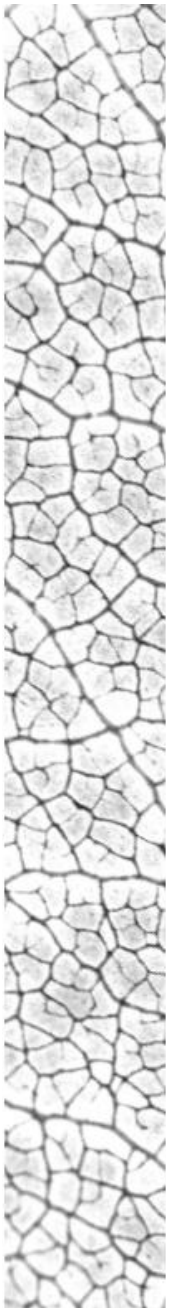

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Features of age-related conditions of the *Crambe tataria* Sebeók in Western Kazakhstan

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Abstract
The study of age-related conditions is necessary to assess the state of populations and develop the measures for its protection. C. tataria is rare throughout the range, its habitats are often destroyed and the plant needs widespread protection. Despite the high degree of rarity and threat of plant destruction in natural populations, there is extremely little information about the characteristics of age-related states of C. tataria. The aim of our research was to study the age-related states of C. tataria in the northwestern part of Kazakhstan. Three periods and 8 age-related states were distinguished in the ontogenesis of C. tataria. The duration of ontogenesis from seedlings to the old generative state makes from 12 to 30 years. In the most arid conditions, plants remain in a virgin state indefinitely without starting to bloom, forming invasive-regressive cenopopulations. Vegetative buds on a shortened shoot are formed only among young generative species; they are not formed among middle-aged and old generative species. The incompleteness of age-related conditions does not provide population stability decrease and indicates a high plasticity of the species under extreme conditions of Cretaceous hills.

Keywords: Crambe tatarica Sebeók, Western Kazakhstan, age-related states, ontogenesis

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INTRODUCTION

The genus *Crambe* L. contains more than 35 species growing in Europe, the Mediterranean, tropical Africa, Wstern and Central Asia and China (Leppik 1975, Kaplan 2012, Liang Jie, Shu Ji 2001). The *Crambe* section in the genus *Crambe*, to which *C. tatarica* belongs, has 16 species (Prina 2009).

C. tatarica is found on Cretaceous deposits of Western Kazakhstan (Vasilieva 1961, Kotov 1979, Darbaeva 1990, Aipiisova 2012). *C. tataria* is rare throughout the entire range, its habitats are often destroyed, and the plant needs widespread protection (Red Book of the USSR 1984, Council Directive 92/43/EEC 1992, Red Book of Kazakhstan 2014). *C. tataria* is of industrial interest because seed oil contains a large amount of erucic acid, providing a high boiling and evaporation point of oil. This property provides resistance to high temperatures and maintains oil in liquid form at low temperatures, which makes the oil a good lubricant and transmission oil (Capelle, Tittonel 1999, Szmatoła et al. 2018, Vargas-Lopez et al. 1999).

The seeds of *C. tataria* collected in Turkey showed a high content of erucic (29.87%), linolenic (15.01%) and linoleic acid (9.00%) (Piovan et al. 2010). Many species of the *Crambe* genus are considered as industrial crops (Tito et al. 2014).

C. tataria has several characteristic biologic features associated with atypical habitats. It is a vivid example of the way the environment leaves an indelible print on the entire morphological appearance and biological properties of the plant. On the other hand, coenopopulations of *C. tataria* are directly related to

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Fig. 1. Pure chalkstone outcrops – typical habitat of *C. tataria*

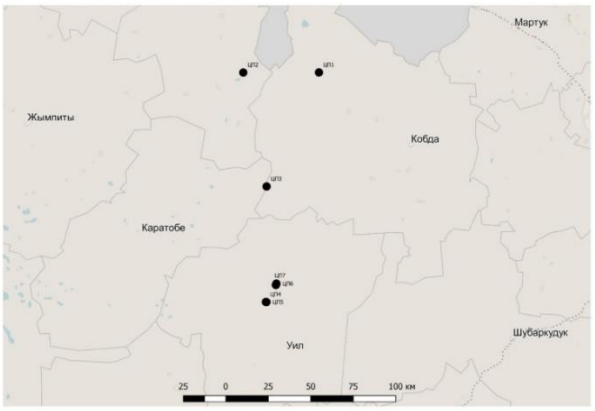

Fig. 2. Study areas on the Sub-Urals plateau

Cretaceous and the destruction of habitats will lead to the extinction of the species.

