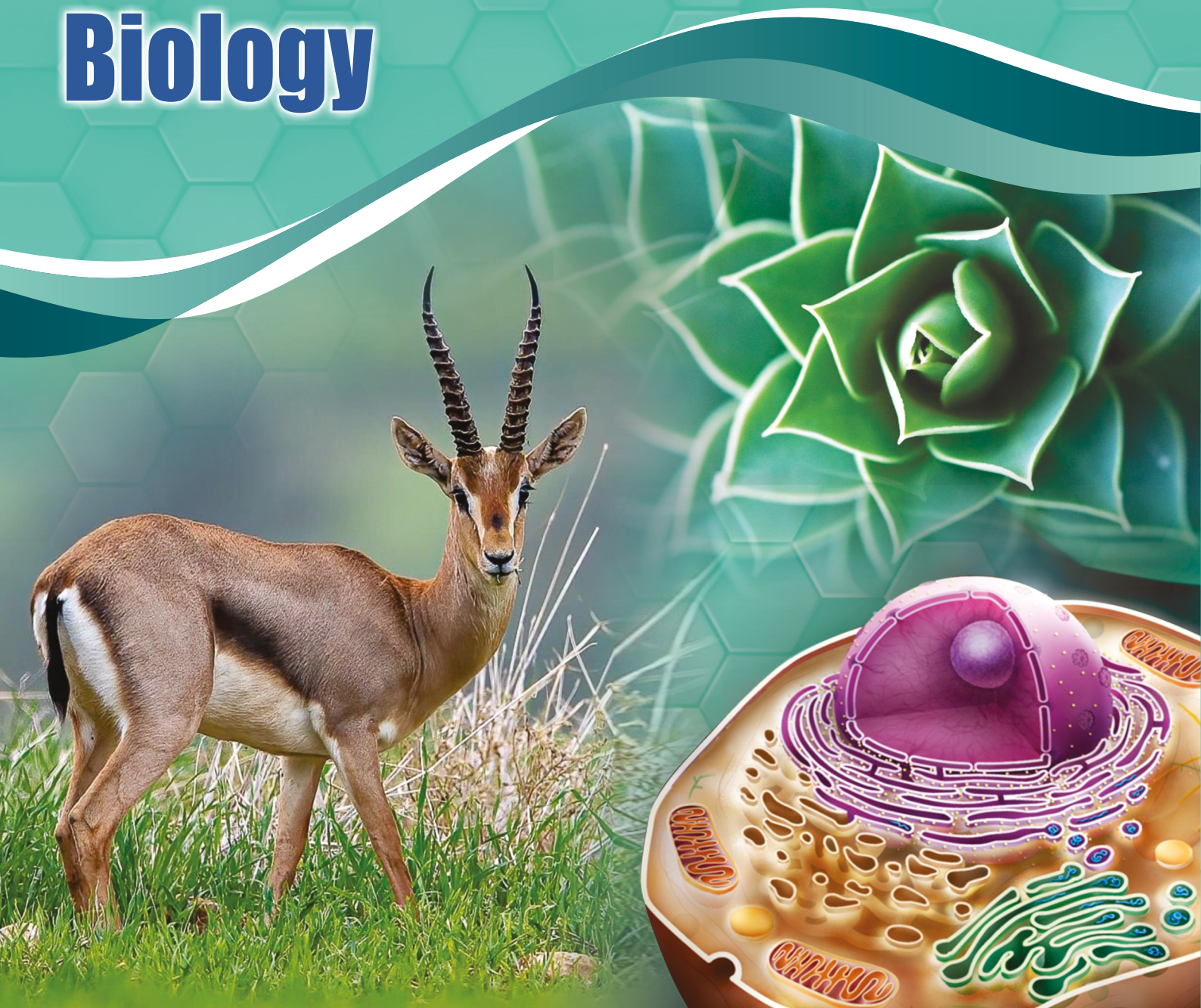




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Research Article

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Cenoflora of the relict species *Anabasis cretacea* Pall. in the Aktobe region

The article presents the results of a study (June-September, 2025) on the cenoflora of the relict species *Anabasis cretacea* Pall. in the Aktobe region. The study confirmed the occurrence of *Anabasis cretacea* Pall. is associated with Cretaceous uplands and escarpments. Based on the analysis of herbarium materials and field investigations, the distribution sites of *Anabasis cretacea* Pall. populations were determined in the Khobdinsky and Uil districts, with a description of the identified 9 cenopopulations. The composition of the plant community, as well as the ecological and cenotic characteristics of the populations of *Anabasis cretacea* Pall. were determined, reflecting the ecological conditions of the calcareous habitats where the studied populations occur. The leading families were Asteraceae (16 species), Brassicaceae (9 species), Chenopodiaceae (8 species), Scrophulariaceae (5 species), Poaceae (4 species). The dominant genera included *Astragalus* L. (5 species), *Anabasis* L. (3 species), and *Artemisia* L. (3 species). Ecobiological analysis confirmed the desert-steppe character of the cenoflora with a minor contribution from meadow species. A complete checklist of cenoflora *Anabasis cretacea* Pall. was presented, where 84 species belonging to 68 genera and 27 families were identified.

Keywords: *Anabasis cretacea* Pall., cenopopulation, cenoflora, plant communities, life form.

Introduction

The Cretaceous uplands represent unique botanical and geobotanical formations located within the steppe and desert zones of Eurasia. In areas where Upper Cretaceous carbonate rocks are exposed or occur near the surface, distinct plant communities composed of calciphilous species have developed. The flora of these chalk outcrops is characterized by a high concentration of rare and predominantly endemic species. The floristic specificity is largely determined by the unique characteristics of the calcareous substrate, the localized and fragmented nature of the habitats, as well as the historical and geological context of the regions in which these outcrops are found [1].

The earliest descriptions of the vegetation of Cretaceous outcrops were given by Guldenstedt (Güldenstädt, 1787, 1791) [2-3].

A number of works (Litvinov, 1902; Dubyansky, 1905; Kozo-Polyansky, 1931; Volodina, 1982; Didukh, 2018, etc.) have been devoted to the study of the flora of the Cretaceous outcrops of the Central Russian Upland, the Don River basin, and the Trans-Volga region. Cretaceous substrates were studied in England (Tansley, 1920; Tansley and Adamson, 1925; Hope-Simpson, 1940; Lloyd and Pigott, 1967, etc.), Belgium (Butaye, 2005), etc. [4-13].

A number of studies have been devoted to studying the vegetation of Cretaceous outcrops in Western Kazakhstan (Yanishvsky, 1905; Kolchenko, 1966; Cherkasova, 1970; Safronova, 1974; Gorchakovskiy and Matyashenko, 1975) etc. [14-18].

According to A.N. Kupriyanov (2020), the flora of the chalk outcrops of Western Kazakhstan has been studied extensively and comprises more than 800 species [19].

The floral diversity of the Cretaceous uplands of the Urals was studied by O.A. Karimova (2017), Ya. M. Golovanov, L.M. Abramova, S.M. Yamalov (2019, 2025), where 40 species listed in the Red Books of different levels and 15 endemic species were identified in the Cretaceous highlands of the Orenburg region. Research has noted that in Kazakhstan, where chalk massifs occupy the largest areas, chalks remain largely without a special protection system [20-22]. Of great scientific interest are Quaternary relicts that

penetrated from the temperate and high latitudes of Eurasia during the periods of the greatest cooling of the Pleistocene. The endangered ancient relics of Kazakhstan are subject to indispensable protection with the allocation of protected areas [23].

Studies by Lu, Y. et al. (2023) show that climate change will lead to a reduction and shift in the distribution range of typical desert species, while relict species will be less affected by climate change. This is due to the fact that, compared with desert species, relict species have a deeper evolutionary history and have developed a wider range of adaptations after drastic environmental changes [24].

The relict species is *Anabasis cretacea* Pall. occurs on chalk substrates in the West Kazakhstan and Aktobe regions [25]. *Anabasis cretacea* Pall. is confined to chalky slopes of uplands, growing within calcephytic communities that develop in erosion-prone areas, and is regarded as a rare species associated with chalk outcrops [26].

Aipeisova (2012) notes that calcephilic and petrophilic floral complexes are characterized by the presence of endems, a significant predominance in the number of subendems, and relict species, which indicates that the ancient core of the flora of the study area are calcephilic and petrophilic floral complexes, on the basis of which the main floral complexes of the modern flora of the Aktobe floral district, which includes the study area, arose [27].

In Russia, this species is classified as rare, vulnerable, and endangered by the taxon, and is listed in the Red Book of the Orenburg, Saratov, Chelyabinsk Regions, and Bashkortostan [28–31].

Floral studies of Cretaceous outcrops in Western Kazakhstan have been the object of scientific research more than once, but despite this, the study of populations of *Anabasis cretacea* Pall. in the Aktobe region was not conducted.

Chalk hills, with their exceptional flora, are widespread in Western Kazakhstan. Within the Aktobe region, they occupy a relatively large area—63,535.1 km² (Darbayeva, 2002), compared to the West Kazakhstan, Atyrau, and neighboring Orenburg regions [32, 33].

The aim of this study is to conduct geobotanical studies to assess the current state of the populations of the relict species *Anabasis cretacea* Pall. in the Aktobe region.

Experimental

Object of study

The relict species *Anabasis cretacea* Pall. is a perennial plant of the Chenopodiaceae family. Semi-shrub, chamaephyte, xerophyte, calciphile. The Trans-Volga-Kazakh-Turanian type [34].

It grows on chalk, marl, variegated clays, less often on gravelly slopes and outcrops of bedrock [35].

Research methods

Geobotanical studies of cenopopulations of the relict species *Anabasis cretacea* Pall. began with the study of herbariums of the genus *Anabasis* L. domestic and foreign herbarium collections to identify the distribution sites of populations of the relict species *Anabasis cretacea* in Aktobe region, in particular in Khobda, Wilsky, Yrgyzsky and Mugalzarsky districts. The floral composition of the *Anabasis cretacea* cenopopulations was studied on standard plots of 100 m², where areas with a high density of *Anabasis cretacea* were selected and 9 cenopopulations were surveyed.

The field work was carried out in June-September 2025 by the route-reconnaissance method, where we outlined the optimal routes for surveying the territory to obtain the most reliable data. The geographical location of the research object was obtained using a GARMIN Etrex 20x GPS navigator, and photographs were taken using a Nikon digital camera.

At the sites of the relict species *Anabasis cretacea*. The ecological conditions of the habitats of the populations were described, took into account exposure, altitude, illumination, soil cover, plant communities, and determined the species composition. The calculation of species units was carried out using the method of constructing sites based on cenopopulations. The biological and morphological classifications of I.G. Serebryakov (1962) [36] were used in the analysis of flora. The assessment of species in relation to moisture was carried out according to the A.P. Shennikov scale [37]. The vital states of the species were determined according to the classification of T.A. Rabotnov [38].

When identifying species collected from *A.cretacea* cenopopulations, the corresponding volumes of the books “Flora of Kazakhstan” (1960), “Illustrated Guide to Plants of Kazakhstan” (1969) were used. Also, certain types were specified by Doctor of Biological Sciences, Professor Aipeisova S.A.

The list of flora species is presented in accordance with the system of A.L. Takhtadzhyan [40]. Latin names of plants according to S.K. Cherepanov [41] and S.A. Abdulina [42]. Kazakh names of plants are given according to S.A. Arystangaliev and E.R. Ramazanov [43].

Results and Discussion

Location, ecological and cenotic state of populations of the relict species *Anabasis cretacea* Pall.

The territory of Aktobe region is located in steppe and desert zones [44]. It is believed that in ancient times, the Aktobe region was twice subjected to devastating floods. The last time, 50 million years ago, the sea stagnated here for a long time, and then retreated, which led to a change in the relief of these places. As a result, there are natural monuments in the Bayganinsky, Kobdinsky, Uilsky, Mugalzarsky and Khromtau districts, which were formed under the influence of destructive water and strong winds. The formations belonging to the Cretaceous period are particularly well preserved [45].

Thus, three populations of *Anabasis cretacea* were studied in the territory of the Aktobe region, in particular in the Kobdinsky and Wilsky districts, and a comprehensive study was conducted in accordance with the goals and objectives set. A geobotanical characterization of plant communities containing the studied 9 cenopopulations of *Anabasis cretacea* was carried out in order to determine their ecological and cenotic relationship (Table 1).

Table 1

Ecological and cenotic characteristics of *Anabasis cretacea* Pall. populations.

| Location | GPS coordinates | The projective cover % |
|--|--|------------------------|
| AO, Khobdinsky district, 30 km southwest of the village. Akyrap, Ishkargantau chalk massif | N 50°32'13.3", E 054°54'32.2" h = 241 m | 40–50 |
| AO, Wilsky district, Akshatau chalk ridge, 3 km from the village. Akshatau | N 49°20'18.0", E 054°30' 29.7" h = 150 m | 50–60 |
| AO, Wilsky district, Akshatau chalk ridge, 11 km northeast of the village. Akshatau, towards Mukushtau mountain | N 49°28'10.6", E 054°35'40.3" h = 135 m | 40–45 |

The first population was studied in the Khobda district on the Ishkaragantau chalk ridge, 30 km southwest of the village of Akyrap, on the chalk ridge of the Ishkaragan River valley, on the watershed of the Bolshaya Hobda and Kiil rivers (Fig. 1).

The finely dissected western edge of the elevated watershed between two wide flat-bottomed valleys occupied by the upper reaches of the left tributaries of the Bol. Khobdy—Ishkargan and Tumansha rivers. Both rivers in this segment are drying watercourses along the talvegs of deeply embedded sayas with steep sides. The main relief of the watershed plateau is a hollow, rolling plain, the heights of which gradually decrease to the east towards the Bol River valley. Hobda; closer to the western edge, the relief becomes sharper and turns into a Cretaceous lowland melkosopochnik, actually bearing the name Ishkargantau. To the south, it passes into the similar, but less sharply dissected Karaganda Mountains massif, which forms the watershed of the tributaries of the Kiil River—the Zhusalisai and Karaganda rivers.

Smelansky I. (2012) notes that the Ishkargantau Cretaceous massif stretches along the Ishkaragan valley for about 15 km, and from 2 to 8 km deep into the plateau. It is a system of fragmentally dissected steeply sloping chalk ridges and hills separated by flat-bottomed, zigzag-shaped dry valleys, often devoid of pronounced talweg. The maximum heights of the watershed are within the massif—278-279 m above sea level. The height difference to the Ishkaragan river terrace is about 100 m, the relative heights of the slopes are within the first tens of meters, up to 50–60 m. The erosive parts of the slopes are composed of rocky chalk, passing below into crumbly and coarse-grained talus, with pediments and deluvial plumes, cones from the inner valleys of the massif, expressed on the slopes. In almost the entire territory of the massif, soils are formed on a Cretaceous substrate [46].

The Cretaceous ridge forms a system of chalk peaks and hills with steep slopes, which is located in the northwestern part of the region. Chestnut soils are represented by carbonate genera [47].

At this site, the following were investigated: 1 — 2-3 cenopopulations. The coordinates of the first population are N 50°32'13.3", E 054°54 '32.2", h = 241 m.

Cenopopulation 1 (CP 1) represents the tasbuyurguna-anabasis-wormwood association — ass. *Nanophyton erinaceum* — *Anabasis cretacea* — *Artemisia salsoloides*. It covers the western and

southwestern slopes, steep, shallow, with erosive forms. The slopes are formed by rocky chalk, which turns into talus and fine-grained plumes. The entire system of Ishkargantau ridges is directed so that the plateau gradually falls to the east and southeast towards the valley. The soils are underdeveloped, formed on a Cretaceous substrate. The total projective coverage is 50 %. Rising to the top, there is an arrangement of calciphilous flora adapted to cretaceous soils, such as *Nanophyton erinaceum*, *Anabasis cretacea*, having the greatest participation in the vegetation cover, along with rare and endemic species such as *Anthemis trotzkiana*, *Linaria cretacea*, *Crambe tataria*.

At the Cretaceous outcrops, there are also *Astragalus albicaulis*, *Matthiola fragrans*, *Ephedra distachya*, *Jurinea kirghisoroum*, *Artemisia terrae-albae*; in the depressions, one can find *Astragalus macropus*, *Convolvulus lineatus*, *Sedum hybridum*, and *Onosma borysthenica*. The community has 39 species. Rising to the top of the Cretaceous ridge, there is a decrease in the species composition.

CP 2 consists of ass. *Anabasis cretacea*-*Anthemis trotzkiana*. with mixed herbs. It represents the northern exposure of the chalk ridge, directed to the river valley, the erosive sections of the slope are covered with stony chalk, turning down into crumbly and coarse-grained talus. They are covered with stony chalk. The soils are underdeveloped, without a humus horizon. The relief is highly dissected. The total projective coverage is 50 %. The slope is darker, with varying degrees of calcification. The vegetation is dense and includes various grass species. The community has 36 species. Common vegetation components are *Anabasis cretacea*, *Artemisia terrae-albae*, *Echinops ritro*, *Galium ruthenicum*. on Cretaceous outcrops, *Tulipa biebersteiniana*, *Centaurea adpressa*, *Allium globosum*, *Iris scariosa*, *Zygophyllum pinnatum*, *Astragalus brachylobus*, *Matthiola tatarica*, *Ephedra distachya* (Fig. 2).

At the foot of the mountain range, carbonate soil is widespread, with a predominance of representatives of the cereals *Psathyrostachys juncea*, *Koeleria cristata*, *Stipa sareptana*. In addition, *Atraphaxis frutescens*, *Scabiosa isetensis*, *Rhammatophyllum pachyrhizum*, *Atriplex cana*, *Convolvulus lineatus* are common between the hill depressions.

CP 3 represents ass. *Anabasis cretacea* — *Artemisia salsoloides*. It covers the top of the chalk hills. The soils are underdeveloped, they represent small fragments of chalk, turning into large-scale cretaceous deposits closer to the foot. Cretaceous deposits are exposed due to erosion and flushing from the plateau. The total projective coverage is 40–45 %. Vegetation is sparse and spotted, and *Nanophyton erinaceum*, *Artemisia salsoloides*, *Anthemis trotzkiana*, *Artemisia terrae-albae*, and *Matthiola fragrans* are most involved in the vegetation cover. According to the rocky slope of *Linaria cretacea*, *Galitzkya spathulata*, *Inula multicaulis* was noted along the slope. *Serratula wolfii* is found on the sole, between the hills of *Limonium gmelinii*. *Euphorbia seguierana* can also be found at the top of the hill with an outlet of rocky rocks. The community is small, with 22 species. There is a decrease in species towards the top of the Cretaceous ridge.

71 species belonging to 58 genera and 25 families were identified in the vegetation cover of the first population.

