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The structure of the populations of *Crambe tataria* Sebeók in the Aktobe Region

Abstract: *Crambe tataria* Sebeók is one from four species of genus *Crambe*, which grow on the territory of Kazakhstan. This species is listed in Red Data Book of Kazakhstan as rare endangered species, and its natural habitats are chalk areas of west part of the country. The structure of seven populations of *Crambe tataria* was studied in the Aktobe Region. The optimum habitat conditions for this species are northern and northeast slopes of chalk uplands, chestnut and light-chestnut soils. In unfavorable conditions of summits and southern slopes of lime uplands, *C. tataria* can form invasive-regressive populations with the prevalence of virgin plants. The variation of the structure of the populations does not lead to a decrease in their resistance, which highlights high plasticity of the species within chalk uplands.

Keywords: *Crambe tataria*, rare endangered species, population, Aktobe Region, population structure, population resistance.

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Introduction. *Crambe tataria* Sebeók is a rare South European Mediterranean species that grows in the south of Russia, Austria, Chech Republic, Slovakia, Hungary, Romania, Bulgaria, and Turkey. In Russia, it grows in the steppe area, south Pre-Urals, submountain region of the Caucasus, and the Crimea. In the northern part of the areal, the species does not spread northward beyond the southern part of the forest-steppe zone. On the east, the spreading is limited by the Ural Mountains range, on the south - by the Caucasus Mountains [1-6]. In the southwest part of Europe, the species grows in the Ukraine, Moldova, Hungary, and south of Austria. As a stranger species, it can be sporadically found in the south of Western Siberia [7], Chelyabinsk Oblast [8] and Omsk [9] Oblast. There is evidence of it being found in Moscow Oblast [10] and south of Italy, where it appeared in 9th-10th centuries during the Huns invasion [11]. In Kazakhstan, it primarily spreads on chalk areas of west Kazakhstan [12-15] (Figure 1).

C. tataria is a rare, endangered species that is included in the Directive on Plant Protection [16]. It is a species included in the Red List of the endangered species of the International Union for Conservation of Nature and Natural Resources and Red List of Kazakhstan [17].

The flora of chalk areas in west Kazakhstan is unique and well researched. It includes a lot of rare species [18, 19]. Five types of species are listed in the Red List of Kazakhstan [17]. Presently, there is an increased interest in researching the population structure of rare plants growing on chalk areas [20].

The age-related structure is one of the significant features of the population because it provides the population system capacity for self-maintenance and determines its stability [21].

The study of the age-related (ontogenetic) structure of the populations of rare species is necessary for evaluation of the plants status and development of protective measures. Despite the actual rarity of *C. tataria*, its population structure is understudied.

The research was aimed to study the population structure of a rare and endangered species *Crambe tataria* Sebeók under the conditions of Aktobe Region. The main task of the study was to identify the population structure of the species.

Рисунок 1 – **Figure 1. *C. tataria* on a chalk slope**

Materials and Methods. The study was performed on the territory of the Aktobe Region. The floristic description was made on the areas with a high density of *Crambe tataria*. In total, seven populations (P) of *C. tataria* were studied.

P-1: 20 km westwards of Akrab Village, 220 m above the sea level, 50 ° 51836' N, 54 ° 93359' W of the chalk bald peak. The soils are not fully developed, lack humus horizon, and are covered with a layer of small chalk lumps. The area of the population is 1000 m ^{2}; total projective cover (TPC) is 10%, TPC of *C. tataria* is 1%. The population includes 22 species. The most widespread species in the canopy are *Anabasis truncata* (Schrenk) Bunge, *Anthemis trotzkiana* Claus ex Bunge, *Kraschenninnikovia ceratoides* (L.) Gueldenst., *Matthiola superba* Conti, *Poa bulbosa* L., and *Seseli eriocephalum* (Pall. ex Spreng.) Schischk.