Despite the high degree of rarity and threat of species destruction in natural populations, they did not study the information on the characteristics of biology and age-related states of *C. tataria*. The aim of our research was to study the age-related states of *C. tataria* in the northwestern part of Kazakhstan to assess the state of populations.

MATERIALS AND METHODS

The features of age-related states of *C. tataria* were studied on the Sub-Urals plateau in the Uil river valley in May 2019. The Sub-Urals plateau is a gently sloping high plain with a pronounced erosion relief with absolute heights of 250-400 m (Nurmagambetov 1991). A characteristic feature of the Sub-Urals plateau is its complex and rather deep fragmenting by river valleys. From east to west, heights fall from 400 to 100 m above sea level. Along the wide interfluve separating the basins of the largest rivers, over 400 km from north to south there are chalky elevations of the interfluve of the Kara-Khobda river basin (a tributary of the river Ilek), flowing to the north-west, and the river Uil, flowing to the south-west, and also between the rivers Uil and Sagiz, are hills with edges heavily indented by tributaries of these rivers. In the basins of the above rivers, plateau-like hills of Akchatau stand out - 244 m, Terekttytau - 245 m, Karatau - 271 m. Populations of *C. tataria* are confined to clay-carbonate rocks of Jurassic age and outcrops of pure Cretaceous (**Fig. 1**).

Clay-carbonate rocks up to 300 m thick crop out within the study area; they are represented by calcareous clays and marls with layers of chalk, in some cases pure chalk predominates. In addition, some populations of *C. tataria* are confined to outcropping steep slopes with outcrops of dense layers of bedrock and chalk (Semenova-Tian-Shanskaia 1996).

The parent rocks in the southern desert steppes on light chestnut soils are loamy and chalky deposits.

Table 1. Age periods of plants (according to A.A. Uranov (1975)

Period	Age-related conditions
Latent (primary dormancy) period (Se)	Seeds
Virginal period	Seedlings (P)
	Juvenile plants (J)
	Immature plants (Im)
	Virginia plants (V)
Reproductive period	Young reproductive plants (G_1)
	Mature reproductive plants (G_2)
	Old reproductive plants (G_3)
Senile (non-reproductive) period	Subsenile (Ss)
	Senile (S)
	Dying (Se)

Surface calcareous light-chestnut, poorly developed and underdeveloped gravelly soils develop on chalk.

At the chalkstone outcrops of the Sub-Ural plateau, *Artemisia salsoloides* communities are formed, the projective cover is no more than 30%. On the upper parts of the chalk slopes, the coverage decreases to 10-15%. Pillow-shaped and creeping forms of plants are characteristic of the grass: *Anabasis cretacea, A. truncata, Linaria cretacea*. Species such as *Lepidium meyeri* are relatively constant. In addition to calcephiles, the presence of *Ephedra distachya, Stipa capillata* is characteristic here (Darbaeva 2002).

Studies were conducted in 13 populations of *C. tataria* (**Fig. 2**).

Features of age-related conditions were studied in situ, plants of the virginal period were additionally studied ex situ in the collection of the Kuzbass Botanical Garden according to the guidelines of T.A. Rabotnov (1950), A.A. Uranov (1975), O.V. Smirnova et al., (1984), and also taking into account the recommendations of the program and methodology for observing cenopopulations of plant species of the Red Book of the USSR (1986).

When assessing the age state of plants, four age periods are distinguished: latent - dormancy (seeds); virginal - plants are in a vegetative state from germination to flowering; reproductive - plants bloom and bear fruit; senile - the period of gradual extinction of plants (**Table 1**).

Fig. 3. Fruits (A); seedling (B)

RESULTS AND DISCUSSION

Latent period. The inflorescence of *C. tataria* is paniculate-branched; middle-aged generative individuals form from 3 to 12 flowering shoots, each of which has from 5 to 13 pieces of lateral shoots of the first order on which shoots of the second order are formed, bearing 6-10 flowers. The fruit is not clearly tetrahedral, mesh-wrinkled, ligneous, not opening, almost a spherical pod of 4-5 mm in diameter (**Fig. 3A**). The weight of 1000 fruits in different populations is from 6.76 to 7.16 g. The seeds are small, light yellow, closely adjacent to the shell of the fruit. The number of fruits on a middle-aged plant can reach 3900 pcs. of which only 45% contain normally developed, undamaged seeds, 26% of fruits with underdeveloped seeds, and 29% of the fruits are damaged by pests of the genus *Phyllotreta, Eurydema, Meligethes.*

Virginal period begins from the moment of germination (the primary root has reached half the length of the seed) until the first reproductive organs appear. In this period, plants undergo several age-related conditions.