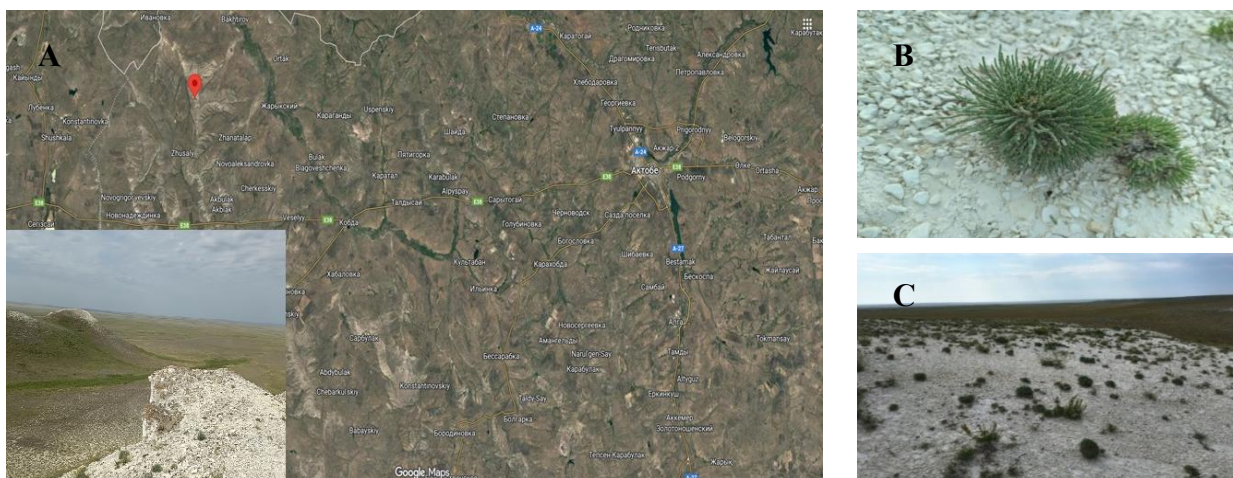


Figure 1. The first population: A, B — Ishkaragantau Cretaceous massif; C, D — *Anabasis cretacea* population (June, 2025)

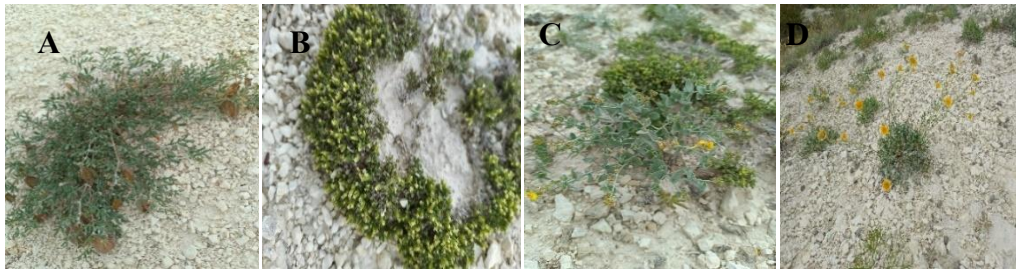


Figure 2. *Zygophyllum pinnatum* (A), *Nanophyton erinaceum* (B), *Linaria cretacea* (C), *Anthemis trotzkiana* (D)

The **second population** was studied in the Wilsky district, 3 km from the village Akshatau, located on the right bank of the Uil River, on the Akshatau chalk ridge, coordinates N 49°20'18.0", E 054°30' 29.7", h = 150 m have been determined (Fig. 3).

According to Smelansky (2012), the website Plantarium <https://www.plantarium.ru/lang/en/page/landscapes/point/1517.html> describes the geographical position of the Akshatau Cretaceous ridge as follows: the right side of the Uil river valley below the confluence of the Kiyf River is formed by a chink (steeply sloping scalloped edge) of a cretaceous plateau armored with calcified sandstones; the elevation difference on the plateau ledge reaches more than 100 m (up to 186 m non the brow of the slope, 80 m n.o.m. on the overflowing terrace of Uila); the general exposition of chinka—east-south-east; The edge of the plateau is deeply and fractionally dissected by valleys and dens, forming a more or less complex maze of straight and curved small-scale ridges, and single remnant hills; on the terrace under the chin, a wide plume formed by Cretaceous limestone and carbonate clays is well defined.

Light chestnut normal soils are found on watershed plains, gentle slope of hills, inter-mountain high plains and river valleys [47].

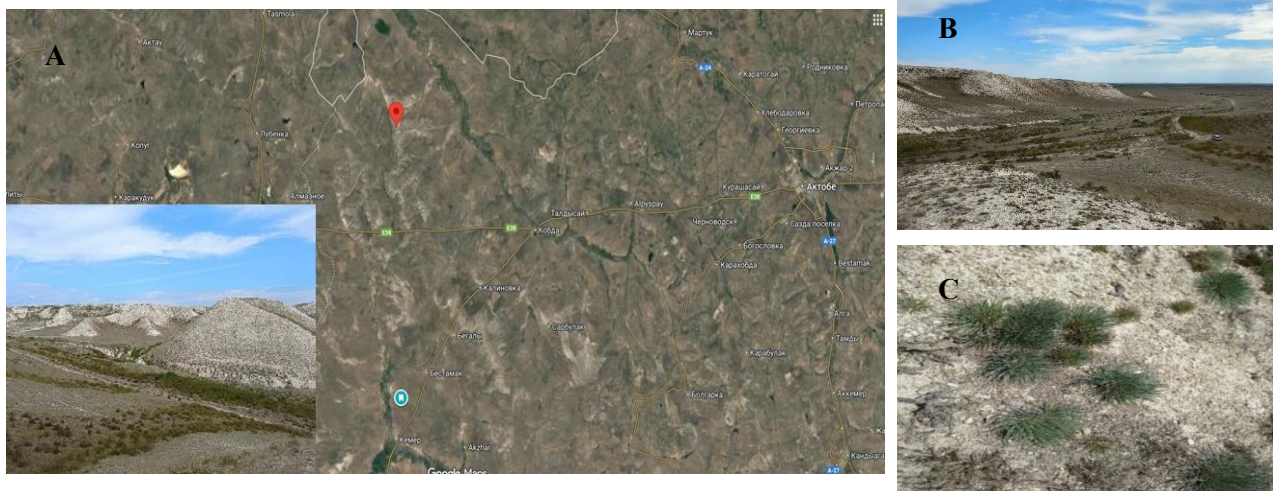


Figure 3. Akshatau Cretaceous ridge (A, B), population of *Anabasis cretacea* Pall. (C) (July-August, 2025)

CP 4 ass. *Nanophyton erinaceum* — *Anabasis cretacea*. It covers the southeastern slope of the Akshatau chalk ridge. Steep chalk slope caused by erosion. The soils are light chestnut. The slope is based on cretaceous rocks such as limestones, marls, interspersed with sandstones, thereby creating a solid frame and leaving it resistant to weathering. The projective coverage is 50–55 %. The cenopopulation (CPU) includes 28 species.

Rising to the top, there is an arrangement of calciferous flora adapted to the cretaceous soils that were located at the top, such as *Nanophyton erinaceum*, *Anabasis cretacea*. The slopes are covered with desert-steppe vegetation of *Artemisia terrae-albae*, *Atraphaxis frutescens*. A wormwood-biyurgun association is common at the foot, honeycombs from *Artemisia gracilescens*, *Koeleria cristata*. In terms of between the hills grows *Amygdalus nana*, *Limonium gmelinii*.

CP 5 ass. *Nanophyton erinaceum* — *Artemisia terrae-albae* — *Anabasis cretacea*. The projective coverage is 55–60 %. It represents the eastern slope, which is less steep than the western ledges. The slope is formed by cretaceous rocks reinforced with sandstones, creating ledges, and dissected by ravines. The more

or less steep walls of the slope, rising up, are covered with calciferous vegetation — *Nanophyton erinaceum*, *Anabasis cretacea*, and the gentle places are occupied by steppe vegetation, such as wormwood. The eastern slope is located near the village of Akshat, which is 3 km away, is interesting and accessible for observation. The soils are light chestnut, fully developed, with chalk inclusions. The community has 24 species.

The vegetation consists of *Nanophyton erinaceum*, *Artemisia terrae-albae*, *Anabasis cretacea*, and on the slope, a small amount of *Anabasis truncata*; closer to the base, *Anabasis salsa*, *Eremogone koriniana*.

In the hollow between the hills, *Artemisia salsoloides* and *Limonium gmelinii* are mixed in.

CP 6 ass. *Artemisia terrae-albae* — *Anabasis cretacea*. The projective coverage is 50 %. It covers the northeastern slope. It is based on cretaceous rocks, with admixtures of limestone, marls, and sandstones. The soils are light chestnut, fully developed. The community has 27 species. The top of the slope is covered with calciferous flora, with a predominance of *Nanophyton erinaceum* and *Anabasis cretacea*, on gentle areas wormwood-thyrsus vegetation.

There are large quantities of *Anabasis salsa*, *Artemisia terrae-albae*, from cereals — *Stipa sareptana*, *Agropyron desertorum*. 46 species (18 families, 39 genera) participate in the plant community of the second population.

The third population is in the Wilsky district, coordinates N 49°28'10.6", E 054°35'40.3", h = 135 m. It was found to the northeast, 11 km from the village. Akshatau, towards Mukushtau mountain. At this site, the following have been investigated: 7 — 8-9 cenopopulations (Fig. 4).

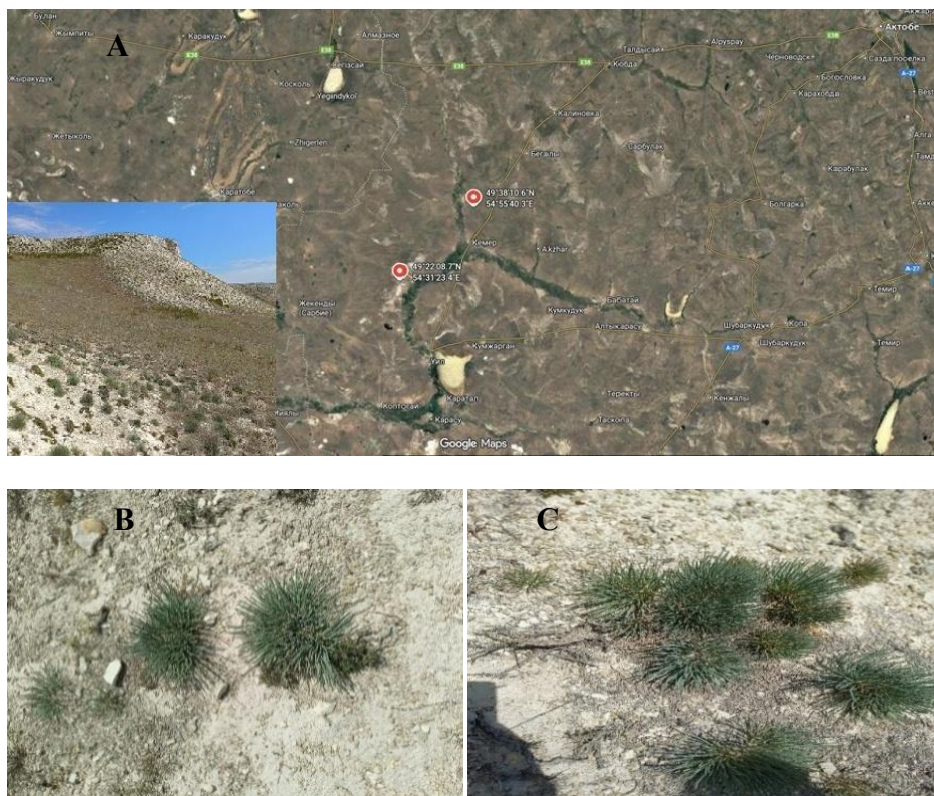


Figure 4. A — Akshatau Cretaceous ridge, B, C — *Anabasis cretacea* Pall. population (July-August, 2025)

CP 7 ass. *Artemisia terrae-albae* — *Anabasis cretacea*, northern slope of the chalk hills. The soils are light chestnut, with a large inclusion of chalk. The projective coverage is 40–45 %. 25 species participate in the vegetation composition, with the largest participation being *Artemisia terrae-albae*, *Anabasis cretacea*, *Anthemis trotzkiana*, *Adonis wolgensis*, *Echinops ritro*, *Onosma polychroma*, *Crambe tataria*, *Eremogone koriniana*. On the slope, *Gypsophila altissima*.

Shrubby vegetation occurs along the depressions: curly-haired *Atraphaxis frutescens*, *Spiraea hypericifolia*. On the bottom of the slope, *Thymus marschallianus*, *Veronica spuria*.

CP 8 ass. *Artemisia salsoloides* — *Anabasis cretacea*, south-western slope of the chalk hills. The projective coverage is 40–45 %. The soils are underdeveloped, light chestnut, with a large number of inclusions in the form of chalk. 19 species participate in the vegetation composition, the most involved are

Scabiosa isetensis, *Nanophyton erinaceum*, *Anabasis cretacea*, *Artemisia salsoloides*, *Crambe tataria*, *Echinops meyeri*, *Erysimum odoratum*, *Atraphaxis frutescens*, on the slopes *Rhammatophyllum pachyrhizum*, *Crinitaria linosyris*, *Limonium gmelinii* in the depressions, *Koeleria cristata* abundantly at the foot.

CP 9 ass. *Nanophyton erinaceum* — *Artemisia salsoloides* — *Anabasis cretacea*. It is located on the top of a chalk massif. The soils are light chestnut, with inclusions of chalk. The projective coverage is 35–40 %. The plant community consists of the following species: *Nanophyton erinaceum*, *Artemisia salsoloides*, *Anabasis cretacea*, *Anthemis trotzkiana*, *Hedysarum razoumovianum*. On the slopes of *Galium ruthenicum*, *Cephalaria uralensis*, on depressions of *Matthiola fragrans*, *Syrenia siliculosa*. There are 19 species in the cenopopulation.

37 species belonging to 32 genera and 16 families were identified in the vegetation cover of the third population.

With the aim of identifying the relict species *Anabasis cretacea*, the flora of the chalk mountain Bestau in the Khobda district was studied (N 50°18'40.5", E 056°06'02.0", h = 288 m). Despite ecological conditions and geological substrate typical for this species, no population of *Anabasis cretacea* was found. This may indicate the possible disappearance of the species from this area (Fig. 5).

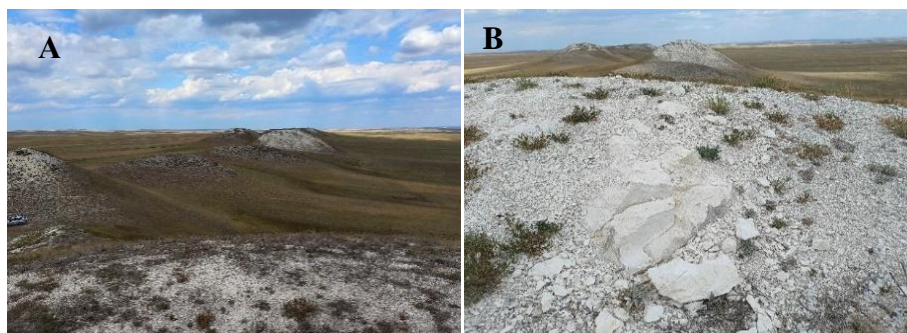


Figure 5. Chalk Mountain Bestau (August, 2025)

Table 2

Composition of cenoflora *Anabasis cretacea* Pall.

| № | Families, genus, species | Ishkaragan N 50°32'13.3", E 054°54'32.2" | Akshatau N 49°20'18.0", E 054°30'29.7" | Akshatau (Mukushtau) N 49°28'10.6", E 054°35'40.3" | Life forms |
|---|---|--|--|---|------------|
| 1 | 2 | 3 | 4 | 5 | 6 |
| | Magnoliophyta MAGNOLIOPSIDA | | | | |
| | Ranunculidae RANUNCULACEAE | | | | |
| | <i>Adonis</i> L. | | | | |
| 1 | <i>Adonis wolgensis</i> Stev. | + | | + | PH |
| | <i>Ranunculus</i> L. | | | | |
| 2 | <i>Ranunculus polyanthemus</i> L. | + | | | PH |
| | Caryophyllidae CARYOPHYLLACEAE | | | | |
| | <i>Dianthus</i> L. | | | | |
| 3 | <i>Dianthus cyri</i> Fisch. et Mey. | + | | | ABH |
| | <i>Eremogone</i> Fenzl. | | | | |
| 4 | <i>Eremogone koriniana</i> (Fisch. ex Fenzl) Ikonn. | + | + | | SDS |
| | <i>Gypsophila</i> L. | | | | |
| 5 | <i>Gypsophila altissima</i> L. | + | + | + | PH |

| 1 | 2 | 3 | 4 | 5 | 6 |
|----|---|---|---|---|-----|
| | CHENOPODIACEAE | | | | |
| | <i>Anabasis</i> L. | | | | |
| 6 | <i>Anabasis cretacea</i> Pall. | + | + | | SDS |
| 7 | <i>Anabasis salsa</i> (C.A. Mey.) Benth. ex Volkens | | + | + | DS |
| 8 | <i>Anabasis truncata</i> (Schrenk.) Bunge | | + | | SDS |
| | <i>Atriplex</i> L. | | | | |
| 9 | <i>Atriplex cana</i> C.A. Mey. | + | + | | SS |
| | <i>Camphorosma</i> L. | | | | |
| 10 | <i>Camphorosma monspeliaca</i> L. | + | + | + | SDS |
| | <i>Krascheninnikovia</i> | | | | |
| 11 | <i>Ceratoides papposa</i> Botsch. et Ikonn. | + | | + | SDS |
| | <i>Nanophyton</i> Less. | | | | |
| 12 | <i>Nanophyton erinaceum</i> (Pall.) Bunge | + | + | + | SDS |
| | <i>Salsola</i> L. | | | | |
| 13 | <i>Salsola laricina</i> Pall. | | | + | SDS |
| | POLYGONACEAE | | | | |
| | <i>Atraphaxis</i> L. | | | | |
| 14 | <i>Atraphaxis frutescens</i> (L.) C. Koch. | + | + | + | S |
| | PLUMBAGINACEAE | | | | |
| | <i>Goniolimon</i> Boiss. | | | | |
| 15 | <i>Goniolimon elatum</i> (Fisch. ex Spreng.) Boiss. | + | | + | PH |
| | <i>Limonium</i> Mill. | | | | |
| 16 | <i>Limonium gmelinii</i> (Willd.) O. Kuntze | + | + | + | PH |
| | BRASSICACEAE | | | | |
| | <i>Alyssum</i> L. | | | | |
| 17 | <i>Alyssum lenense</i> Adam | + | | | SDS |
| | <i>Galitzkya</i> L. | | | | |
| 18 | <i>Galitzkya spathulata</i> (Steph.) V. Boczantzeva | + | | | PH |
| | <i>Crambe</i> L. | | | | |
| 19 | <i>Crambe tatarica</i> Sebeók. | + | + | + | PH |
| | <i>Erysimum</i> L. | | | | |
| 20 | <i>Erysimum odoratum</i> Ehrh. | + | | + | ABH |
| | <i>Lepidium</i> L. | | | | |
| 21 | <i>Lepidium songaricum</i> Schrenk | + | | | PH |
| | <i>Matthiola</i> R. Br. | | | | |
| 22 | <i>Matthiola fragrans</i> Bunge. | + | + | + | SDS |
| 23 | <i>Matthiola tatarica</i> (Pall) DC. | + | | + | PH |
| | <i>Rhammatophyllum</i> O.E. Schulz | | | | |
| 24 | <i>Rhammatophyllum pachyrhizum</i> (Kar. et Kir) | | | + | SS |
| | <i>Syrenia</i> Andrz. | | | | |
| 25 | <i>Syrenia siliculosa</i> (Bieb.) Andrz. | + | + | + | ABH |
| | EUPHORBIACEAE | | | | |
| | <i>Euphorbia</i> L. | | | | |
| 26 | <i>Euphorbia seguierana</i> Neck. | + | | | PH |