P-2: 20 km westwards of Akrab Village, 226 m above the sea level, 50 ° 51792' N, 54 ° 32769' W, southeastern slopes of chalk peaks with a slope of 20 ° . The soils are not fully developed, lack humus horizon, and are covered with a layer of small chalk lumps. The area of the population is 300 m ^{2}, TPC is 15%, TPC of C. tataria is 1%, the population includes only 20 species. The most widespread species in the canopy are *Anabasis truncata* (Schrenk) Bunge, *Anthemis trotzkiana* Claus ex Bunge, *Centaurea sibirica* L., *Echinops meyeri* (DC.) Iljin, *Nanophyton erinaceum* (Pall.) Bunge, *Rindera tetraspis* Pall., and *Rhammatophyllum pachyrhizum* (Kar. & Kir.) O.E.Schulz.

P-3: 40 km to Wil Village, bald peaks of Akshatau, 160 m above the sea level, 49 ° 93420' N, 54 ° 51433' W, eastern slope of chalk bald peaks, valley, 20 ° slope. The soils are fully developed, light chestnut, mellow loamy with inclusions of lumps of pure chalks. The area of the population is 1000 m ^{2}, TPC is 30%, TPC of *C. tataria* is 5%. The population includes 38 species. The most widespread species in the canopy are *Allium decipiens* Fisch. ex Schult. & Schult. f., *Alyssum tortuosum* Waldst. et Kit. ex Willd., *Anthemis trotzkiana* Claus ex Bunge, *Artemisia aralensis* Krasch., *A.salsaloides* Willd., *Astragalus aktubiensis* Knjasev, *A. varius* S.G. Gmel, *Ferula caspica* M.Bieb., *Limonium caspium* (Willd.) Gams, and *Taraxacum turgaicum* Schischk.

P-4: 40 km to Wil Village, bald peaks of Akshatau, 143 above the sea level, 49 ° 33529' N, 54 ° 50869' W, valley occupied by brushwood along the shores of temporary water flow. The soils are chestnut, fully developed, loamy. The area of the population is 1000 m ^{2}, TPC is 100%, TPC of *C. tataria* is 5%. The population includes 33 species. The most widespread species in the canopy are *Achillea nobilis* L., *Agropyron cristatum* (L.) Beauv., *Camphorosma monspeliaca* L., *Centaurea kasakorum* Iljin, *Echinops meyeri* L., *Ephedra distachya* L., *Euphorbia microcarpa* Prokh., *Ranunculus polyrhizos* Steph., *Rhinopetalum karelinii* Fisch. ex Alexander, *Scorzonera tuberosa* Pall.,

Tanacetum santolina C.Winkl., *Tragopogon ruber* S.G.Gmel., and *Tulipa biebersteiniana* Schult. & Schult. f.

P-5: 15 km northeastwards of Akshatau Village, 126 m above the sea level, 49 ° 33475' N, 54 ° 51334' W, northern slopes of chalk bald peaks. The soils are light chestnut, fully developed with numerous chalk inclusions. The area of the population is 2500 m^2, TPC is 30%, TPC of C. tataria is 3%. The area of the population includes 32 species. The most widespread species in the canopy are *Achillea micrantha* Willd., *A. millefolium* L., *Adonis wolgensis* Steven, *Artemisia marschalliana* Spreng., *Bromopsis inermis* (Leyss.) Holub, *Chaerophyllum prescottii* DC., *Chorispora tenella* (Pall.) DC., and *Galatella villosa* (L.) Rchb. f.

P-6: 15 km northeastward of Akshatau Village, Mukashtau mountains (a complex of chalk small Akshatau mountains), 192 m above the sea level, 49 ° 43102' N, 54 ° 59277' W, the southwestern slope of chalk bold peaks. The soils are chestnut, not fully developed with numerous chalk inclusions. The area of the population is 200 m^2, TPC is 20%, TPC of C. tataria is 3%. The area of the population includes 29 species. The most widespread species in the canopy are *Allium inderiense* Fisch. ex Bunge, *Anthemis trotzkiana* Claus ex Bunge, *Artemisia lerchiana* Weber, *Echinops meyeri*, *Ephedra lomatolepis* Schrenk, *Glycyrrhiza korshinskyi*, *Onosma simplicissima* L., *Rhammatophyllum pachyrhizum* (Kar. & Kir.) O.E.Schulz, *Scorzonera pubescens* DC., *Seseli eriocephalum* (Pall. ex Spreng.) Schischk, and *Zygophyllum pinnatum* Cham.