Sprouts (p) - age-related condition from germination to the death of cotyledons. Seeds are in endogenous rest. Germination of freshly harvested seeds does not occur. The germination of seeds that have undergone natural stratification during the winter period, collected in the spring of next year, have a soil germination of 10%, the germination period is two weeks. Germination of seeds is above-ground: a hook-shaped curved hypocotyl appears above the surface of the soil, then it straightens, bringing the pericarp to the surface. The cotyledons are small oval, later they increase in size, acquire a leaf-like shape and persist for a long time. In seedlings, the leading root develops faster, which in this age state reaches 7 cm, significantly exceeding the length of the aerial part. The subordinate roots appear on the underground part of the hypocotyl (**Fig. 3B**).

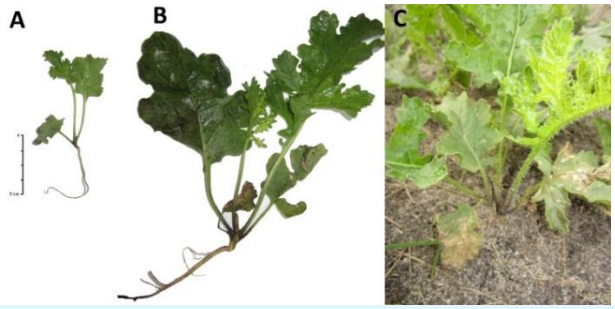

Fig. 4. Age-related conditions: seedling (A); juvenile condition (B); transitional stage from juvenile to immature state (C)

The first true leaf is whole, slightly lobed, long petiolate 2–3 cm long and up to 1.5 cm wide (**Fig. 4A**), the following leaves are deeply pinnate lobed, forming a small rosette. The root system is represented by a rooted, slightly branching root. After the appearance of a rosette shoot from real leaves, the hypocotyl is shortened, bringing the leaf rosette closer to the surface of the soil, a transverse wrinkle appears on it. The cotyledons dry after 3-4 true leaves appear in the rosette (**Fig. 4A**).

The juvenile individuals (j) are characterized by simplicity of organization, lack of formation of signs and properties inherent in adulthood. In this age state, a rosette of 3-4 large leaves is formed, directed obliquely upward. The first leaves are lobed, the subsequent deep lobed. A characteristic feature of juvenile individuals is the lack of hard pubescence characteristic of subsequent age-related conditions. The root system is represented by a rod root up to 12 cm long (**Fig.4 B**, **C**). In nature, juvenile individuals are extremely rare and dry with the onset of May heat. In culture conditions, the plants are in a juvenile state for about a month.

The immature state of *C. tataria* is rare in situ but is well observed in culture. In this state, the leaves are 4–5 cm from lobed to almost pinnately separate (the base of the leaf runs down to the petiole). The root is tap-like at the base of the leaf rosette, forms a shortened rosette rhizome, turning into a long tap-root.

Virginal condition (v) begins from the moment of the appearance of cirrus-lobed leaves with lobes descending on the leaf petiole and lasts under unfavorable conditions of chalky elevations for more than ten years. In the second year after the emergence of seedlings, the plants under natural conditions are in the virgin state (**Fig. 5**).

Young virginal individuals form a rosette of two to three large cirrus leaves with 2-3 pairs of leaflets assuming a plagiotropic state (**Fig. 6 A**). During this period, a shortened rhizome forms on which vegetative buds are laid. In subsequent years, leaf sizes are constantly increasing. At the age of 5 years, they reach