Continuation of Table 2

| 1 | 2 | 3 | 4 | 5 | 6 |
|----|---|---|---|---|-----|
| | Rosidae CRASSULACEAE | | | | |
| | <i>Sedum</i> L. | | | | |
| 27 | <i>Sedum hybridum</i> L. | + | | | PH |
| | ROSACEAE | | | | |
| | <i>Amygdalus</i> L. | | | | |
| 28 | <i>Amygdalus nana</i> L. | | + | | S |
| | <i>Filipendula</i> Adans. | | | | |
| 29 | <i>Filipendula vulgaris</i> Moench | + | | | PH |
| | <i>Spiraea</i> L. | | | | |
| 30 | <i>Spiraea hypericifolia</i> L. | + | + | + | S |
| | RHAMNACEAE | | | | |
| | <i>Rhamnus</i> L. / <i>Frangula</i> L. | | | | |
| 31 | <i>Frangula alnus</i> Mill. | | + | | S |
| | FABACEAE | | | | |
| | <i>Astragalus</i> L. | | | | |
| 32 | <i>Astragalus albicaulis</i> DC. | + | | | SDS |
| 33 | <i>Astragalus brachylobus</i> DC. | + | | | S |
| 34 | <i>Astragalus macroceras</i> C.A. Mey. | + | | | SS |
| 35 | <i>Astragalus macropus</i> Bunge. | + | | | SS |
| 36 | <i>Astragalus vulpinus</i> Willd. | + | | | SS |
| | <i>Caragana</i> L. | | | | |
| 37 | <i>Caragana balchaschensis</i> (Kom.) Pojark. | | + | | S |
| | <i>Hedysarum</i> L. | | | | |
| 38 | <i>Hedysarum razoumovianum</i> Fisch. et Helm. | + | | + | SDS |
| 39 | <i>Hedysarum tsherkassovae</i> Knjasev sp.nov | + | + | | PH |
| | ZYGOPHYLLACEAE | | | | |
| | <i>Zygophyllum</i> L. | | | | |
| 40 | <i>Zygophyllum pinnatum</i> Cham. | + | | | PH |
| | SANTALACEAE | | | | |
| | <i>Thesium</i> L. | | | | |
| 41 | <i>Thesium arvense</i> Horvátovszky | + | + | | PH |
| | APIACEAE | | | | |
| | <i>Seseli</i> L. | | | | |
| 42 | <i>Seseli eriocephalum</i> (Pall. ex Spreng.) Schischk. | + | + | + | PH |
| 43 | <i>Seseli libanotis</i> (L.) Koch | + | + | + | PH |
| | CAPRIFOLIACEAE | | | | |
| 44 | <i>Lonicera tatarica</i> L. | | + | | S |
| | DIPSACACEAE | | | | |
| | <i>Cephalaria</i> Schrad. | | | | |
| 45 | <i>Cephalaria uralensis</i> (Mur.) Roem. et Schult. | + | + | | SDS |
| | <i>Scabiosa</i> L. | | | | |
| 46 | <i>Scabiosa isetensis</i> L. | + | + | + | PH |
| | Lamiidae RUBIACEAE | | | | |
| | <i>Galium</i> L. | | | | |
| 47 | <i>Galium ruthenicum</i> Willd. | + | + | + | PH |

| CONVOLVULACEAE | | | | | |
|-----------------------|---|---|---|---|-----|
| <i>Convolvulus</i> L. | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 |
| 48 | <i>Convolvulus fruticosus</i> Pall. | + | | | SS |
| 49 | <i>Convolvulus lineatus</i> L. | + | | | SS |
| BORAGINACEAE | | | | | |
| <i>Onosma</i> L. | | | | | |
| 50 | <i>Onosma borysthenica</i> Klok. | + | + | + | ABH |
| 51 | <i>Onosma polychroma</i> Klok. ex M. Pop. | + | | + | PH |
| SCROPHULARIACEAE | | | | | |
| <i>Linaria</i> Mill. | | | | | |
| 52 | <i>Linaria cretacea</i> Fisch. ex Spreng. | + | | | PH |
| <i>Pedicularis</i> L. | | | | | |
| 53 | <i>Pedicularis dasystachys</i> Schrenk | + | | | PH |
| <i>Verbascum</i> L. | | | | | |
| 54 | <i>Verbascum phoeniceum</i> L. | | + | | PH |
| <i>Veronica</i> L. | | | | | |
| 55 | <i>Veronica incana</i> L. | + | + | + | PH |
| 56 | <i>Veronica spuria</i> L. | + | + | | PH |
| LAMIACEAE | | | | | |
| <i>Phlomis</i> L. | | | | | |
| 57 | <i>Phlomis tuberosa</i> L. | + | + | | PH |
| <i>Salvia</i> L. | | | | | |
| 58 | <i>Salvia stepposa</i> Shost. | + | | | PH |
| Thymus L. | | | | | |
| 59 | <i>Thymus marschallianus</i> Willd. | + | + | + | SDS |
| Asteridae ASTERACEAE | | | | | |
| <i>Achillea</i> L. | | | | | |
| 60 | <i>Achillea nobilis</i> L. | + | + | | PH |
| <i>Anthemis</i> L. | | | | | |
| 61 | <i>Anthemis trotzkiana</i> Claus ex Bunge. | + | | + | SDS |
| <i>Artemisia</i> L. | | | | | |
| 62 | <i>Artemisia gracilescens</i> Krasch. et Iljin. | | + | | SDS |
| 63 | <i>Artemisia salsoloides</i> Willd. | + | + | + | SDS |
| 64 | <i>Artemisia terrae-albae</i> Krasch. | + | + | + | SDS |
| <i>Centaurea</i> L. | | | | | |
| 65 | <i>Centaurea adpressa</i> Ledeb. | + | + | | PH |
| <i>Cousinia</i> | | | | | |
| 66 | <i>Cousinia astracanic</i> (Spreng.) Tamamsch. | + | + | + | PH |
| <i>Galatella</i> L. | | | | | |
| 67 | <i>Crinitaria linosyris</i> (L.) Less. | + | + | + | PH |
| 68 | <i>Crinitaria villosa</i> (L.) Grossh. | + | | | PH |
| <i>Echinops</i> L. | | | | | |
| 69 | <i>Echinops ritro</i> L. | + | + | | PH |
| 70 | <i>Echinops meyeri</i> (DC.) Iljin | | | + | PH |

Continuation of Table 2

| 1 | 2 | 3 | 4 | 5 | 6 |
|----|---|---|---|---|-----|
| | <i>Hieracium</i> L. | | | | |
| 71 | <i>Hieracium virosum</i> Pall. | | + | | PH |
| | <i>Inula</i> L. | | | | |
| 72 | <i>Inula multicaulis</i> Kar. | + | | | SS |
| | <i>Jurinea</i> L. | | | | |
| 73 | <i>Jurinea kirghisoroum</i> Janisch. | + | | | SDS |
| | <i>Serratula</i> L. | | | | |
| 74 | <i>Serratula wolfii</i> Andrae | + | + | | PH |
| | <i>Tanacetum</i> L. | | | | |
| 75 | <i>Tanacetum millefolium</i> (L.) Tzvel. | + | + | | PH |
| | LILIOPSIDA Liliidae | | | | |
| | IRIDACEAE | | | | |
| | <i>Iris</i> L. | | | | |
| 76 | <i>Iris scariosa</i> Willd. ex Link | + | | | PH |
| | LILIACEAE | | | | |
| | <i>Tulipa</i> L. | | | | |
| 77 | <i>Tulipa biebersteiniana</i> Schult. et Schult. fil. | + | | | PH |
| | ALLIACEAE | | | | |
| | <i>Allium</i> L. | | | | |
| 78 | <i>Allium globosum</i> Bieb. ex Redouté. | + | | | PH |
| | POACEAE | | | | |
| | <i>Agropyron</i> Gaertn. | | | | |
| 79 | <i>Agropyron desertorum</i> (Fisch. ex Link.) Schult. | | + | + | PH |
| | <i>Koeleria</i> Pers. | | | | |
| 80 | <i>Koeleria cristata</i> (L.) Pers. | + | + | + | PH |
| | <i>Psathyrostachys</i> | | | | |
| 81 | <i>Psathyrostachys juncea</i> (Fisch.) Nevski | + | + | + | PH |
| | <i>Stipa</i> L. | | | | |
| 82 | <i>Stipa sareptana</i> A. Beck. | + | + | + | |
| 83 | <i>Stipa capillata</i> L. | + | + | + | PH |
| | Кл. GNETOPSIDA | | | | |
| | EPHEDRACEAE | | | | |
| | <i>Ephedra</i> L. | | | | |
| 84 | <i>Ephedra distachya</i> L. | + | | | PH |
| | Note. Life forms: S — shrub; Ss — semi-shrub; DS — dwarf shrub; SDD — semi-dwarf shrub; PH — perennial herbs; ABH — annual and biennial herbs | | | | |

Thus, 71 species belonging to 58 genera and 25 families were identified in the territory of the first population. The second population consists of 46 species belonging to 39 genera and 18 families. The third population includes 37 species belonging to 32 genera and 16 families.

As a result of the determination of the cenoflora of three populations of *Anabasis cretacea*: 84 plant species belonging to 68 genera and 27 families were identified (see Table 2). Life forms have been identified (Table 2), the leading flora families (Fig. 6).

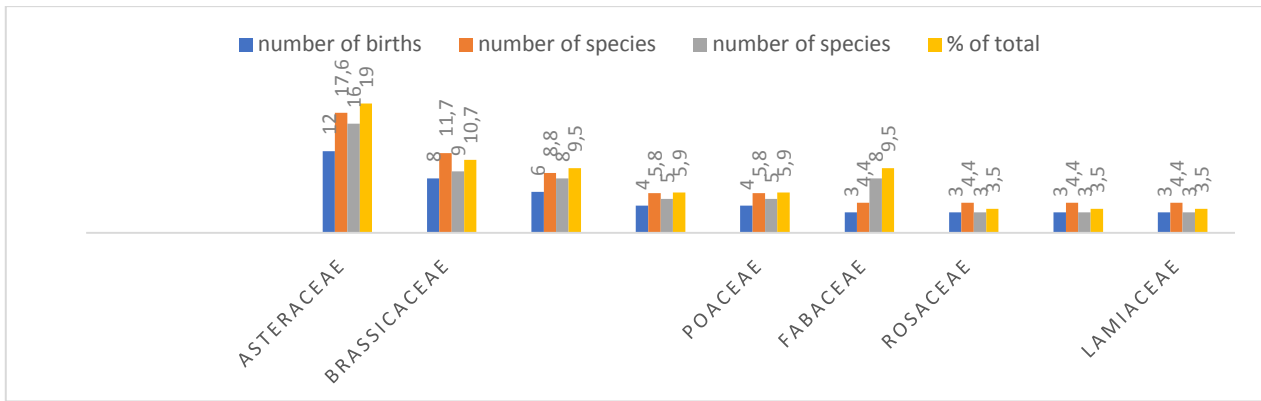


Figure 6. Leading families of the flora of *Anabasis cretacea* Pall.

As shown in Table 3, the 9 leading families account for 60 species, which is 69.7 (%) of the total composition of the cenoflora.

The most numerous in their species composition are such families as: Asteraceae (16 species), Brassicaceae (9 species), Chenopodiaceae (8 species), Scrophulariaceae (5 species), Poaceae (4 species). The leading genera are *Astragalus* L. (5 species), *Anabasis* L. (3 species), and *Artemisia* L. (3 species).

As in the flora of the Aktobe floral district (AFD) [48], Asteraceae ranks first in terms of the number of species. Brassicaceae occupies the second position in terms of the number of species, which is in third place in the flora of the AFD. This is due to the greater proportion of steppe species in the study area.

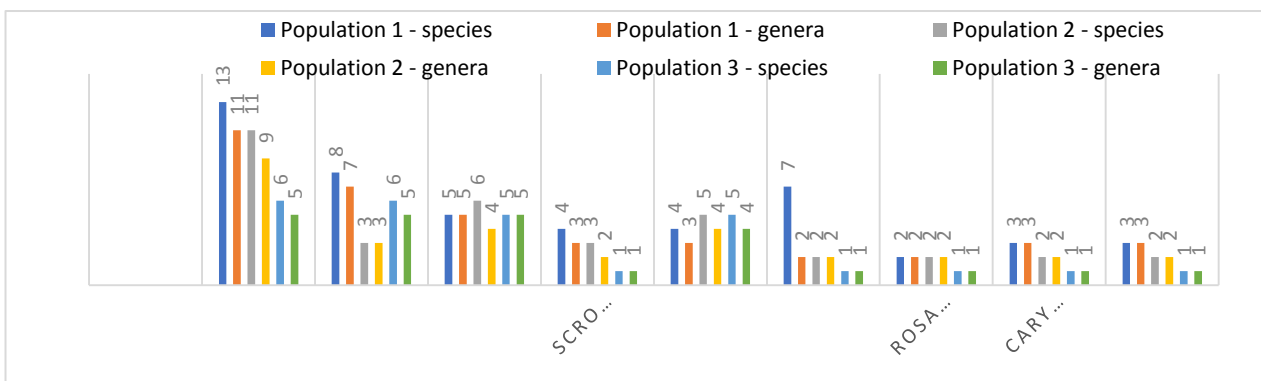


Figure 7. Comparative characteristics of species and genera by family in populations

In the first population, the family Asteraceae is represented by 13 species, Brassicaceae — 8 species, Fabaceae — 7 species, Chenopodiaceae — 5 species; in the second population, Asteraceae — 11 species, Chenopodiaceae — 6 species, Poaceae — 5 species; in the third population, Brassicaceae are more numerous — 7 species, Asteraceae — 6 species, Chenopodiaceae and Poaceae — 5 species. The remaining families are represented (19 families) by 1-2 species in each population (Fig. 7).

In addition, in the cenoflora of *Anabasis cretacea*, a significant number are perennial — 79 species, and biennial (annual-biennial) — 5 species (Fig. 8).

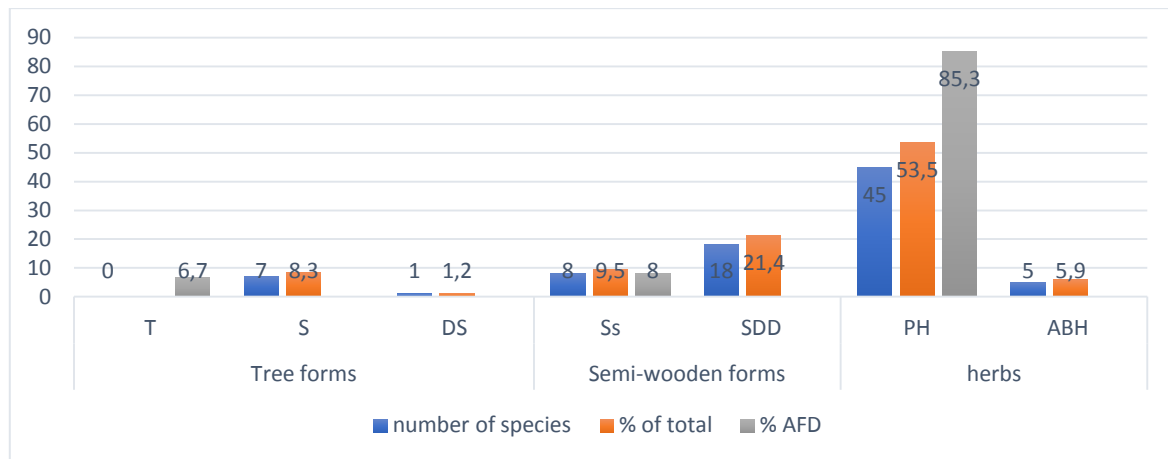


Figure 8. Proportion of life forms in different types of vegetation (%)

We have compared the ratio of life forms in different types of plants with AFD. The comparison revealed that the percentage of tree forms in the study area (9.5 %) is higher than the AFD index by 2.8 %. Herbaceous plants account for 59.5 %, which is 25.8 % less than in the flora of the AFD [48]. This is due to a large proportion of steppe species.

As shown in Table 5, the overwhelming majority of woody and semi-woody forms are represented by subshrubs (8 species), semi-dwarf shrubs (18 species), shrubs (7 species), and dwarf shrubs (1 species). There are 46 species of perennial herbaceous plants, and 5 species of biennial herbaceous plants.

Conclusion

The ecological and cenotic state and floral composition of 9 cenopopulations of the relict species *Anabasis cretacea* Pall. have been studied on the territory of Aktobe region. Calcifytic endemes are dominant in the community of three populations, which is explained by the ecological conditions of the habitats.

The cenoflora of *Anabasis cretacea* includes 84 species belonging to 27 families and 68 genera. Numerous families by species composition are Asteraceae (16 species), Brassicaceae (9 species), Chenopodiaceae (8 species), Fabaceae (8 species), Scrophulariaceae (5 species), Poaceae (5 species). The leading genera are *Astragalus* L. (5 species), *Anabasis* L. (3 species), and *Artemisia* L. (3 types).

In order to preserve the distinctive Cretaceous flora, including relict and endemic species such as *Anabasis cretacea*, a micro-reserve should be established on the Akshatau massif in the vicinity of S. Uil, as previously proposed by Aipeisova (2013) [48], which will ensure the limitation of anthropogenic impact.

Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Kozhabergenova A.B.** — conceptualization, investigation, writing-original draft preparation, formal analysis project administration; **Aipeisova S.A.** — conceptualization, investigation, data curation, methodology, project administration; **Atayeva G.M.** — visualization, investigation; **Maniukiewicz W.** — review and editing, supervision; **Silantiyeva M.M.** — methodology, review, supervision.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Матяшенко Г.В. Динамика растительности на меловых обнажениях Подуральского плато / Г.В. Матяшенко. — Новосибирск: Наука, 1985. — 111 с.
- 2 Güldenstädt J.A. Reisen durch Russland und im Caucasischen Gebürge / J.A. Güldenstädt; Auf Befehl der Russisch-Kayserlichen Akademie der Wissenschaften herausgegeben von P.S. Pallas. — 1787. — Saint Petersburg. Bd 1; Bd 2.