P-7: 15 km northeastward of Akshatau Village, Mukashtau mountains (complex of chalk small Akshatau mountains), 125 m above the sea level, 49 ° 42394' N, 54 ° 58876' W, steep norther slope of 30 ° on chalk bald peaks. The soils are chestnut, fully developed, loamy, and loose with numerous chalk lumps inclusions. The area of the population is 3000 m^2, TPC is 35%, TPC of *C. tataria* is 5%. The area of the population includes 26 species. The most widespread species in the canopy are *Agropyron cristatum* (L.) Beauv., *Astragalus testiculatus* Pall., *Caragana laeta* Kom., *Centaurea kasakorum* Iljin, *Goldbachia laevigata* (M. Bieb.) DC., *Nepeta cataria* L., *Serratula gmelinii* Tausch., and *Verbascum phoeniceum* L.

The borders of the population were defined by generally accepted methods [21]. The area of the population was identified using JPS system. Floristic descriptions were performed by a standard method in the area of 100 m^2. The authors evaluated the species composition, and general and individual projecting cover of each species. Twenty model plots (1 m^2) were set inside the population area. A *C. tataria* species of any age was used as a counting unit. Age-related conditions of plants were defined according to the methodical recommendations [21-23]. The authors studied the structures of the population according to the Program and method of observation of plant populations [24]. A type of population was identified by Rabotnov's method [22] and the classification of "delta-omega" [25].

The index of age population (Δ) was calculated by the formula:

$$\Delta = \sum K_i m_i / \sum K_i,$$

where $\sum K_i$ is the sum of plants in all age-related conditions, m_i is the age-related condition of species [23]. Efficiency index (ω) was calculated by the formula:

$$\omega = \sum p_i e_i,$$

where $p_i = n_i/n$ is the share of plants of i^{th} condition in the specified population, n_i is the absolute number of plants of i^{th} condition, $n = \sum n_i$ is the total amount of plants, e_i - energetic effectiveness [25].

Population recovery index (I) is calculated by the formula:

$$I = \sum j \to v / \sum g1 \to g3,$$

where $\sum j \to v$ is the sum of plants in all age-related conditions of the pre-generative period, $\sum g1 \to g3$ is the sum of plants in all age-related conditions of the generative period [26].

Results and Discussion. By environmental condition, *C. tataria's* habitats can be divided into favorable and unfavorable ones. Favorable habitat conditions are observed in the populations P-3,

P-4, P-5, P-7. As a rule, they are located on the northeast and north slopes or in the valley and have fully developed loose soil. Unfavorable habitat conditions are observed in the populations P-1, P-2 and P-6. These habitats are located on the peaks, south, or southwest slopes and have not fully developed soils with high water permeability, which are primarily alkaline.

The best total projective cover (TPC) was observed in the valley along the shores of the water flow (100%). For *C. tataria*, this is an uncommon place for the habitat. Its species spread in narrow lines along the swarded areas of steppe vegetation. Its share in the projective cover is 5%. In the rest of habitats, TPC varies from 10% to 35%. The biggest share of *C. tataria* in TPC was observed in P-3 (17%) and P-7 (14%). In the rest population, it occupies 6%-10% (Table 1).

The spread of the species on chalk uplands is uneven. The largest populations occupy 2500 - 3000 m^2 and are found on north and northeast slopes that are more protected from direct solar isolation and have more developed soil horizon. Single species that did not form populations were found on chalk uplands in the area of diluvial outwash. The highest density of species (more than 100 pcs/100 m^2) was observed in the populations located in more favorable environmental conditions (P-3 and P-4), except for P-1, due to a higher number of plants in a virgin condition.