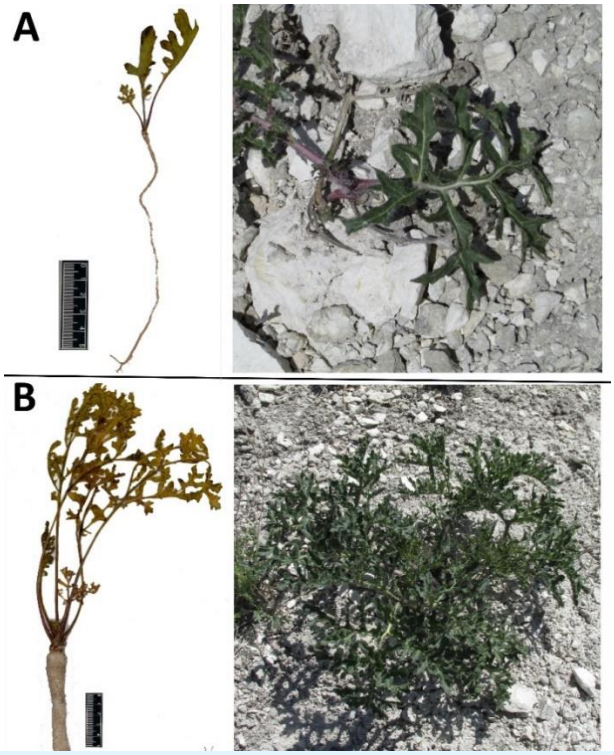

Fig. 5. Virginity state of *C. tataria*

Fig. 6. Age conditions: immunity: (imm) 2-3 years (A); virgin state (v), 3-6 years (B), 7-12 years (C); middle-aged generative individuals (D)

Fig. 7. A young generative individual (G_1)

Fig. 8. Middle-aged condition

20 cm, with 3-4 pairs of leaflets, the first-order lobes are dissected into second-order lobes (**Fig. 6B**). The maximum age of plants in the virgin state was 12 years. At this age, virginal leaves can reach 60 cm, with 5-7 pairs of second-order leaflets, which in turn are cut almost to the main vein (**Fig. 6 C**). The age of virginal individuals is determined by the number of small scars in the form of a thin cushion formed on a shortened rhizome. The roots of 7–9 year old virginal individuals can reach a depth of 100 cm and have a thickness at the base of the rosette of 2–2.5 cm. The main root is of the rod type, cylindrical and unbranched. The powerful root development allows preserving the mesophytic appearance of the plant in extremely arid conditions of chalk outcrops. The transition from the virginal to generative condition on the southwestern and southern slopes is obviously extremely rare.

In extremely unfavorable growing conditions, we have not found a single flowering individual.

Generative period is the time from the first to the last flowering. In hollows, on the northern and northeastern slopes, the transition from the virginal to generative state occurs rather quickly at the age of 5–7 years (**Fig. 7**). On a short rosette shoot, in addition to vegetative buds, 1-2 terminal buds form, from which generative shoots develop. It differs from other rooted rosette species (Bylova 1974, 1976); later on, vegetative buds form only in young generative individuals, in middle-aged generative individuals they do not from, and a sharp change in leaf morphology occurs. The stalk leaves are broad-lanceolate of 7–12 cm, cirrus separate, have 3–7 pairs of dissected leaflets (**Fig. 6 D**), they are many times smaller than vegetative leaves. On the underground shortened shoot, age rollers are clearly visible, and under them in the place of dead shoots are generative buds. With age, the underground rhizome branches into two, very rarely into three parts (**Fig. 8**).

The rapid growth of generative shoots in the last ten days of April is ensured by a powerful rod root extending to a depth of 150 cm.

Intensive branching of shoots was noted in middle-aged generative individuals: on the first-order shoot, 4-6 second-order shoots are formed, which carry numerous third-order shoots. The root system is represented by a thick cylindrical rod subramous root with a diameter of up to 5–7 cm, extending deeper into the soil over 150 cm.

In old-aged generative individuals, there is a decrease in the number of stem leaves and their sizes, weak branching of shoots and a decrease in the number of flowers on third-order shoots. A shortened shoot is represented by an overgrown caudex in which some particles begin to die, and some of them form again poorly developed rosette shoots. The oldest plant discovered by us was over thirty years old. We did not find plants in a senile state.

CONCLUSION

We studied the age-related conditions of *Crambe tataria* Sebeók, which grows on the chalkstone heights of the Sub-Urals plateau of Western Kazakhstan.

C. tataria is a herbaceous long-stemmed polycarpic, xerophyte, found on chalk hills. The main root is preserved throughout life and that allows us to attribute it to the group of rooted simple deep-root plants that do not have skeletal lateral roots.

Three periods and 8 age-related states were distinguished in the ontogenesis of *C. tataria*. Plants have high seed productivity, however, about half of the seeds are damaged by pests. Seeds have endogenous dormancy; germination of freshly harvested seeds does not occur. Seeds are largely damaged by pests. Germination of seeds that have undergone natural stratification have a germination rate of 10%. The duration of ontogenesis from seedlings to the old generative state lasts from 12 to 30 years. Ontogenesis is incomplete since under the most arid conditions, plants remain in the virgin state for an indefinite period of time without starting flowering. Vegetative buds form only in young generative individuals, while middle-aged and old generative individuals do not develop such buds.

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