- 3 Гильденштедт И.А. Дневник путешествия в Южную Россию в 1773–1774 гг. / И.А. Гильденштедт // Записки Одесского общества истории и древностей. — 1879. — Т. 11. — С. 180–228.
- 4 Литвинов Д.И. О реликтовом характере флоры каменистых склонов в Европейской России / Д.И. Литвинов // Труды Ботанического музея Императорской Академии наук. — СПб., вып. 1. — С. 76–109.
- 5 Дубянский В.А. Характер растительности меловых обнажений в бассейне р. Хопра / В.А. Дубянский // Известия Санкт-Петербургского ботанического сада. — 1905. — Вып. 5(3).
- 6 Козо-Полянский Б.М. В стране живых ископаемых: очерк из истории горных боров на степной равнине ЦЧО / Б.М. Козо-Полянский. — М.: Госучпедиздат, 1931. — 184 с.
- 7 Володина Н.Г. Флора меловых обнажений Волгоградской области / Н.Г. Володина // Флора степей и полупустынь. — Волгоград, 1982. — С. 34–47.
- 8 Didukh, Y. Syntaxonomy of chalk outcrop vegetation of the order Thymo cretacei-Hyssopetalia cretacei / Y. Didukh, O. Chusova, O. Demina // Hacquetia. — 2018. — 17(1). — 85–109. <https://doi.org/10.1515/hacq-2017-0013>
- 9 Tansley A.G. Studies of the vegetation of the English chalk. I. Early stages of development of woody vegetation on chalk grassland / A.G. Tansley // Journal of Ecology. — 1920. — Vol. 10.
- 10 Tansley A.G. Studies of the vegetation of the English chalk. III. The chalk grasslands of the Hampshire-Sussex border / A.G. Tansley, R.S. Adamson // Journal of Ecology. — 1925. — Vol. 13, No. 2. — P. 177–223.
- 11 Hope-Simpson J.F. Studies of the vegetation of the English chalk. VI. Late stages in succession leading to chalk grassland / J.F. Hope-Simpson // Journal of Ecology. — 1940. — Vol. 28, No. 2. — P. 386–402. <https://doi.org/10.2307/2256236>
- 12 Lloyd P.S. The influence of soil conditions on the course of succession on the chalk of Southern England / P.S. Lloyd, C.D. Pigott // Journal of Ecology. — 1967. — Vol. 55, No. 1. — P. 137–146.
- 13 Butaye J. Phytosociology and phytogeography of the calcareous grasslands on Devonian limestone in southwest Belgium [Electronic resource] / J. Butaye, O. Honnay, D. Adriaens, L.M. Delescaille, M. Hermy // Belgian Journal of Botany. — 2005. — Vol. 138, No. 1. — P. 24–38. — Access mode: <http://www.jstor.org/stable/20794563>
- 14 Янишевский Д.Э. *Jurinea kirghisorum* / Д.Э. Янишевский // Труды Общества естествоиспытателей при Казанском университете. — 1905. — Т. XV, вып. 1. — С. 1–16.
- 15 Кольченко О.Т. К изучению флоры меловых обнажений Подуральского мелового плато / О.Т. Кольченко, Л.И. Макарова // Материалы по флоре и растительности Северного Прикаспия. — Л.: Изд-во АН СССР, 1966. — Т. 2. — Ч. III. — С. 143–154.
- 16 Черкасова Г.И. Новый вид морской лаванды из меловых обнажений Западного Казахстана / Г.И. Черкасова // Бюллетень Московского общества испытателей природы. Отдел биологии. — 1970. — № 4. — С. 216.
- 17 Сафронова И.Н. О растительности меловых возвышенностей степной части Актыубинской области / И.Н. Сафронова // Ботанический журнал. — 1974. — Т. 59, № 11. — С. 1640–1647.
- 18 Горчаковский П.Л. Флора меловых холмов Западного Казахстана / П.Л. Горчаковский, Г.В. Матяшенко // Тезисы докладов XII Международного ботанического конгресса. — Л.: Изд-во АН СССР, 1975. — Т. 1. — С. 128.
- 19 Куприянов А.Н. Ценофлора катрана татарского (*Crambe tatarica* Sebeók) в Западном Казахстане / А.Н. Куприянов, Б.А. Туралин, Н.В. Курбатова, М.С. Курманбаева, К.Т. Абидулова, А.А. Базаргалиева // Экспериментальная биология. — 2020. — Т. 82, № 1. — С. 52–62. <https://doi.org/10.26577/eb.2020.v82.i1.04>
- 20 Каримова О.А. М. Анализ современного состояния популяций редких видов растений природного памятника Троицкие меловые горы (Оренбургская область) / О.А. Каримова, Л.М. Абрамова, Ю.М. Голованов // Arid Ecosyst. — 2017. — Т. 7, № 1. — С. 41–48. <https://doi.org/10.1134/S2079096117010073>
- 21 Голованов Ю.М. Меловые возвышенности Оренбургской области — уникальный ареал редких видов растений и растительных сообществ / Ю.М. Голованов, Л.М. Абрамова // Arid Ecosyst. — 2019. — Т. 9, № 1. — С. 89–96. <https://doi.org/10.1134/S2079096119020069>
- 22 Голованов Ю.М. Особенности флоры меловых возвышенностей Приуралья и сопредельных территорий / Ю.М. Голованов, С.М. Ямалов // Арид Экосист. — 2025. — Т. 15, № 1. — С. 58–68. <https://doi.org/10.1134/S2079096124700574>
- 23 Винтерголлер Б.А. Редкие растения Казахстана / Б.А. Винтерголлер. — Алма-Ата: Издательство Наука КазССР, 1976. — 200 с.
- 24 Lu Y. Relict plants are better able to adapt to climate change: Evidence from desert shrub communities / Y. Lu, B. Zhang, M. Zhang, M. Jie, S. Guo, Y. Wang // Plants. — 2023. — Vol. 12. <https://doi.org/10.3390/plants12234065>
- 25 Дарбаева Т.Е. Эколого-исторические свиты флоры меловых возвышенностей Северо-Западного Казахстана / Т.Е. Дарбаева // Ботанический журнал. — 2003. — Т. 88, № 9.
- 26 Айпеисова С.А. Редкие и исчезающие растения Актыубинской области: учебное пособие / С.А. Айпеисова. — Актобе, 2011. — 165 с.
- 27 Айпеисова С.А. К истории формирования флоры Актыубинского флористического округа и обзор реликтов / С.А. Айпеисова // Известия Национальной академии наук Республики Казахстан. Серия биологическая и медицинская. — 2013. — № 1 (295). — С. 3–9.
- 28 Красная книга Оренбургской области: редкие и находящиеся под угрозой исчезновения виды животных, растений и грибов / Институт степи Уральского отделения Российской академии наук. — Воронеж: ООО «МИР», 2019. — 488 с.

- 29 Красная книга Саратовской области: грибы, лишайники, растения, животные / Министерство природных ресурсов и экологии Саратовской области. — Саратов: Папирус, 2021. — 496 с.
- 30 Красная книга Челябинской области: животные, растения, грибы / Министерство экологии Челябинской области; Областное государственное учреждение «Особо охраняемые природные территории Челябинской области». — Москва, 2005.
- 31 Красная книга Республики Башкортостан [в 2-х т.] / под ред. Б.Н. Миркина. — 2-е изд., доп. и перераб. — Уфа: МедиаПринт, 2011. — Т. 1: Растения и грибы. — 383 с.
- 32 Дарбаева Т.Е. Конспект флоры меловых возвышенностей Северо-Западного Казахстана / Т.Е. Дарбаева. — Уральск, 2002. — 132 с.
- 33 Darbayeva, T.E. Chalk hills of northwestern Kazakhstan as a biodiversity refugium [Electronic resource] / T.E. Darbayeva, N.Y. Ramazanova // Bulletin of European Grassland Group. — 2012. — Vol. 17. — P. 15–18. — Access mode: <https://edgg.org/publ/members/SP0042.pdf>
- 34 Айпеисова С.А. Конспект флоры Актыбинского флористического округа / С.А. Айпеисова. — Актобе, 2012. — 34 с.
- 35 Флора Казахстана / под ред. Н.В. Павлова. — Алма-Ата: Издательство Академии наук КазССР, 1960. — Т. 3. — С. 288-289.
- 36 Серебряков И.Г. Экологическая морфология растений. Жизненные формы покрытосеменных и хвойных / И.Г. Серебряков. — М.: Высшая школа, 1962. — 380 с.
- 37 Шенников А.П. Экология растений / А.П. Шенников. — М.: Советская наука, 1950. — 375 с.
- 38 Работнов Т.А. Жизненный цикл многолетних травянистых растений в луговых ценозах / Т.А. Работнов // Труды БИН АН СССР. Серия 3. Геоботаника. — 1950. — Т. 6. — С. 7–204.
- 39 Иллюстрированный определитель растений Казахстана / под ред. В.П. Голоскокова. — Алма-Ата: Изд-во «Наука» Казахской ССР, 1969. — Т. 1. — 644 с.
- 40 Тахтаджян А.Л. Цветковые растения / А.Л. Тахтаджян. — 2-е изд. — 2009. — 871 с.
- 41 Черепанов С.К. Сосудистые растения СССР / С.К. Черепанов. — Л.: Наука, 1981. — 510 с.
- 42 Абдулина С.А. Список сосудистых растений Казахстана / С.А. Абдулина; под ред. Р.В. Камелина. — Алматы, 1998. — 187 с.
- 43 Арыстангалиев С.А. Растения Казахстана / С.А. Арыстангалиев, Э.Р. Рамазанов. — Алма-Ата: Гылым, 1977. — 77 с.
- 44 Гельдыева Г.В. Ландшафты Казахстана / Г.В. Гельдыева, Л.К. Веселова. — Алма-Ата: Гылым, 1992. — 175 с.
- 45 Сергеева А.М. Природное и культурное наследие Актыбинской области: охрана и рациональное использование / А.М. Сергеева, А.Ж. Эбденов, А.М. Мадемов, Г.Ж. Сулейменова, Ф.С. Досмуратов. — Алматы: Казахское национальное географическое общество, 2016. — 208 с.
- 46 Смелянский И. Ишкаргантау: фотографии ландшафтов и местообитаний [Электронный ресурс] / И. Смелянский. — 2012. — Режим доступа: <https://www.plantarium.ru/lang/en/page/landscapes/point/1880.html> (дата обращения: 20.10.2025).
- 47 Агроклиматические ресурсы Актыбинской области: научно-прикладной справочник / под ред. С.С. Байшоланова. — Астана: [б. и.], 2017. — 136 с.
- 48 Айпеисова С.А. Флора Актыбинского флористического округа / С.А. Айпеисова. — Актобе, 2013. — С. 156–185.

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Актобе облысындағы *Anabasis cretacea* Pall. реликті түрінің ценофлорасы

Мақалада Актобе облысындағы *Anabasis cretacea* Pall. реликті түрінің ценофлорасын (маусым-қыркүйек, 2025) зерттеу нәтижелері келтірілген, бұл *Anabasis cretacea* Pall. бор таулары мен шындарына сәйкес келетіндігін растады. Қазіргі уақытта зерттеліп отырған аумақта оның табиғи популяциялары мен қорғау шаралары туралы мәліметтер шектеулі, бұл жүргізілген жұмыстың өзектілігін айқындайды. Гербарий материалдары мен далалық зерттеулерді зерттеу барысында бөлінген 9 ценопопуляцияны сипаттай отырып, Қобда және Ойыл аудандарында *Anabasis cretacea* Pall. популяцияларының таралу орындары анықталды. Өсімдіктер қауымдастығының құрамы, *Anabasis cretacea* Pall. популяцияларының экологиялық-ценотикалық жарамдылығы айқындалды, мұнда ценофлора зерттелетін популяциялар пайда болатын кальцефитті тіршілік ету ортасының экологиялық жағдайларын көрсетеді. Жетекші тұқымдастар — Asteraceae (16 түр), Brassicaceae (9 түр), Chenopodiaceae (8 түр), Scrophulariaceae (5 түр), Poaceae (4 түр). Басым тұқымдастар — *Astragalus* L. (5 түр), *Anabasis* L. (3 түр), *Artemisia* L. (3 түр). Экобиологиялық талдау шалғынды түрлердің аз болуымен ценофлораның шөл-дала сипатын растады. *Anabasis cretacea* Pall. ценофлорасының толық тізімі ұсынылған, мұнда 68 туысқа, 27 тұқымдасқа жататын 84 түрі анықталды. Осылайша Актобе облысындағы *Anabasis cretacea* Pall. ценофлорасының қазіргі жағдайына баға берілді.

Кілт сөздер: *Anabasis cretacea* Pall., ценопопуляция, ценофлора, өсімдіктер қауымдастығы, тіршілік формасы.

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Ценофлора реликтового вида *Anabasis cretacea* Pall. в Актюбинской области

В статье представлены результаты исследования (июнь-сентябрь, 2025 г.) ценофлоры реликтового вида *Anabasis cretacea* Pall. в Актюбинской области, что подтвердило приуроченность *Anabasis cretacea* Pall. к меловым возвышенностям и чинкам. На данный момент сведения о его природных популяциях и охране на исследуемой территории остаются ограниченными, что подчёркивает актуальность проведённой работы. В ходе изучения гербарных материалов и полевых исследований определены места распространения популяций *Anabasis cretacea* Pall. в Хобдинском и Уилском районах, с описанием выделенных 9 ценопопуляций. Определен состав растительного сообщества, эколого-ценотическая приспособленность популяций *Anabasis cretacea* Pall., где ценофлора отражает экологические условия кальцефитных местообитаний, в которых формируются исследуемые популяции. Ведущими семействами являются Asteraceae (16 видов), Brassicaceae (9 видов), Chenopodiaceae (8 видов), Scrophulariaceae (5 видов), Poaceae (4 вида). Доминирующими родами являются *Astragalus* L. (5 видов), *Anabasis* L. (3 вида), *Artemisia* L. (3 вида). Экобиологический анализ подтвердил пустынно-степной характер ценофлоры с незначительным участием луговых видов. Представлен полный перечень ценофлоры *Anabasis cretacea* Pall., где выявлено 84 вида, относящихся к 68 родам и 27 семействам. Таким образом, дана оценка современному состоянию ценофлоры *Anabasis cretacea* Pall. в Актюбинской области.

Ключевые слова: *Anabasis cretacea* Pall., ценопопуляция, ценофлора, растительные сообщества, жизненная форма.

References

- 1 Matyashenko, G.V. (1985). *Dinamika rastitelnosti na melovykh obnazheniakh Podural'skogo plato* [Vegetation dynamics on chalk outcrops of the sub-Ural plateau]. Novosibirsk: Nauka [in Russian].
- 2 Güldenstädt, J.A. (1787). *Reisen durch Russland und im Caucasischen Gebürge* [Travels through Russia and in the Caucasian Mountains]. (Vols. 1–2, P.S. Pallas, Ed.). Saint Petersburg: Imperial Academy of Sciences [in German].
- 3 Gildenstedt, I.A. (1879). *Dnevnik puteshestviia v Yuzhnuu Rossiiu v 1773–1774 gg.* [Diary of a journey to Southern Russia in 1773–1774]. *Zapiski Odesskogo obshchestva istorii i drevnostei — Notes of the Odessa Society of History and Antiquities*, 11, 180–228 [in Russian].
- 4 Litvinov, D.I. (1902). О реликтовом характере флоры каменистых склонов в Европейской России [On the relict nature of the flora of rocky slopes in European Russia]. *Trudy Botanicheskogo muzeia Imperatorskoi Akademii nauk — Proceedings of the Botanical Museum of the Imperial Academy of Sciences*, 1, 76–109. Saint Petersburg [in Russian].
- 5 DUBYANSKY, V.A. (1905). Kharakter rastitelnosti melovykh obnazhenii v basseine reki Hopra [The nature of vegetation of chalk outcrops in the Koper River basin]. *Izvestiia Sankt-Peterburgskogo botanicheskogo sada — News of the St. Petersburg Botanical Garden*, 5(3). Saint Petersburg [in Russian].
- 6 Kozo-Polyansky, B.M. (1931). *V strane zhivyykh iskopaemykh: Ocherk iz istorii gornyykh borov na stepnoi ravnine TsChO* [In the land of living fossils: an essay on the history of mountain pine forests on the steppe plain of the Central Caucasus]. Moscow: Gosuchpedizdat [in Russian].
- 7 Volodina, N.G. (1982). Flora melovykh obnazhenii Volgogradskoi oblasti [Flora of chalk outcrops of the Volgograd region]. *Flora stepei i polupustyn — Flora of steppes and semi-deserts* (pp. 34–47). Volgograd [in Russian].
- 8 Didukh, Y., Chusova, O., & Demina, O. (2018). Syntaxonomy of chalk outcrop vegetation of the order Thymo cretacei-Hyssopetalia cretacei. *Hacquetia*, 17(1), 85–109. <https://doi.org/10.1515/hacq-2017-0013>
- 9 Tansley, A.G. (1920). Studies of the vegetation of the English chalk. I. Early stages of development of woody vegetation on chalk grassland. *Journal of Ecology*, 10, 1.
- 10 Tansley, A.G., & Adamson, R.S. (1925). Studies of the vegetation of the English chalk. III. The chalk grasslands of the Hampshire Sussex border. *Journal of Ecology*, 13(2), 177–223.
- 11 Hope-Simpson, J.F. (1940). Studies of the Vegetation of the English Chalk: VI. Late Stages in Succession Leading to Chalk Grassland. *Journal of Ecology*, 28(2), 386–402. <https://doi.org/10.2307/2256236>
- 12 Lloyd, P.S., & Pigott, C.D. (1967). The influence of soil conditions on the course of succession on the chalk of Southern England. *Journal of Ecology*, 55(1), 137–146.
- 13 Butaye, J., Honnay, O., Adriaens, D., Delescaille, L. -M., & Hermy, M. (2005). Phytosociology and phytogeography of the calcareous grasslands on Devonian limestone in southwest Belgium. *Belgian Journal of Botany*, 138(1), 24–38. Retrieved from <http://www.jstor.org/stable/20794563>