Table 1 - Features of *C. tataria* populations

Parameter	P-1	P-2	P-3	P-4	P-5	P-6	P-7
Projective cover,%	10	15	30	100	30	20	35
Projective cover, *C. tataria* %	1	1	5	5	3	3	5
Population area, m^2	1000	300	1000	1000	2500	200	3000
Species density, pcs/100 m^2	140	10	150	115	98	40	50
Number of reproductive species in the population, pcs	530	0	200	300	1650	20	1800
Age index in the population (Δ)	0.18	0.15	0.11	0.16	0.31	0.13	0.15
Efficiency index (ω)	0.50	0.47	0.34	0.46	0.70	0.42	0.55
Population recovery index (I)	1.64	0	6.50	2.83	0.48	3.00	0.11

Population-demographic studies focus on the spectrum of age-related (ontogenetic) conditions that represents the intra-population distribution of species depending on the environmental conditions [27]. A certain ratio of the age-related groups provides a precise understanding of a general condition of a population, its capability of self-maintenance, and prospectives of its development.

Age-related spectra of the studied populations are presented in Figure 2. None of the populations included species that could be classified as senile or obsolescent. The types of age-related spectra are primarily left-sided, except for P-5 and P-7 that are right-sided. P-2 has a bimodal distribution with its maximum values in immature and young generative species.

C. tataria, studied by the age-related spectra, are classified as normal because they are capable of self-maintaining by the seed pathway and do not depend on stranger seeds. Nearly all the populations, except for P-7, are invasive because they have pre-generative species prevailing. Usually, such populations are characterized as young and expanding ones [28]. But in case of the population of *C. tataria*, this is associated with unfavorable development conditions. Probably, it is explained by the fact that plants that grow on the peaks, south and southwest slopes start to wither in virgin and even immature conditions not reaching the generative stage. Those populations are called invasive-regressive [29]. They can exist for a long time provided a population receives stranger seeds from outside. Taking into account that *C. tataria* has a tumbleweed lifeform, seeds can be obtained from other populations.

