^2 in relation to the total number was 0.85-12.1. Their ecological density ranged from 2.12 to 18.07.

The indexes of recovery and aging of *T. kaufmanniana* coenopopulations were also studied. It has been established that the species recovery index is 0.14-1.03, and the aging index is 0-0.05. The fact that the aging index in the studied coenopopulations has a value close to zero (0-0.05) is explained by the absence or a small number of individuals in the senile period. This is due to the fact that most of the tubers die in the generative period, and the senile period is very short (Table 3).

4. Conclusions

The vast majority of *T. kaufmanniana* CPs were normal and represented by a full range of age groups. The lack of a senile age group observed in some cases is explained by the species biology and the successive state of CPs.

An analysis of the ontogenetic structure of *T. kaufmanniana* showed that most of the coenopopulations of this species belong to the transient (CP 1, 3, 4, 5, 6, 8) and mature (CP 2, 7) types. The transient type of most coenopopulations was due to the high potential seed productivity of the representatives of the species. Under natural conditions, seed germination was 25-35%. In the reduction of individuals of the species in the natural range, the role of anthropogenic influences is great. During the study of *T. kaufmanniana* coenopopulations along the roads in the area of the Kamchik pass, we witnessed the collection of plants in large numbers by passing people.

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Data Availability Statement

Data and materials supporting the results or analyses presented in this study freely available. The name of dataset is ‘Tulipa kaufmanniana’ which is assessable via DOI: 10.17632/4mwp4r7kh5.1

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