- 14 Yanishevsky, D.E. (1905). *Jurinea kirghisorum*. *Trudy Obshchestva estestvoispytatelei pri Kazanskom universitete — Proceedings of the Society of Naturalists at Kazan University*, 15(1), 1–16 [in Russian].
- 15 Kolchenko, O.T., & Makarova, L.I. (1966). K izucheniiu flory melovykh obnazhenii Podural'skogo melovogo plato [On the study of the flora of chalk outcrops of the Podural Plateau]. *Materialy po flore i rastitelnosti Severnogo Prikaspiia — Materials on flora and vegetation of the Northern Caspian Region*, 2(3), 143–154. Leningrad: Izdatel'stvo Akademii nauk SSSR [in Russian].
- 16 Cherkasova, G.I. (1970). Novyi vid morskoi lavandy iz melovykh obnazhenii Zapadnogo Kazakhstana [A new species of sea lavender from the chalk outcrops of Western Kazakhstan]. *Bulletin Moskovskogo obshchestva ispytatelei prirody. Otdel biologii — Bulletin of the Moscow Society of Nature Testers. Department of Biology*, 4, 216 [in Russian].
- 17 Safronova, I.N. (1974). O rastitelnosti melovykh vozvyshehnostei stepnoi chasti Aktiubinskoi oblasti [On the vegetation of chalk uplands of the steppe part of the Aktobe region]. *Botanicheskii zhurnal — Botanical journal*, 59(11), 1640–1647 [in Russian].
- 18 Gorchakovskiy, P.L., & Matyashenko, G.V. (1975). Flora melovykh kholmov Zapadnogo Kazakhstana [The flora of chalk hills of Western Kazakhstan]. *Tezisy dokladov XII Mezhdunarodnogo botanicheskogo kongressa — Abstracts of the XII International Botanical Congress, 1*, 128. Leningrad: Izdatel'stvo Akademii nauk SSSR [in Russian].
- 19 Kupriyanov, A.N., Turalin, B.A., Kurbatova, N.V., Kurmanbayeva, M.S., Abidkulova, K.T., & Bazargaliev, A.A. (2020). Tsenoflora katrana tatarskogo (*Crambe tataria* Sebeók) v Zapadnom Kazakhstane [Cenoflora of *Crambe tataria* Sebeók in Western Kazakhstan]. *Ekspierimental'naiia biologiiia — Experimental biology*, 82(1), 52–62. <https://doi.org/10.26577/eb.2020.v82.i1.04> [in Russian].
- 20 Karimova, O.A., Abramova, L.M., & Golovanov, Y.M. (2017). Analiz sovremennogo sostoiianiia populiatsii redkikh vidov rastenii prirodnoho pamiatnika Troitskie melovye gory (Orenburgskaia oblast) [Analysis of the current state of populations of rare plant species of the natural monument Troitskie chalk hills (Orenburg region)]. *Arid Ecosystems*, 7(1), 41–48. <https://doi.org/10.1134/S2079096117010073> [in Russian].
- 21 Golovanov, Y.M., & Abramova, L.M. (2019). Melovye vozvyshehnosti Orenburgskoi oblasti — unikalnyi areal redkikh vidov rastenii i rastitelnykh soobshchestv [Chalk uplands of the Orenburg region — a unique habitat for rare plant species and plant communities]. *Arid Ecosystems*, 9(1), 89–96. <https://doi.org/10.1134/S2079096119020069> [in Russian].
- 22 Golovanov, Y.M., & Yamalov, S.M. (2025). Osobennosti flory melovykh vozvyshehnostei Priuralia i sopredelnykh territorii — Features of the flora of chalk uplands of the Pre-Urals and adjacent territories. *Arid Ecosystems*, 15(1), 58–68. <https://doi.org/10.1134/S2079096124700574> [in Russian].
- 23 Vintergoller, B.A. (1976). *Redkie rasteniia Kazakhstana* [Rare plants of Kazakhstan]. Alma-Ata: Izdatel'stvo Nauka KazSSR [in Russian].
- 24 Lu, Y., Zhang, B., Zhang, M., Jie, M., Guo, S., & Wang, Y. (2023). Relict plants are better able to adapt to climate change: Evidence from desert shrub communities. *Plants*, 12. <https://doi.org/10.3390/plants12234065>
- 25 Darbaeva, T.E. (2003). Ekologo-istoricheskie svity flory melovykh vozvyshehnostei Severo-Zapadnogo Kazakhstana [Ecological and historical suites of the flora of Cretaceous uplands of Northwestern Kazakhstan]. *Botanicheskii Zhurnal — Botanical Journal*, 88(9) [in Russian].
- 26 Aypeisova, S.A. (2011). *Redkie i ischezaiushchie rasteniia Aktiubinskoi oblasti: Uchebnoe posobie* [Rare and endangered plants of the Aktobe region: A textbook]. Aktobe [in Russian].
- 27 Aypeisova, S.A. (2012). K istorii formirovaniia flory Aktiubinskogo floristicheskogo okruga i obzor reliktoev [On the history of flora formation of the Aktobe floristic district and a review of relicts]. *Izvestiia Natsionalnoi Akademii Nauk Respubliki Kazakhstan. Seria biologicheskaiia i meditsinskaiia — Proceedings of the National Academy of Sciences of the Republic of Kazakhstan. The series is biological and medical*, 1(295), 3–9 [in Russian].
- 28 (2019). *Krasnaia kniga Orenburgskoi oblasti: Redkie i nakhodiashchiesia pod ugrozoi ischeznoveniia vidy zhivotnykh, rastenii i gribov* [Red Data Book of the Orenburg Region: Rare and endangered species of animals, plants, and fungi]. Institut stepi Uralskogo otdeleniia Rossiiskoi akademii nauk. Voronezh: OOO «MIR» [in Russian].
- 29 (2021). *Krasnaia kniga Saratovskoi oblasti: Griby, lishainiki, rasteniia, zhivotnye* [Red Data Book of the Saratov Region: Fungi, lichens, plants, and animals]. Saratov: Papirus [in Russian].
- 30 (2005). *Krasnaia kniga Cheliabinskoi oblasti: zhivotnye, rasteniia, griby* [Red Data Book of the Chelyabinsk Region: animals, plants, fungi]. Ministerstvo ekologii Cheliabinskoi oblasti & Oblastnoe gosudarstvennoe uchrezhdenie “Osobo okhraniaemye prirodnye territorii Cheliabinskoi oblasti. Moscow [in Russian].
- 31 (2011). *Krasnaia kniga Respubliki Bashkortostan* [Red Data Book of the Republic of Bashkortostan]. Vols. 1-2. Vol. 1: Rasteniia i griby [Plants and fungi]. Ufa [in Russian].
- 32 Darbayeva, T.E. (2002). *Konspekt flory melovykh vozvyshehnostei Severo-Zapadnogo Kazakhstana* [Conspectus of the flora of the chalky highlands of Northwestern Kazakhstan]. Uralsk [in Russian].
- 33 Darbayeva, T.E., & Ramzanova, N.Yu. (2012). Chalk hills of northwestern Kazakhstan as a biodiversity refugium. *Bulletin of European Grassland Group*, 17, 15–18. Retrieved from <https://www.edgg.org/publ/members/SP0042.pdf>.
- 34 Aypeisova, S.A. (2012). *Konspekt flory Aktiubinskogo floristicheskogo okruga* [Conspectus of the flora of the Aktobe floristic district]. Aktobe [in Russian].
- 35 Pavlov, N.V. (Ed.). (1960). *Flora Kazakhstana* [Flora of Kazakhstan] (Vol. 3, pp. 288-289). Alma-Ata: Izdatel'stvo Akademii nauk KazSSR [in Russian].
- 36 Serebryakov, I.G. (1962). *Ekologicheskaiia morfologiia rastenii: Zhiznennye formy pokrytosemennykh i khvoinykh* [Ecological morphology of plants. Life forms of angiosperms and conifers]. Moscow: Vysshiaia Shkola [in Russian].

- 37 Shennikov, A.P. (1950). *Ekologiya rastenii* [Plant ecology]. Moscow: Sovetskaya Nauka [in Russian].
- 38 Rabotnov, T.A. (1950). Zhiznennyi tsikl mnogoletnikh travianistykh rastenii v lugovykh tsenozakh [Life cycle of perennial herbaceous plants in meadow cenoses]. *Trudy Botanicheskogo Instituta Akademii Nauk SSSR. Seriya 3. Geobotanika — Proceedings of the Botanical Institute of the Academy of Sciences of the USSR. Series 3. Geobotany*, 6, 7–204 [in Russian].
- 39 Goloskokova, V.P. (Ed.). (1969). *Illiustrirovanniyi opredelitel rastenii Kazakhstana* [Illustrated guide to the plants of Kazakhstan]. (Vols. 1-2. Vol. 1.). Alma-Ata: Izdatelstvo “Nauka” Kazakhskoi SSR [in Russian].
- 40 Takhtadzhyan, A.L. (2009). *Tsvetkovye rasteniia* [Flowering plants] (2nd ed.) [in Russian].
- 41 Cherepanov, S.K. (1981). *Sosudistyie rasteniia SSSR* [Vascular plants of the USSR]. Leningrad: Nauka [in Russian].
- 42 Abdulina, S.A. (1998). *Spisok sosudistykh rastenii Kazakhstana* [Checklist of vascular plants of Kazakhstan] (R.V. Kamelin, Ed.). Almaty [in Russian].
- 43 Arystangaliev, S.A., & Ramazanov, E.R. (1977). *Rasteniia Kazakhstana* [Plants of Kazakhstan]. Alma-Ata: Gylym [in Russian].
- 44 Geldyeva, G.V., & Veselova, L.K. (1992). *Landshafty Kazakhstana* [Landscapes of Kazakhstan]. Alma-Ata: Gylym [in Russian].
- 45 Sergeeva, A.M., Abdenov, A.Zh., Mamedov, A.M., Suleimenova, G.Zh., & Dosmuratov, F.S. (2016). *Prirodnoe i kulturnoe nasledie Aktiubinskoi oblasti: Okhrana i ratsionalnoe ispolzovanie* [Natural and cultural heritage of the Aktobe region: Protection and sustainable use]. Almaty: Kazakhstokoe natsionalnoe geograficheskoe obshchestvo [in Russian].
- 46 Smelansky, I. (2012). Ishkargantau: fotografii landshaftov i mestoobitaniia [Ishkargantau: Photographs of landscapes and habitats]. *plantarium.ru*. Retrieved from <https://www.plantarium.ru/lang/en/page/landscapes/point/1880.html> [in Russian].
- 47 Baisholanov, S.S. (Ed.). (2017). *Agroklimaticheskie resursy Aktiubinskoi oblasti: Nauchno-prikladnoi spravochnik* [Agroclimatic resources of the Aktobe region: Scientific and applied reference book]. Astana [in Russian].
- 48 Aipeisova, S.A. (2013). *Flora Aktiubinskogo floristicheskogo okruga* [Flora of the Aktobe floristic district] (pp. 156–185). Aktobe [in Russian].

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Review

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Modern studies on the biodiversity of *Sarcocystis* and their role in ecosystems

The review summarizes current data on the biodiversity of parasites of the genus *Sarcocystis* and their significance for ecosystems, veterinary medicine, and public health. Sarcocystoses are considered diseases of pronounced veterinary and zoonotic importance, as they lead to reduced productivity in farm animals, deterioration of meat quality, and may cause pathological effects in humans. Information on the taxonomic and geographic diversity of representatives of the genus, the specificity of intermediate and definitive hosts, as well as the influence of environmental factors on parasite circulation has been analyzed. It is noted that the actual species diversity of *Sarcocystis* significantly exceeds the number of morphologically described forms, which is associated with the active implementation of molecular genetic identification methods. Modern diagnostic approaches are reviewed, including morphological and histological studies, as well as molecular methods using markers such as 18S rRNA, *cox1*, and ITS-1, which make it possible to clarify taxonomic boundaries, identify cryptic species, and analyze phylogenetic relationships. The need to integrate classical parasitological and molecular methods to improve diagnostic accuracy, enhance monitoring, and develop preventive measures is emphasized. It is concluded that an interdisciplinary approach combining parasitology, epizootology, ecology, and molecular biology is essential, as it provides a deeper understanding of the evolutionary relationships between parasite and host and forms a scientific basis for the effective control and prevention of zoonotic sarcocystosis.

Keywords: *Sarcocystis*, biodiversity, ecology, parasites, morphology, molecular identification, zoonoses, bioindicators.

Introduction

Sarcocystosis is one of the most widespread protozoan infections affecting domestic and wild animals, as well as humans. The causative agents belong to the genus *Sarcocystis* (phylum *Apicomplexa*), which is characterized by a complex life cycle involving obligatory alternation of intermediate and definitive hosts [1–3]. The disease has both veterinary and zoonotic significance, as certain species, such as *S. hominis* and *S. suihominis*, are capable of infecting humans [4–7]. In recent decades, the study of sarcocystosis has acquired an interdisciplinary character, encompassing parasitology, molecular biology, epizootology, and ecology.

The relevance of studying the biodiversity of *Sarcocystis* is determined by its high prevalence, its significant role in animal population dynamics, and its potential use as a bioindicator of ecosystem health. Modern research approaches make it possible not only to refine the taxonomic structure of the genus but also to reveal new aspects of the impact of these parasites on the biosphere [8].

Recent advances in molecular characterization have revolutionized the identification of *Sarcocystis* species, overcoming the limitations of traditional morphological methods. Although morphological features, such as cyst wall structure, have historically been used for diagnosis, they often fail to reliably differentiate closely related species [9, 10]. Molecular genetic methods employing markers such as 18S rRNA, 28S rRNA, ITS-1, and mitochondrial cytochrome c oxidase subunit I (*cox1*) have become essential for taxonomic identification [11]. The *cox1* gene has emerged as a particularly promising DNA barcode marker, demonstrating superior efficiency in discriminating closely related species compared to *ssrRNA* genes, with intra-specific sequence identity of 98.5–100 % and interspecific identity of 58–92 % [12]. These molecular diagnostic approaches have proven to be more time- and cost-effective than electron microscopy and have helped overcome the limited sensitivity of serological methods [10]. Phylogenetic analyses using these markers

have shown that some previously recognized species may represent distinct taxa with specific host ranges [7].

The aim of this review study is to analyze diagnostic methods, systematize and evaluate current approaches to the identification of the genus *Sarcocystis* in animals and humans, and determine their role in understanding the biodiversity and eco-epidemiological significance of these parasites.

This review provides a scientific basis for further investigation of sarcocystosis as a complex biological phenomenon integrating morphological, molecular-genetic, ecological, and veterinary-medical aspects. The data summarized in the review highlight directions for improving diagnostics through the combined use of classical and molecular methods, as well as for developing approaches to the prevention and control of zoonotic forms of the disease.

Experimental

Review method. This review was conducted based on a structured analysis of the scientific literature related to protozoa of the genus *Sarcocystis* Lankester, 1882. Relevant publications were identified through the academic databases Web of Science, Scopus, and RINC, including articles published. The literature search was performed using the following keywords: *Sarcocystis*, biodiversity, molecular identification, parasite ecology, and zoonotic infections. Particular attention was given to studies reporting the application of molecular genetic methods (18S rRNA, *cox1*, ITS-1, and other markers), as well as to data concerning the role of sarcocysts in biocenoses.

Literature sources. The present review is based on the analysis of 62 scientific sources, including a limited number of studies conducted in Kazakhstan, as well as publications devoted to the investigation of sarcocystosis in countries of the Eurasian region. The genus *Sarcocystis* is characterized by exceptional biodiversity and a complex system of host–parasite interactions, which determines the sustained scientific interest and ongoing research activity in this field. Current evidence indicates that the actual number of species considerably exceeds the number of forms described on the basis of morphological characteristics [7]. This discrepancy is largely explained by the broad specificity of definitive hosts and, conversely, the relatively narrow specificity of intermediate hosts, which together create a rich mosaic of species diversity.

Results and Discussion

The genus *Sarcocystis* is characterized by an exceptionally high level of biodiversity and represents one of the most species-rich groups of protozoan parasites among apicomplexan organisms. Members of this genus are obligate intracellular parasites infecting mammals, birds, and reptiles worldwide. Some *Sarcocystis* species have pronounced pathogenic and zoonotic significance for both animals and humans [2, 13].

The combination of an obligatory two-host life cycle, high ecological plasticity, and varying degrees of host specificity contributes to the formation of a complex and mosaic biodiversity structure within this genus. Sarcocystosis is a parasitic disease caused by intracellular protozoan parasites of the genus *Sarcocystis* (phylum *Apicomplexa*, order *Coccidiida*, family *Sarcocystidae*), which is characterized by a complex and, in many aspects, still incompletely resolved taxonomy. The life cycle of these parasites involves an obligate alternation between an intermediate host, typically a herbivorous or omnivorous animal, and a definitive host, usually a carnivorous or omnivorous species [14]. Currently, more than 220 species of *Sarcocystis* have been described, although the complete life cycle has been established only for a limited number of species associated with specific host pairs [2, 15].

Numerous *Sarcocystis* species have been recorded in cattle, each exhibiting distinctive life-cycle characteristics and host associations. The most common and well-studied species include *Sarcocystis cruzi* Hasselmann, 1923 (syn. *S. bovicanis*), with canids as definitive hosts, and *Sarcocystis bovifelis* Hu, Liu, Li, Zhang, Chen, 2017, with felids serving as definitive hosts. In addition, *Sarcocystis hominis* Railliet, 1891 and *Sarcocystis heydorni* Dubey, Fayer, Rosenthal, 2002 have been identified in cattle and are considered zoonotic, as humans may act as definitive hosts following the consumption of infected meat [15]. The presence of these species underscores the importance of sarcocystosis in veterinary sanitary control and food safety systems. Other reported species include *Sarcocystis hirsuta* Railliet, 1886, *Sarcocystis bovifelis*, *Sarcocystis bovini* Blanchard, 1885 and others, reflecting the complex species structure of sarcocysts in this animal group [16].

Sheep and goats are also hosts to multiple *Sarcocystis* species *Sarcocystis tenella* Railliet, 1886 and *Sarcocystis arieticanis* Heydorn, 1975, whereas in goats *Sarcocystis capracanis* Heydorn, 1975 and *Sarcocystis moulei* Levine, 1986 are commonly identified [17]. These species exhibit a high degree of host

specificity and participate in life cycles involving carnivores, such as dogs and cats, as definitive hosts [18]. In contrast to bovine sarcocysts, the zoonotic potential of *Sarcocystis* species identified in sheep and goats is considered limited [19]. Nevertheless, the high prevalence of infection and pronounced tissue localization of sarcocysts make these species important targets for veterinary surveillance and population monitoring in small ruminants.

Recent molecular-genetic studies have demonstrated that even in sheep and goats, whose *Sarcocystis* species composition is considered relatively well characterized, the existence of cryptic species remains likely. This finding highlights the necessity of applying integrative approaches to clarify the true biodiversity of sarcocysts in small ruminants.

Pigs and wild boars serve as intermediate hosts for species such as *Sarcocystis miescheriana* Miescher, 1843 and *Sarcocystis suihominis* Railliet & Lucet, 1891, with the latter regarded as zoonotic because humans may act as definitive hosts after consuming insufficiently cooked pork. Molecular studies have confirmed the presence of these species in the musculature of domestic pigs and wild boars, emphasizing the importance of veterinary sanitary inspection of meat products [20].

Horses serve as intermediate hosts for a relatively limited number of *Sarcocystis* species, in contrast to cattle and small ruminants, which exhibit greater species diversity. The best known and most widespread species associated with horses is *Sarcocystis bertrami* Doflein, 1901 (syn. *S. fayeri*), for which dogs and other canids serve as definitive hosts [20]. Epizootiologically, equine sarcocystosis is closely linked to the presence of dogs, which play a key role in maintaining parasite circulation. Contamination of feed and water with sporocysts shed by definitive hosts is considered the primary route of infection in both agricultural and private farming systems. Although infections are typically subclinical, clinical manifestations, including muscle weakness, reduced performance, and inflammatory changes, may occasionally occur, which is particularly relevant for sport and breeding horses. Specific *Sarcocystis* species have also been described in camels, llamas, and other herbivores, reflecting the parasite's broad adaptive capacity across ecosystems and host networks [21].