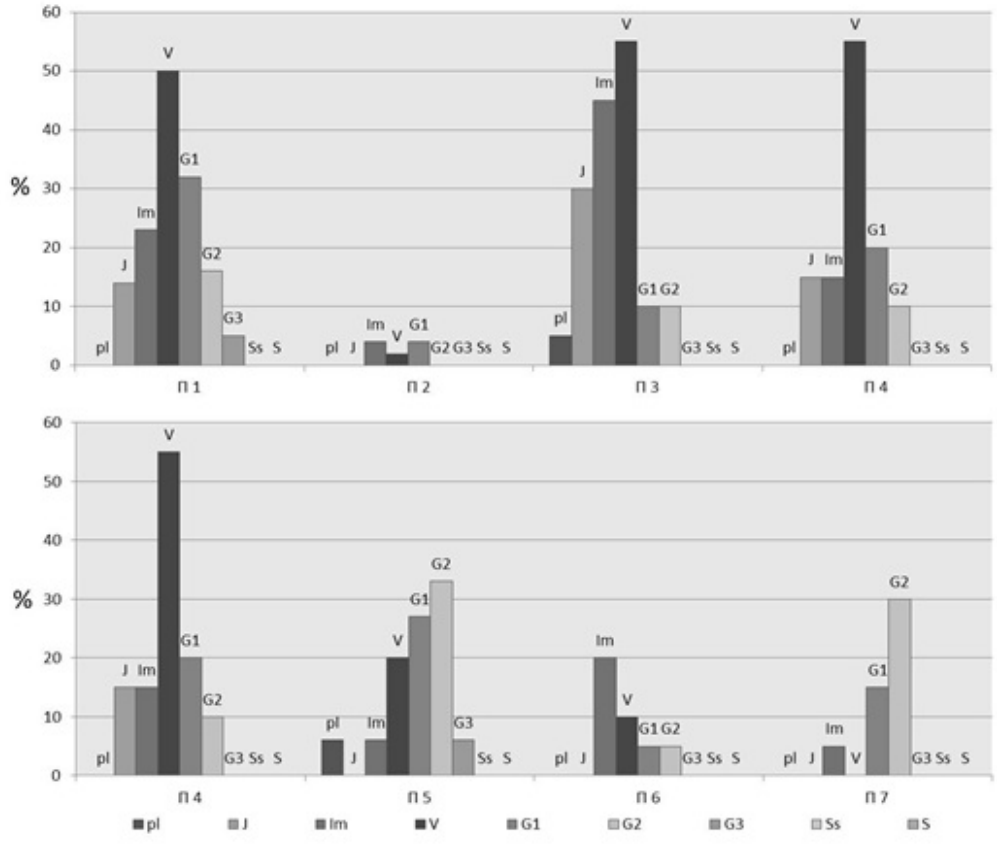

Рисунок 2 – **Figure 2. Age-related structure of *C. tataria* populations**

According to the classification of "delta-omega", nearly all the (P) populations are young, except for P-5 that is young and close to maturing according to the Zhivotovsky's classification [25] (Figure 2). Efficiency index (ω) is <0.6 as in young populations. Only in P-7, it is equal to 0.7, which makes it closer to a transition type. The index of population recovery (I) is normally >1, except for P-2, P-5 and P-7, where it is <1, and in P-2, it is 0 because generative species were not revealed (Table 1).

Conclusion. The analysis of the age-related structure of *C. tataria* population showed that the interpretation of a certain ontogenetic spectrum should be performed with the account and understanding of the environment of *C. tataria* habitat. The studies showed that the optimum habitat for this species is chestnut and light chestnut soil that are fully developed and have chalk inclusions. On the other hand, *C. tataria* can form invasive-regressive populations in extreme soil and ecological conditions on the peaks and south slopes of chalk uplands. The variance of the population structure does not lead to a decrease in the resistance of the population resistance. It highlights high plasticity of the species that grow on chalk uplands.

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Структура популяций *Crambe tataria* Sebeók в Актюбинской области

Аннотация.*Grambe tataria Sebeok* - один из четырех видов рода Crambe, произрастающих на территории Казахстана. Этот вид занесен в Красную книгу Казахстана как редкий и находящийся под угрозой исчезновения, а его естественной средой обитания являются меловые районы западной части страны. В Актюбинской области изучена структура семи популяций редкого, исчезающего вида *Grambe tataria Sebeok.* Оптимальными местообитаниями являются северные, северо-восточные склоны меловых возвышенностей, каштановые и светло-каштановые почвы. В неблагоприятных условиях вершин и южных склонов меловых возвышенностей *G. tataria* способен образовывать инвазионно-регрессивные популяции с преобладанием особей виргинильного состояния. Варьирование структуры популяций не приводит к снижению их устойчивости, что подчеркивает высокую пластичность вида внутри меловых возвышенностей.

Ключевые слова. *Grambe tataria,* редкий, находящийся под угрозой исчезновения вид, популяция, Актюбинская область, структура популяций, устойчивость популяций.

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Ақтөбе облысындағы *Crambe tataria* Sebeók популяциясының құрылымы

Аңдатпа. Қазақстан аумағында өсетін *Crambe tataria* Sebeók, Crambe, туысының төрт түрінің бірі. Бұл түр, Қазақстанның Қызыл кітабында сирек кездесетін және жойылып кету қаупі төнген түрлердің тізіміне енгізілген, ал оның табиғи мекендеу ортасы елдің батыс аймағының Борлы аудандары болып табылады. Ақтөбе облысында жеті популяцияның құрылымы зерттелді. Ақтөбе облысында *Crambe tataria* Sebeók сирек кездесетін, жойылып бара жатқан түрдің жеті популяциясының құрылымы зерттелді. Бор қыратының солтүстік, солтүстік-шығыс беткейлері, каштан және ашық-каштан топырақтары қолайлы өсетін жерлер болып табылады. Биік бор шыңдарының оңтүстік беткейлері қолайсыз жағдайларда. *C. tataria* виргинелді жағдайы инвазиялық регрессивті популяциялар дарақтарын құруға қабілетті. Популяциялар құрылымының өзгеруі олардың тұрақтылығының төмендеуіне алып келмейді, бұл бор төбешіктеріндегі түрлердің жоғары икемділігін көрсетеді.

Түйін сөздер: *Crambe tataria*, сирек, жойылып кету қауіпі төнген түр, популяция, Ақтөбе облысы, популяция құрылымы, популяцияның тұрақтылығы.

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