A considerable diversity of *Sarcocystis* species has been reported in birds, and for several species the complete life cycle has been elucidated or widespread occurrence documented. Examples include *Sarcocystis falcatula* Stiles, 1893, *Sarcocystis calchasi* Olias, Gruber, Hafez, Heydorn & Mehlhorn, 2009, *Sarcocystis halioti* Prakas, Butkauskas, 2012, and *Sarcocystis wobeseri* Prakas, Butkauskas, Švažas & Juozaitytė-Ngugu, 2014, which infect various avian intermediate hosts, while raptors and other carnivorous species serve as definitive hosts [22]. Studies demonstrate a high species richness of *Sarcocystis* in the musculature of gulls and other birds, as well as substantial intraspecific genetic variability, underscoring the complexity of parasite biodiversity in avifauna.

From an ecological perspective, birds play a crucial role in the dissemination of *Sarcocystis* across large geographic areas, including migratory routes, thereby contributing to parasite circulation in diverse ecosystems. Migration facilitates the transfer of genetically distinct *Sarcocystis* lineages between regions and promotes the formation of complex spatial population structures.

In addition to mammals and birds, *Sarcocystis* species have been recorded in reptiles and other vertebrate groups, further expanding the taxonomic range of this parasite within global fauna [23].

In humans, zoonotic species *Sarcocystis hominis* Railliet & Lucet, 1891 and *Sarcocystis suihominis* Railliet & Lucet, 1891 have been documented, with humans acting as definitive hosts after consuming infected beef or pork, respectively [13]. Clinical manifestations of intestinal sarcocystosis in humans are generally rare and associated with foodborne transmission; however, confirmed cases of muscular sarcocystosis, in which humans serve as intermediate hosts, have been reported only sporadically due to both low detection rates and diagnostic challenges. Current evidence suggests the possible involvement of additional, incompletely characterized *Sarcocystis* species, highlighting the need for further molecular investigations.

The high species diversity of *Sarcocystis* and the complexity of host–parasite interactions make this genus an attractive subject for epizootiological, taxonomic, and molecular studies. In particular, molecular approaches, including analyses of ITS1, *cox1*, and other genetic markers, have facilitated the detection of hidden species diversity, refinement of phylogenetic relationships, and clarification of host specificity patterns within *Sarcocystis* spp.

A summary of the principal *Sarcocystis* species, their hosts, morphological characteristics, and diagnostic methods is presented in Table 1.

Main Sarcocystis species in animals, their morphological characteristics, significance, and diagnostic methods

| Intermediate host | <i>Sarcocystis</i> species | Cyst morphology / wall structure | Significance | Diagnostic methods |
|----------------------------------|---|--|--|--|
| Cattle | <i>S. cruzi</i> , <i>S. hirsuta</i> , <i>S. hominis</i> | Thin-walled (<i>S. cruzi</i>); thick-walled with finger- like protrusions (<i>S.</i> <i>hirsuta</i>) | Animal pathology, human infection risk | Histology, PCR (cox1, 18S rRNA), sequencing |
| Sheep | <i>S. tenella</i> , <i>S. arieticanis</i> | Differences in wall thick- ness | Economic losses, reduced meat quali- ty | Light microscopy, PCR identification |
| Goats | <i>S. capracanis</i> , <i>S. moulei</i> | Differences in cyst wall capsule | Pathology, reduced productivity | Microscopy, molecular markers (ITS-1) |
| Pigs | <i>S. miescheriana</i> , <i>S. suihominis</i> | <i>S. suihominis</i> — thick- walled cysts, zoonotic importance | Human health risk (<i>S. suihominis</i>) | Histology, PCR, immunohistochemistry |
| Domestic birds (ducks, geese) | <i>Sarcocystis rileyi</i> Stiles, 1893, <i>Sarcocystis wobeseri</i> Prakas, Butkauskas, Švažas & Juozaitytė- Ngugu, 2014 | Ducks — multiple cysts in muscles (<i>S. rileyi</i>); geese — thin-walled (<i>S.</i> <i>wobeseri</i>) | Mass infections in wild and domestic birds | Morphology, PCR (cox1), molecular phylogeny |
| Wild birds | <i>Sarcocystis halieti</i> Prakas & Butkauskas, 2012, <i>Sarcocystis</i> <i>columbae</i> Blanchard, 1885 | High morphological di- versity, narrow host spec- ificity | Important role in biocenoses | PCR, sequencing, marker comparison (18S, ITS-1) |
| Humans (intermediate host) | <i>S. hominis</i> , <i>S. suihominis</i> | Thick-walled cysts in muscles | Zoonotic hazard, foodborne infections | Biopsy, histology, molecular methods |

The data presented in Table 1 summarize the species diversity of *Sarcocystis*, their host specificity, and diagnostic approaches, highlighting the complexity of host–parasite relationships and providing a basis for analyzing the role of these parasites in ecosystem functioning [11].

Life cycle

Parasites of the genus *Sarcocystis* require a two-host life cycle with distinct developmental stages occurring in definitive and intermediate hosts, including both sexual and asexual reproduction. In intermediate hosts, only asexual stages of the parasite are present. However, in humans the life cycle may vary: they can act as definitive hosts for certain species, such as *Sarcocystis hominis* (associated with beef consumption) and *S. suihominis* (associated with pork consumption), resulting in intestinal infection (Fig. 1), or as intermediate hosts for other species, for example *S. nesbitti*.

Sarcocystis nesbitti has been identified in humans and non-human primates serving as intermediate hosts, while snakes are presumed to act as definitive hosts. However, this identification is based primarily on phylogenetic comparisons with related species in which snakes were confirmed definitive hosts, and definitive evidence of the complete life cycle has not yet been fully established [6].

In the typical life cycle, definitive hosts become infected by ingesting tissues of intermediate hosts containing mature sarcocysts. Sexual development of the parasite occurs in the intestinal epithelium of the definitive host, resulting in the formation of oocysts that sporulate and release sporocysts, which are shed with feces into the environment. Intermediate hosts acquire infection through ingestion of food or water contaminated with sporocysts. Following invasion, sporozoites undergo a series of asexual developmental stages, including merogony within vascular endothelial cells, before forming tissue cysts (sarcocysts) primarily in skeletal muscles, myocardium, and occasionally in other organs.

The ecological success of *Sarcocystis* is largely attributed to this obligate predator–prey transmission pattern, which facilitates efficient circulation of the parasite within food webs. This life-cycle strategy con-

tributes to the widespread distribution of *Sarcocystis* species and their ability to persist across diverse ecosystems and host communities.

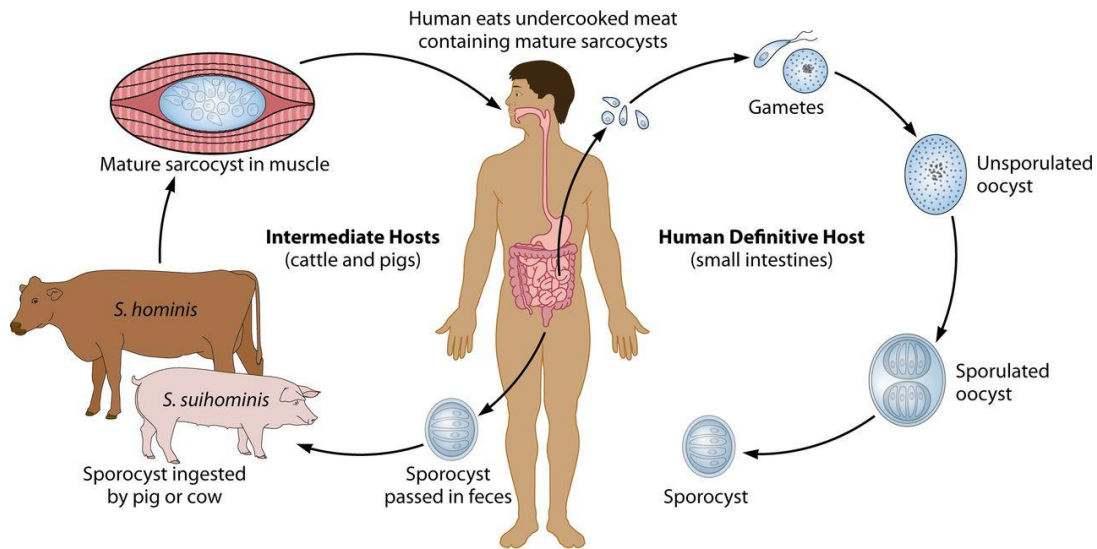


Figure 1. Life cycle of *Sarcocystis* (Fayer R., 2015)

In bovines, the biological life cycle involves carnivores, such as dogs, acting as definitive hosts, while cattle serve as intermediate hosts [24]. The cycle includes three key stages: schizogony (asexual reproduction in intermediate hosts), and gametogony and sporogony (sexual stages occurring in definitive hosts) [25].

After ingestion of sporocysts or oocysts shed in the feces of definitive hosts, digestive enzymes and bile salts in cattle disrupt the sporocyst wall, releasing four motile sporozoites. These penetrate the intestinal wall and disseminate throughout the body, initially localizing within endothelial cells of small arteries. This is followed by a series of successive cycles of asexual multiplication (merogony or schizogony), the number and timing of which vary depending on the species. During early cycles, crescent-shaped merozoites are formed, structurally similar to sporozoites. Subsequent generations are detected in arterioles, capillaries, and veins of various organs. The final stage of merogony results in the invasion of motile, crescent-shaped merozoites into skeletal, cardiac, and smooth muscle cells, and less frequently into nervous tissue, where sarcocyst formation begins [6].

At early stages within muscle cells, a metrocyte (mother cell) develops, undergoing repeated divisions that ensure cyst growth and formation of a protective wall isolating the parasite from surrounding tissues. As maturation progresses, metrocytes differentiate into bradyzoites (cystozoites), and the sarcocyst becomes infective to the definitive host. Maturation may require two months or longer, and sarcocysts can persist in host tissues for years. They vary considerably in size, shape, and ultrastructural characteristics of the cyst wall, including thickness and the presence of peripheral protrusions (cytophaneres), which have important taxonomic value. Internal structures may include septa dividing the cyst cavity into compartments. Sarcocysts are most commonly localized in skeletal muscles, myocardium, diaphragm, tongue, and esophagus, and more rarely in structures of the central nervous system [13].

This life-cycle pattern is largely universal for the genus and reflects the typical endogenous development characteristic primarily of vascular species (e.g., *S. cruzi*, *S. tenella*), although localization and timing of schizogony may vary among other representatives of the genus [6].

The sexual phase of the *Sarcocystis* life cycle occurs in the definitive host following ingestion of meat containing mature sarcocysts. Digestive processes disrupt the cyst wall, releasing bradyzoites that invade epithelial cells of the small intestinal villi. Here they differentiate into gamonts: microgamonts (male forms) and macrogamonts (female forms). Multiple divisions of microgamonts produce motile microgametes, one of which fertilizes a macrogamont to form an oocyst. Sporulation occurs within the intestine, resulting in the formation of two sporocysts, each containing four sporozoites. Oocysts, or more commonly liberated sporocysts, are excreted with feces into the environment. Sporocysts of most species are morphologically similar, oval in shape, approximately $10 \times 15 \mu\text{m}$ in size, and contain four sporozoites and residual granules. In zoonotic species such as *S. hominis* and *S. suis hominis*, sporocysts are immediately infective upon excre-

tion. The sexual phase of the life cycle is the most conserved developmental stage among representatives of the genus *Sarcocystis* and proceeds according to a similar pattern in most species [6].

Distribution of sarcocystosis

The distribution of parasites, including *Sarcocystis*, is closely associated with climatic conditions and anthropogenic landscape transformation. Because the life cycle of *Sarcocystis* depends on interactions between intermediate and definitive hosts and their contact with environmental reservoirs such as feed and water sources, climate change—including rising temperatures and extreme weather events—may alter epidemiological patterns and transmission pathways. Studies of other complex parasitic systems indicate that climatic shifts contribute to range expansion and increase contact opportunities among host species, potentially facilitating the wider spread of zoonotic infections [26].

Anthropogenic factors, such as land-use changes, agricultural intensification, urbanization, and ecosystem disturbance, further enhance interactions between wild and domestic species, thereby promoting parasite transmission and the emergence of epizootic and zoonotic foci. Evidence suggests that habitat alteration and biodiversity loss may increase parasite transmission among host populations and represent risk factors for the emergence of new outbreaks [26].

Agricultural practices, including livestock management, sanitary conditions, and interactions between carnivorous and herbivorous animals, also significantly influence the epidemiology of *Sarcocystis* transmission, determining the degree of parasite circulation within populations and the risk of zoonotic outbreaks through food chains [27].

Globally, *Sarcocystis* species occur from temperate to tropical regions, with distribution patterns largely determined by host ranges and migratory movements (Table 2). For example, *S. rileyi* is widely distributed among northern waterfowl in North America and Northern Europe, whereas *S. cruzi* and *S. hominis* predominate among domestic ruminants in Asia and South America. These geographic patterns reflect host ecology and may even serve as indicators of wildlife migration routes [14, 28, 29].

Table 2

Global distribution and prevalence of sarcocystosis in domestic and wild animals

| Host species | Region / Country | Prevalence (%) | Dominant / identified species | Notes on distribution & epidemiology | References |
|--------------------------|--------------------------------------|--|---|---|------------|
| Cattle | Global (21 countries, meta-analysis) | 62.7 % | <i>S. cruzi</i> (76.4 %), <i>S. hominis</i> (30.2 %), <i>S. hirsuta</i> (8.7 %) | Cosmopolitan; higher in extensive systems; zoonotic relevance (<i>S. hominis</i>) | [6, 14] |
| Cattle | Asia (various countries) | 50–90 % | <i>S. cruzi</i> <i>predominant</i> | High prevalence in warm-temperate zones; linked to dog–cattle cycle | [30] |
| Cattle | Kazakhstan (Kostanay, North) | up to 77.4 % (cox1 PCR) | <i>S. cruzi</i> , <i>S. bovifelis</i> , <i>S. dehongensis</i> | Molecular confirmation; high carcass infection rate | [31, 32] |
| Sheep | China | 33.85 % | <i>S. tenella</i> , <i>S. arieticanis</i> | Associated with production losses | [33] |
| Sheep | Kazakhstan (East) | ~18 % (macrocyts) | <i>Sarcocystis</i> spp. | Macroscopic cysts; need for monitoring | [34] |
| Pigs | Europe, Asia, Americas | 15–45 % | <i>S. miescheriana</i> , <i>S. suihominis</i> | Influenced by management system | [35] |
| Horses | Europe, Central Asia | >50 % (regional data) | <i>Sarcocystis</i> spp. | Muscle alterations; meat inspection relevance | [36] |
| Waterfowl (Anseriformes) | North America | Variable; local outbreaks | <i>S. rileyi</i> | Mass epizootics; linked to migratory flyways | [14] |
| Waterfowl | Northern Europe | Local epizootics | <i>S. rileyi</i> | Expanding range; climate-linked spread | [14] |
| Passerines & raptors | Europe, Asia | Not population-based; multiple species | >40 avian spp. | High host specificity; molecular identification expanding diversity | [23, 25] |

Continuation of Table 2

| Host species | Region / Country | Prevalence (%) | Dominant / identified species | Notes on distribution & epidemiology | References |
|---------------------------|--|--|--|--|--------------|
| Game fauna (wild mammals) | Lithuania | 8 species identified | <i>S. albifronsi</i> , <i>S. wobeseri</i> , <i>S. anasi</i> , <i>S. cornixi</i> , others | First European record of <i>S. rileyi</i> in wildlife | [14, 37, 38] |
| Sika deer | Japan | 7 species | <i>S. japonica</i> , <i>S. matsuoae</i> , <i>S. gjerdei</i> , <i>S. pilosa</i> , <i>S. ovalis</i> | High diversity; molecular taxonomy | [39] |
| Farmed sika deer | Lithuania | 5 species | <i>S. frondea</i> , <i>S. nipponi</i> + 3 known spp. | Demonstrates spillover between wild and farmed systems | [40] |
| Deer (general) | Europe, Asia | ≥9 spp. | Multiple | Indicator of wildlife biodiversity and molecular detection capacity | [41] |
| Humans | Europe, Asia, Americas, Africa (sporadic reports world-wide) | Intestinal form: usually low (<10 % in surveyed populations); Muscular form: rare (<100 documented cases world-wide) | <i>S. hominis</i> , <i>S. suihominis</i> | Occurs globally; intestinal infection acquired through consumption of raw or undercooked beef or pork; often asymptomatic or mild gastrointestinal symptoms; muscular sarcocystosis reported mainly in Southeast Asia and travelers; zoonotic significance | [42, 43] |

Sarcocystosis is widely prevalent among livestock worldwide. A global meta-analysis across 21 countries reported a prevalence of 62.7 % in cattle, with *S. cruzi* (76.4 %), *S. hominis* (30.2 %), and *S. hirsuta* (8.7 %) being the most common species [14]. In birds, biodiversity is even greater, with more than 40 described species, many exhibiting strict host specificity [23, 30, 44]. Of particular importance is *S. rileyi*, responsible for mass outbreaks among waterfowl in Europe and North America. Recent molecular studies have also identified new species in passerine and raptorial birds [1, 25].

In sheep, prevalence may reach approximately 33.85 % in certain regions of China, particularly involving *S. tenella* and *S. arieticanis*, emphasizing the importance of infection control to prevent production losses [33]. In pigs, infection rates range from 15 % to 45 % across different production systems, indicating widespread transmission dynamics [35]. Overall, *Sarcocystis* exhibits a cosmopolitan distribution, occurring in nearly all regions where livestock production is practiced. Its prevalence is strongly influenced by ecological and management factors, including the presence of definitive hosts, husbandry systems, sanitary practices, and food sources [33].

Recent studies have documented considerable *Sarcocystis* diversity in wild mammals across different geographic regions. In Lithuania, comprehensive surveys of game fauna identified eight *Sarcocystis* species, including the first European records of *S. rileyi* and newly described species such as *S. albifronsi*, *S. wobeseri*, *S. anasi*, and *S. cornixi* [14, 37-38]. Studies of sika deer in Japan revealed seven species, including three newly described taxa (*S. japonica*, *S. matsuoae*, and *S. gjerdei*), alongside previously known species such as *S. pilosa* and *S. ovalis* [39]. Similarly, investigations of farmed sika deer in Lithuania identified two new species (*S. frondea* and *S. nipponi*) in addition to three previously recognized taxa [40]. These findings demonstrate that deer alone may harbor at least nine distinct *Sarcocystis* species, highlighting the remarkable diversity of these parasites in wild mammalian hosts and the crucial role of molecular methods in their discovery [1, 41].

In Kazakhstan, sarcocystosis is widespread among livestock, as confirmed by both classical and molecular studies. Investigations of cattle in the Kostanay region revealed a high prevalence of sarcocysts consistent with *Sarcocystis bovicanis* (syn. *S. cruzi*) and other species, indicating extensive regional distribution [31]. Molecular analyses based on the *cox1* gene demonstrated infection rates reaching approximately 77.4 % of examined carcasses, with three species (*S. cruzi*, *S. bovisfelis*, and *S. dehongensis*) identified in northern Kazakhstan [32]. Sarcocystosis has also been confirmed in horses, with studies in northern regions reporting infection in more than half of examined animals, accompanied by notable muscular tissue altera-

tions relevant to meat quality and veterinary surveillance [36]. In sheep from eastern Kazakhstan, macrocysts of *Sarcocystis* spp. were detected in approximately 18 % of examined animals, underscoring the need for continuous monitoring and diagnostic efforts [34].

Human sarcocystosis is reported in many regions of the world, including Europe, Asia, North and South America, and Africa. However, the prevalence of the disease varies significantly depending on the form of infection, sanitary conditions, and dietary habits of the population [6, 14, 42-43]. The intestinal sarcocystosis form is found in Europe, Asia, Africa, North and South America, indicating its global distribution, especially in areas where raw meat is consumed or proper heat treatment is lacking. The muscular form, although rare, is most commonly reported in tropical and subtropical regions, especially in areas where potential definitive hosts (e.g., reptiles) are present, such as Southeast Asia. Cases of muscular sarcocystosis have also been reported in travellers, making the epidemiology of the disease worldwide, but with high-frequency foci in certain climatic and environmental conditions [6].

Clinical signs of sarcocystosis in animals

Sarcocystosis in animals is characterized by a wide spectrum of clinical manifestations, ranging from asymptomatic infections to severe systemic disorders, depending on the stage of invasion, host species, infection intensity, and parasite localization. Many chronic cases remain undetected without laboratory or pathological examination, increasing the significance of subclinical pathology in the epidemiology of the disease.

The intestinal sarcocystosis form occurs in humans as the final host when consuming meat containing mature sarcocysts: Humans serve as the definitive host for *Sarcocystis hominis*, which is associated with the consumption of raw or undercooked beef, and for *Sarcocystis suihominis*, which is associated with raw or undercooked pork. This form occurs worldwide, although clinical manifestations are usually mild (nausea, abdominal pain, diarrhoea) and often go unnoticed in standard diagnostics. Intestinal cases have been reported in Europe (e.g., Germany, the Netherlands, Poland), Asia (China, Thailand, Laos), Australia, South America, and other regions, indicating widespread global distribution even with rare detection of the disease. In epidemiological studies of sarcocystosis in developing countries, infections have been recorded even in poor hygienic conditions, for example, in some communities in Australia. The infection can be detected in faeces in the form of sporocysts or oocysts after consumption of contaminated meat, and although most cases remain clinically insignificant, outbreaks and cases with significant symptoms have been reported among volunteers and in conditions of natural infection [6].

The muscular form of sarcocystosis is much less common in humans, but it is more serious in terms of clinical manifestations: Less than 100 reliably confirmed cases of muscular sarcocystosis have been described in the literature, making it a rare but significant disease. Most of these cases are associated with tropical regions, especially in Southeast Asia (e.g., Malaysia), where cases have been repeatedly reported in tourists and local residents. In this form, humans act as intermediate hosts for species other than *S. hominis* and *S. suihominis* (e.g., *Sarcocystis nesbitti* with a possible reptilian definitive host). Infection occurs when sporocysts are ingested, most likely from contaminated food or water, allowing the parasite to develop first in the vascular endothelium and then in muscle tissue. Clinical symptoms of the muscular form include fever, myalgia, headaches, eosinophilia, and weakness, and diagnosis usually requires a muscle biopsy to detect sarcocysts [6, 14].

In cattle, sarcocystosis most often proceeds asymptotically or with mild clinical signs, particularly during the chronic muscular stage. However, under conditions of high parasite burden or during the acute phase, clinical manifestations may include weakness, anorexia, reduced productivity, and depression. Anemia, emaciation, and progressive cachexia may also develop, especially in young animals [21]. Experimental infections have demonstrated fever, lethargy, tachycardia, and, in some cases, abortion [45]. These manifestations are frequently masked by concurrent infections, complicating diagnosis and leading to underestimation of the clinical impact of sarcocystosis on herd health.

In addition, cattle may develop sarcocystosis-associated inflammatory lesions of skeletal muscles, known as bovine eosinophilic myositis (BEM). Affected animals often appear clinically normal during life, but muscle lesions are detected at slaughter, resulting in carcass condemnation and substantial economic losses due to reduced meat quality and productivity [46].

In small ruminants and carnivorous animals, sarcocystosis is generally asymptomatic or subclinical, particularly in cases of mild to moderate infection. In sheep and goats, severe infections may lead to systemic disturbances, including general weakness, anemia, decreased appetite, and progressive weight loss, while in severe cases neurological disorders and abortions may occur [33-34]. In pigs, heavy parasite loads are asso-

ciated with lameness, generalized weakness, and inflammatory lesions of cardiac and skeletal muscles, such as endocarditis and myocarditis, leading to deterioration in overall condition and reduced productivity [47].

In dogs, sarcocystosis is typically asymptomatic, especially in the intestinal form. However, in young animals with high infection intensity, nonspecific signs such as digestive disturbances, reduced appetite, and growth retardation may occur [48]. The muscular form of sarcocystosis in dogs is considerably less common but may be accompanied by myositis, generalized weakness, and muscle pain, significantly complicating clinical presentation and requiring differential diagnosis from other myopathies [49].

In other host species, including camels, rodents, and birds, sarcocysts often result in subclinical infections but may adversely affect animal health in cases of heavy infestation. Experimental studies in small vertebrates have reported weakness, emaciation, and severe pathological effects on vital organs at high infection intensities [50].

One of the characteristic features of sarcocystosis is its frequently asymptomatic course, particularly during the chronic muscular stage. This latent pathology is largely attributable to the deep localization of sarcocysts within muscle tissue, where they do not initially cause overt pain or clinical symptoms. Nevertheless, parasites may produce toxic metabolites, such as sarcocystin, which exert both mechanical and toxic effects on host tissues, ultimately leading to metabolic disturbances and reduced animal productivity [51].

Chronic infection may also be associated with mild myositis, destruction of muscle fibers, and lymphohistiocytic infiltration, changes that are often detectable only through histological examination, even when animals appear clinically healthy [51].

Such subclinical forms present a significant epizootiological challenge, as infected animals may serve as reservoirs for parasite transmission, maintaining infection cycles and increasing the risk of zoonotic spread while remaining undetected in livestock production systems and slaughter facilities.

Diagnostic approaches to sarcocystosis

Diagnosis of sarcocystosis in livestock represents a complex task requiring the integration of morphological, microscopic, serological, and molecular methods, as no single approach provides sufficient sensitivity and specificity when used in isolation. Diagnostic challenges arise from the wide host range, variable clinical manifestations, and morphological similarities among *Sarcocystis* species. In modern practice, complementary methods are applied to improve diagnostic accuracy and informativeness in both animal and human investigations.

Macroscopic, microscopic, and histological methods

Macroscopic examination is based on visual inspection of muscle tissues and internal organs for cysts visible to the naked eye (macrocyts). These cysts may reach several millimeters in size and are most commonly detected in striated muscles, the diaphragm, and myocardium during necropsy or postmortem meat inspection. Although macroscopic evaluation remains a fundamental step in diagnostic assessment, it frequently fails to detect smaller microscopic cysts.

Microscopic examination includes light microscopy and the tissue compression method, in which muscle samples are pressed between glass slides and examined under magnification to detect sarcocysts. This method allows visualization of characteristic banana-shaped bradyzoites within cysts; however, it does not reliably determine species identity without additional diagnostic techniques [34].

Histological methods involve tissue fixation, paraffin embedding, sectioning, and staining (e.g., hematoxylin–eosin, Mallory’s stain). Histology enables visualization of cyst wall structure, localization within muscle fibers, inflammatory responses, and parasite morphology at the cellular level. Nevertheless, morphologically similar cyst wall structures among closely related *Sarcocystis* species often prevent accurate species identification, particularly in the absence of electron microscopy.

Serological tests (ELISA, IFAT)

Serological methods aim to detect circulating antibodies against *Sarcocystis* antigens in live animals and humans. The most widely used techniques include:

ELISA (enzyme-linked immunosorbent assay)—enables detection of specific antibodies in serum samples. ELISA has demonstrated higher sensitivity compared with visual and microscopic methods alone, significantly increasing detection rates in cattle by identifying antibodies even in cases of subclinical microscopic infection [52].

IFAT (indirect fluorescent antibody test)—visualizes antigen–antibody binding using fluorescent labeling. Comparative studies indicate that IFAT exhibits sensitivity comparable to ELISA in detecting antibodies against *Sarcocystis* spp.; however, it requires specialized fluorescence microscopy for result interpretation [53].

Serological methods have several limitations, including potential cross-reactivity with antigens of other apicomplexan parasites, poor correlation between antibody titers and infection severity or stage, and the inability to determine species identity [53].

Modern molecular methods

Molecular techniques provide high sensitivity and specificity, enabling not only parasite detection but also accurate species identification.

PCR (polymerase chain reaction)—a fundamental method for amplifying specific *Sarcocystis* DNA regions, commonly targeting 18S rRNA or *cox1* genes. PCR can detect parasite DNA even at low infection intensities and in tissue samples such as meat or muscle biopsies [54-55].

PCR-RFLP (restriction fragment length polymorphism)—extends PCR by incorporating enzymatic digestion of amplified fragments to detect species-specific genetic variations, making it useful for epidemiological studies and species differentiation [56].

LAMP (loop-mediated isothermal amplification)—an alternative molecular technique characterized by high sensitivity and rapid visual detection without the need for thermal cycling. In *Sarcocystis* diagnostics, LAMP has demonstrated greater sensitivity than conventional PCR for detecting *S. tenella* and *S. gigantea* infections in sheep [57].

NGS (next-generation sequencing)—enables parallel sequencing of multiple genetic regions, facilitating comprehensive genetic analysis, discovery of novel species, and construction of phylogenetic relationships. Although highly informative, NGS requires advanced laboratory infrastructure and bioinformatic processing.

Each diagnostic approach possesses specific strengths and limitations, and their combined application is considered the most effective strategy for accurate detection and identification of *Sarcocystis* infections. A comparative overview of sensitivity and specificity among these methods is presented in Table 3.

Table 3

Comparison of sensitivity and specificity of diagnostic methods for sarcocystosis

| Method | Sensitivity | Specificity | Limitations |
|------------|---------------------------------|-------------|---|
| Macroscopy | Low for microcysts | Moderate | Does not detect microscopic cysts |
| Microscopy | Moderate | Moderate | Depends on operator experience |
| Histology | Moderate-high | Moderate | Not always species-specific |
| ELISA | High relative to visual methods | Moderate | Antibodies may persist |
| IFAT | High | Moderate | Requires a fluorescence microscope |
| PCR | High | High | Requires specific primers |
| PCR-RFLP | High | Very high | Requires restriction enzymes |
| LAMP | Very high | High | Relatively new method, requires standardization |
| NGS | Very high | Very high | Expensive; complex data processing |

Molecular methods, particularly PCR-RFLP and LAMP, demonstrate higher sensitivity and greater ability to detect low-intensity infections compared with traditional morphological and serological approaches and are therefore preferred for epidemiological studies [58].

To improve diagnostic accuracy for sarcocystosis, the combined use of multiple methods has proven especially effective. The combination of morphological examination and ELISA—visual and microscopic inspection of muscle tissues for preliminary detection supplemented by ELISA to identify seropositive animals—significantly increases detection rates compared with the use of a single method alone [53].

Similarly, the integration of microscopy and PCR-RFLP enhances diagnostic precision: microscopic detection of cysts followed by molecular species identification improves the accuracy of species determination and supports epidemiological investigations, as demonstrated in studies of cardiac muscle infections in cattle [56].

The combined use of PCR and LAMP also provides advantages; LAMP can serve as a rapid screening tool, while PCR can be used to confirm results, ensuring high sensitivity while reducing time and costs.

Research on the genus *Sarcocystis* continues to evolve, encompassing novel molecular approaches, genomics, the development of preventive and therapeutic measures, and the application of parasites in environmental monitoring. These directions are closely linked to veterinary medicine, epidemiology, food safety, and the One Health framework, which integrates animal, human, and environmental health.

Future perspectives in sarcocystosis research

One of the key challenges in modern parasitology is the expansion of molecular marker sets for accurate identification of *Sarcocystis* species and assessment of their phylogenetic relationships. Traditionally, 18S rRNA regions and the mitochondrial *cox1* gene have been widely used and have demonstrated high sensitivity and specificity in taxonomic identification [59-60]. However, distinguishing closely related lineages and assessing intraspecific diversity requires the development of additional genetic markers, including microsatellite loci, SNP panels, and mitochondrial genomes. These approaches will facilitate clarification of transmission pathways, infection sources, and evolutionary patterns of the parasite.

The emergence of whole-genome sequencing (WGS) and comparative genomic analyses among *Sarcocystis* species offers new opportunities for investigating molecular structure, adaptive mechanisms, and genetic resilience of the parasite. Genomic approaches enable the identification of genes involved in invasiveness, virulence, and survival across diverse host species, thereby significantly expanding understanding of *Sarcocystis* biology at the molecular level [61].

Recent studies indicate that parasites, including *Sarcocystis*, can serve as bioindicators of ecosystem health. Environmental sampling—of water, soil, and feed—combined with molecular detection methods allows identification of sporocysts and zoonotic species without direct tissue sampling from animals. Pilot studies have reported detection of *Sarcocystis* in water, hay, and soil, emphasizing the importance of environmental monitoring for assessing infection risks in animals and humans [38, 59]. Such approaches enable early detection of contamination of pastures and water sources with infective sporocysts, often long before clinical cases become apparent, making environmental surveillance a critical component of epizootic and zoonotic prevention systems.

Future research perspectives in sarcocystosis can be summarized into several strategic directions:

- Expansion of molecular marker sets for accurate taxonomy, assessment of genetic diversity, and epidemiological investigations of *Sarcocystis*.
- Application of genomics and WGS to identify genetic determinants of virulence and adaptation, enabling more precise tracking of parasite evolution and spread.
- Development of vaccines and targeted therapeutic agents based on molecular antigens and immunogenic structures of the parasite.
- Implementation of environmental monitoring using molecular methods in natural substrates (water, soil, and feed) to prevent epizootic outbreaks and assess the impact of anthropogenic changes on transmission cycles of *Sarcocystis*.

These research directions contribute to a deeper understanding of *Sarcocystis* biology, improved disease control in livestock populations, and reduction of zoonotic transmission risks, ultimately enhancing veterinary and public health safety.

Conclusion

Sarcocystosis remains one of the most widespread protozoan infections of veterinary and medical significance. Pathogens of the genus *Sarcocystis* are characterized by high ecological plasticity, a complex life cycle, and broad host specificity. To date, dozens of species have been identified that infect domestic and wild animals as well as humans. Climate change, urbanization, and the intensification of livestock production contribute to the transformation of parasite life cycles and the expansion of the geographic ranges of certain species, thereby increasing the epizootic and potential zoonotic significance of sarcocystoses.

From an ecological perspective, sarcocysts represent an important component of biocenoses and can be considered bioindicators of ecosystem health. Their study has not only fundamental but also applied importance—from assessing the epizootological situation in livestock production to predicting risks of zoonotic infections. The analysis of contemporary research on the biodiversity of parasites of the genus *Sarcocystis* has shown that these apicomplexan protozoa should be regarded not only as causative agents of invasive diseases in animals but also as functionally significant elements of ecosystems. The species diversity of *Sarcocystis*, their strict trophic associations with definitive and intermediate hosts, and the high sensitivity of

parasite systems to environmental changes make them important participants in ecosystem processes and indicators of biocenotic status.

Morphological characteristics of sarcocysts have limited diagnostic value and require confirmation using molecular genetic methods. The use of 18S rRNA, ITS-1 markers, and the *cox1* gene has enabled clarification of species identity and the establishment of phylogenetic relationships within the genus. Modern studies convincingly demonstrate that the actual biodiversity of *Sarcocystis* is significantly greater than previously defined taxonomic frameworks.

Future research perspectives are associated with the integration of morphological, molecular, and ecological approaches. This will allow a deeper understanding of evolutionary relationships between parasites and their hosts, mechanisms of adaptation, and the role of sarcozoans in regulating animal population dynamics. Interdisciplinary studies combining parasitological, genetic, and ecological methods open new opportunities for assessing biodiversity and the epidemiological potential of sarcocysts.

Thus, the present publication contributes to the formation of an integrative perspective on *Sarcocystis* as a component of ecosystems, uniting data from parasitology, ecology, and molecular biology. The presented syntheses emphasize the value of using *Sarcocystis* as model organisms for studying the stability of parasitic systems and as bioindicators of environmental change. The conclusions obtained may be applied in the development of environmental monitoring programs, assessment of epizootic risks, and planning of further fundamental and applied research within the framework of the “One Health” concept.

Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Suleimanova K.U.** — conceptualization, data curation, investigation; **Suleimanova K.U., Zhabykpayeva A.G.** — data curation, formal analysis, supervision, writing draft, editing; **Balabayev B.K., Kubekova B. Zh.** — investigation, writing draft, editing, preparation of table; **Šarkūnas M.** — formal analysis, editing.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Cawthorn R.J. Sarcocystis: Infection and disease of humans, livestock, wildlife, and other hosts / R.J. Cawthorn, C.A. Speer // *Coccidiosis of Man and Domestic Animals* / Ed. P.L. Long. — 2nd ed. — Boca Raton: CRC Press, 2019. — P. 145–172. <http://doi.org/10.1201/9781351070744-6>
- 2 Prakas P. Protozoan parasites from genus *Sarcocystis* and their investigations in Lithuania / P. Prakas, D. Butkauskas // *Ekologija*. — 2012. — Vol. 58 (1). — P. 9–17. <http://doi.org/10.6001/EKOLOGIJA.V58I1.2349>
- 3 Wieser S.N. *Sarcocystis* spp. of New and Old World camelids: Ancient origin, present challenges / S.N. Wieser, S.M. Giuliano // *Pathogens*. — 2024. — Vol. 13 (3). — P. 196. <http://doi.org/10.3390/pathogens13030196>
- 4 Castro-Forero S.P. *Sarcocystis* spp., a parasite with zoonotic potential / S.P. Castro-Forero et al. // *Bulgarian Journal of Veterinary Medicine*. — 2022. — Vol. 25 (4). — P. 550–559. <http://doi.org/10.15547/bjvm.2019-0129>
- 5 Korpysa-Dzirba W. *Sarcocystis* spp. — an underestimated parasite with zoonotic potential associated with food of animal origin / W. Korpysa-Dzirba, E. Bilska-Zajac, M. Rozycki, A. Belcik, J. Karamon, A. Gontarszyk et al. // *Medycyna Weterynaryjna*. — 2024. — Vol. 80 (1). — P. 12–20. <http://doi.org/10.21521/mw.6838>
- 6 Fayer R. Human infections with *Sarcocystis* species / R. Fayer, J.P. Dubey, B.M. Rosenthal // *Clinical Microbiology Reviews*. — 2015. — Vol. 28 (2). — P. 295–311. <http://doi.org/10.1128/CMR.00113-14>
- 7 Gjerde B. Molecular characterisation of *Sarcocystis rileyi* from a common eider (*Somateria mollissima*) in Norway / B. Gjerde // *Parasitology Research*. — 2014. — Vol. 113 (9). — P. 3501–3509. <http://doi.org/10.1007/s00436-014-4025-1>
- 8 Chhabra M.B. *Sarcocystis* and sarcocystosis in India: Status and emerging perspectives / M.B. Chhabra, S.R. Samantaray // *Journal of Parasitic Diseases*. — 2013. — Vol. 37 (1). — P. 1–10. <http://doi.org/10.1007/s12639-012-0135-y>
- 9 Tenter A.M. Current research on *Sarcocystis* species of domestic animals / A.M. Tenter // *International Journal for Parasitology*. — 1995. — Vol. 25 (11). — P. 1311–1330. [http://doi.org/10.1016/0020-7519\(95\)00068-D](http://doi.org/10.1016/0020-7519(95)00068-D)
- 10 Stojceki K. Molecular diagnostics of *Sarcocystis* spp. infections / K. Stojceki, J. Sroka, T. Cencek // *Polish Journal of Veterinary Sciences*. — 2012. — Vol. 15 (3). — P. 589–596. <http://doi.org/10.2478/V10181-012-0090-7>
- 11 Swar S.O. Recent advances in molecular characterization of *Sarcocystis* species in some meat-producing animals: An updated review / S.O. Swar, B.H. Shnawa // *Asian Journal of Agriculture and Biology*. — 2021. — Vol. 9 (1). — P. 12–25. <http://doi.org/10.35495/ajab.2020.09.502>

- 12 Gjerde B. Phylogenetic relationships among *Sarcocystis* species in cervids, cattle, and sheep inferred from the mitochondrial cytochrome c oxidase subunit I gene / B. Gjerde // *International Journal for Parasitology*. — 2013. — Vol. 43 (7). — P. 579–591. <http://doi.org/10.1016/j.ijpara.2013.02.004>
- 13 Fayer R. *Sarcocystis* spp. in human infections / R. Fayer // *Clinical Microbiology Reviews*. — 2004. — Vol. 17 (4). — P. 894–902. <http://doi.org/10.1128/CMR.17.4.894-902.2004>
- 14 Dubey J.P. *Sarcocystosis of Animals and Humans* / J.P. Dubey, R. Calero-Bernal, B.M. Rosenthal, C.A. Speer, R. Fayer — 2nd ed. — Boca Raton: CRC Press, 2016. — 481 p.
- 15 Zeng H. *Sarcocystis* species in bovine carcasses from a Belgian abattoir: a cross-sectional study / H. Zeng, I. Van Damme, T.W. Kabi et al. // *Parasites & Vectors*. — 2021. — Vol. 14. — 271. <http://doi.org/10.1186/s13071-021-04788-1>
- 16 Shams M. Molecular epidemiology, species distribution, and zoonotic importance of the neglected meat-borne pathogen *Sarcocystis* spp. in cattle (*Bos taurus*): A global systematic review and meta-analysis / M. Shams, L. Shamsi, A. Asghari, M.H. Motazedian, B. Mohammadi-Ghalehbin, M. Omidian, N. Nazari, A. Sadrebazzaz // *Acta Parasitologica*. — 2022. — Vol. 67 (3). — P. 1055–1072. <http://doi.org/10.1007/s11686-022-00563-z>
- 17 Baranauskaitė A. Molecular identification of protozoan *Sarcocystis* in different types of water bodies in Lithuania / A. Baranauskaitė, Ž. Strazdaitė-Žielienė, E. Servienė, D. Butkauskas, P. Prakas // *Life*. — 2023. — Vol. 13 (1). — 51. <http://doi.org/10.3390/life13010051>
- 18 Moré G.A. *Sarcocystosis in Animals* [Electronic resource] / G.A. Moré // *MSD Veterinary Manual*. — 2021 (rev. 2024). — Access mode: <https://www.msdsvetmanual.com>
- 19 Marandykina-Prakienė A. *Sarcocystis* species richness in sheep and goats from Lithuania / A. Marandykina-Prakienė, D. Butkauskas, N. Gudiškis et al. // *Veterinary Sciences*. — 2023. — Vol. 10 (8). — 520. <http://doi.org/10.3390/vetsci10080520>
- 20 da Rosa G. Molecular identification of *Sarcocystis* species in wild boar (*Sus scrofa*) and pigs (*Sus scrofa domesticus*) in Brazil / G. da Rosa, I.J. Roman, L.T. Gressler, J.F. Cargnelutti, F.S.F. Vogel // *Veterinary Parasitology: Regional Studies and Reports*. — 2024. — Vol. 50. — 101020. <http://doi.org/10.1016/j.vprsr.2024.101020>
- 21 Gaston A.M. *Sarcocystosis in Animals*. By Gastón A. Moré, DVM, PhD [Electronic resource] / A.M. Gaston. — Immunoparasitology Laboratory, National University of La Plata, Buenos Aires, Argentina. Reviewed/Revised Jan 2021 | Modified Sept 2024. — Access mode: <https://www.msdsvetmanual.com/musculoskeletal-system/sarcocystosis/sarcocystosis-in-animals>
- 22 Prakas P. *Sarcocystis* infection in domestic and wild avian hosts: Inseparable flight partners / P. Prakas, R. Calero-Bernal, J.P. Dubey // *Veterinary Parasitology*. — 2025. — 335. — 110413. <https://doi.org/10.1016/j.vetpar.2025.110413>
- 23 Juozaitytė-Ngugu E. The Richness of *Sarcocystis* Species in the Common Gull (*Larus canus*) and Black-Headed Gull (*Larus ridibundus*) from Lithuania / E. Juozaitytė-Ngugu, P. Prakas // *Parasitologia*. — 2023. — 3(2). — P. 172–180. <https://doi.org/10.3390/parasitologia3020018>
- 24 Prakas P. Molecular identification of four *Sarcocystis* species in cattle from Lithuania, including *S. hominis*, and development of a rapid molecular detection method / P. Prakas, Ž. Strazdaitė-Žielienė, V. Januškevičius, F. Chiesa, A. Baranauskaitė, E. Rudaitytė-Lukošienė et al. // *Parasites & Vectors*. — 2020. — 13(1). — 610. <http://doi.org/10.1186/s13071-020-04490-3>
- 25 Baranauskaitė A. Detection of *Sarcocystis* parasites in environmental samples from Lithuanian farms. Food and Waterborne / A. Baranauskaitė, P. Prakas, M. Petrauskas, S. Rubiola, E. Servienė, Ž. Strazdaitė-Žielienė // *Parasitology*. — 2025. — 39. — e00267. <https://doi.org/10.1016/j.fawpar.2025.e00267>
- 26 Эпидемиология и модели систем «хозяин-паразит». — [Электронный ресурс]. — Павлодар: Торайгыров университет, 2017. — Режим доступа: <https://textbook.tou.edu.kz/books/009/7.html>
- 27 Pradhan A.K. Zoonoses from animal meat and milk / A.K. Pradhan, S. Karanth, In: Knowles M.E., Anelich L.E., Boobis A.R., Popping B. (Ed.). // *Present Knowledge in Food Safety*. Academic Press. — 2023. — P. 394–411. <https://doi.org/10.1016/B978-0-12-819470-6.00029-9>
- 28 Maky M.A. Molecular identification of *Sarcocystis* spp. in meat and meat products in Qena, Upper Egypt. / M.A. Maky, E.S. Mohammed // *Journal of Animal Health and Production*. — 2020. — 9(1). — P. 88–93. <http://dx.doi.org/10.17582/journal.jahp/2020/9.1.88.93>
- 29 Obadih H.I. First molecular detection of *Sarcocystis suis* in a domestic pig of Nigeria / H.I. Obadih, S.N. Wieser, I.N. Nzelu, O.S. Olaolu, H.S. Jagab, E.T. Obishakin et al. // *Parasitology Research*. — 2024. — 123(2). — P. 367–375. <http://dx.doi.org/10.1007/s00436-024-07901-2>
- 30 Tang K. Prevalence and Genetic Characterization of Morphologically Indistinguishable *Sarcocysts* of *Sarcocystis cruzi* in Cattle and *Sarcocystis poephagicanis* in Yaks / K. Tang, D. Lamu, T. Qin, Z. Liao, M. Zhang, Z. Wu, S. Deng, J. Tao, J. Hu. // *Diversity*. — 2023. — 15(11). — 1136. <https://doi.org/10.3390/d15111136>
- 31 Bermukhametov Zh.Zh. Bovine *Sarcocystosis* in Kostanay Region / Zh.Zh. Bermukhametov, O.V. Tomaruk, K.U. Suleymanova, R.M. Rychshanova // *Herald of Science of S. Seifullin Kazakh Agrotechnical Research University: Veterinary Sciences*. — 2023. — 2(002). — P. 14–19. [http://dx.doi.org/10.51452/kazatuvc.2023.2\(002\).1428](http://dx.doi.org/10.51452/kazatuvc.2023.2(002).1428)
- 32 Bermukhametov Z. Identification of *Sarcocystis* Species in Cattle Muscles: Experience of Kazakhstan / Z. Bermukhametov, K. Suleimanova, P. Prakas, O. Tomaruk, A. Shevtsov, B. Abdygulov, B. Mustafin, B. Baimenov, Y. Sokharev, R. Rychshanova // *International Journal of Veterinary Science*. — 2025. — 14(1). — P. 32–38. <http://dx.doi.org/10.47278/journal.ijvs/2024.206>
- 33 Feng Y. A Systematic Meta-Analysis of Global *Sarcocystis* Infection in Sheep and Goats / Y. Feng, R. Guo, X. Sang, X. Zhang, M. Li, X. Li, N. Yang, T. Jiang // *Pathogens*. — 2023. — 12. — 902. <https://doi.org/10.3390/pathogens12070902>
- 34 Оразғалиев С.М. Патоморфологическая диагностика при саркоцистозе овец / С.М. Оразғалиев, О.Н. Зайковская, Ж.М. Нуржуманова, А.С. Койгельдинова, Г.А. Амантай. — Научно-практический журнал Западно-Казахстанского аграрно-

технического университета имени Жангир хана. Наука и образование. — 2025. — № 3-2(80). — С. 87–95. <https://doi.org/10.52578/2305-9397-2025-3-2-87-95>

35 Gastón M. Sarcocystis spp. and Toxoplasma gondii in muscles from wild boars (*Sus scrofa*) consumed in Switzerland / M. Gaston, F. Carlotta, A.W. Oehm, R. Maja, H. Andrew, C.F. Frey, B. Walter // International Journal for Parasitology: Parasites and Wildlife. — 2025. — 27. — 101114. <https://doi.org/10.1016/j.ijppaw.2025.101114>

36 Bermukhametov Z. Equine Sarcocystosis in the Northern Region of the Republic of Kazakhstan / Z. Bermukhametov, K. Suleimanova, O. Tomaruk, B. Baimenov, P. Shevchenko, A. Batyrbekov, Z. Mikniene, A.O. Girisgin, R. Rychshanova // Animals. — 2024. — 14(16). — 2299. <https://doi.org/10.3390/ani14162299>

37 Prakas P. Identification and intraspecific genetic diversity of *Sarcocystis rileyi* from ducks (*Anas* spp.) in Lithuania and Finland / P. Prakas, A. Oksanen, D. Butkauskas, A. Sruoga, L. Kutkienė, S. Švažas // Journal of Parasitology. — 2014. — 100(5). — P. 657–661. <http://dx.doi.org/10.1645/13-493.1>

38 Prakas P. Diversity and ecology of *Sarcocystis* in Lithuanian game fauna / P. Prakas, G. Valkiūnas, M. Žalakevičius, J.R. Lazutka, J.R. Stonis, A. Paulauskas // Acta Zoologica Lituanica. — 2011. — 21(2). — P. 157–165.

39 Abe N. Morphological and molecular characteristics of seven *Sarcocystis* species from sika deer (*Cervus nippon centralis*) in Japan, including three new species / N. Abe, K. Matsuo, J. Moribe, Y. Takashima, T. Irie, T. Baba, B. Gjerde // International Journal for Parasitology: Parasites and Wildlife. — 2019. — 10. — P. 252–262. <https://doi.org/10.1016/j.ijppaw.2019.10.002>

40 Rudaitytė-Lukošienė E. Morphological and molecular identification of *Sarcocystis* spp. from sika deer (*Cervus nippon*), including two new species *Sarcocystis frondea* and *Sarcocystis nipponi* / E. Rudaitytė-Lukošienė, P. Prakas, D. Butkauskas, L. Kutkiene, I. Vepštaitė-Monstavičė, E. Serviene // Parasitology Research. — 2018. — 117(5). — P. 1305–1315. <http://dx.doi.org/10.1007/s00436-018-5816-8>

41 Hu J. Description of *Sarcocystis platyrhynchos* n. sp. from domestic ducks (*Anas platyrhynchos*) in China / J. Hu, M. Zhang, Z. Wu, H. Zeng, J. Tao // Parasites & Vectors. — 2023. — 16(1). — P. 1–12. <http://dx.doi.org/10.1186/s13071-023-05710-8>

42 Nimri L. Unusual case presentation of intestinal *Sarcocystis hominis* infection in a healthy adult / L. Nimri // JMM Case Rep. — 2014. — Dec 1; 1(4): e004069. doi: 10.1099/jmmcr.0.T00019. PMID: 28663816; PMCID: PMC5415925.

43 Rathish B. *Sarcocystis*. StatPearls [Electronic resource] / B. Rathish. — Treasure Island (FL): StatPearls Publishing, 2022. — Access mode: <https://www.ncbi.nlm.nih.gov/books/NBK574577/>

44 Juozaitytė-Ngugu E. The role of birds of the family Corvidae in transmitting *Sarcocystis* protozoan parasites / E. Juozaitytė-Ngugu, S. Švažas, D. Šneideris, E. Rudaitytė-Lukošienė, D. Butkauskas, P. Prakas // Animals. — 2021. — 11(11). — 3258. <https://doi.org/10.3390/ani11113258>

45 Dubey J.P. A review of *Sarcocystis* of domestic animals and of other coccidia of cats and dogs. / J.P. Dubey // Journal of the American Veterinary Medical Association. — 1976. — 169(10). — P. 1061–1078. PMID: 824260

46 Zhu Z. The Occurrence and Meta-Analysis of Investigations on *Sarcocystis* Infection among Ruminants in Mainland China. / Z. Zhu, Z. Ying, Z. Feng, Q. Liu, J. Liu // Animals. — 2023. — 13. — 149. <https://doi.org/10.3390/ani13010149>

47 Barrows P.L. Experimental *Sarcocystis suicanis* infections: disease in growing pigs. / P.L. Barrows, A.K. Prestwood, C.E. Green // American Journal of Veterinary Research. — 1982. — 43(8). — P. 1409–1412 PMID: 6808876

48 Shvedova G.I. Muscular sarcocystosis in dogs [Electronic resource] / G.I. Shvedova, E.O. Rystova // Innovative processes in agriculture. — 2024. — P. 145–149. — Access mode: <https://repository.rudn.ru/ru/records/article/record/167453>

49 Chapman J. Clinical muscular sarcocystosis in a dog. / J. Chapman, M. Mense, J.P. Dubey // Journal of Parasitology. — 2005. — 91(1). — P. 187–190. <http://dx.doi.org/10.1645/GE-406R>

50 Šukytė T. Molecular Confirmation of Accipiter Birds of Prey as Definitive Hosts of Numerous *Sarcocystis* Species, including *Sarcocystis* sp., Closely Related to Pathogenic *S. calchasi* / T. Šukytė, D. Butkauskas, E. Juozaitytė-Ngugu, S. Švažas, P. Prakas // Pathogens. — 2023. — 12(6). — 752. <https://doi.org/10.3390/pathogens12060752>

51 Pagano T.B. Muscular Sarcocystosis in Sheep Associated With Lymphoplasmacytic Myositis and Expression of Major Histocompatibility Complex Class I and II. / T.B. Pagano, F. Prisco, D. De Biase, G. Piegari, M.P. Maurelli, L. Rinaldi, G. Cringoli, S. Papparella, O. Paciello // Veterinary Pathology. — 2020. — 57(2). — P. 272–280. <https://doi.org/10.1177/0300985819891257>

52 Glamazdin I.G. Visual and molecular-serological diagnosis of sarcocystosis in cattle. / I.G. Glamazdin, Y. Rutaganira, O.A. Panova, N.Yu. Sysoeva, D. Khalim // Russian Journal of Parasitology. — 2024. — 18(2). — P. 163–169. <http://dx.doi.org/10.31016/1998-8435-2024-18-2-163-169>

53 Tenter A.M. Comparison of Dot-ELISA, ELISA and IFAT for the detection of IgG antibodies to *Sarcocystis muris* in experimentally infected and immunized mice / A.M. Tenter // Veterinary Parasitology. — 1988. — 29(2-3). — P. 89–104. [https://doi.org/10.1016/0304-4017\(88\)90119-7](https://doi.org/10.1016/0304-4017(88)90119-7)

54 Dalir Ghaffari A. Microscopic and Molecular Detection of *Sarcocystis cruzi* in the Heart Muscle of Cattle / A. Dalir Ghaffari, A. Dalimi, M. Pirestani // Iranian Journal of Parasitology. — 2022. — 17(4). — P. 535–542. <https://doi.org/10.18502/ijpa.v17i4.11281>

55 Abdolahi N. Prevalence and molecular analysis of *Sarcocystis* species infection in slaughtered cattle in Alborz, Iran. / N. Abdolahi, A. Heidari, A. Bairami, A. Miahipour, M. Sezavar, A. Teimuri, S. Bahadory // Veterinary and Animal Science. — 2025. — 27. — 100431. <https://doi.org/10.1016/j.vas.2025.100431>

56 Hamidinejat H. Molecular detection of *Sarcocystis* species in slaughtered sheep by PCR-RFLP from south-western Iran / H. Hamidinejat, H. Moetamedi, A. Alborzi, A. Hatami // Journal of Parasitic Diseases. — 2014. — 38(2). — P. 233–237. <https://doi.org/10.1007/s12639-012-0231-z>

- 57 Chen Y. Development of a highly specific LAMP assay for detection of *Sarcocystis tenella* and *Sarcocystis gigantea* in sheep / Y. Chen, J. Peng, Z. Zhu, W. Zhang, L. Wang, J. Xu, Q. Liu, J. Liu // Parasitology Research. — 2024. — 123(9). — 324. <https://doi.org/10.1007/s00436-024-08349-0>
- 58 Stojceki K. Molecular diagnostics of *Sarcocystis* spp. infections / K. Stojceki, J. Karamon, J. Sroka, T. Cencek // Polish Journal of Veterinary Sciences. — 2012. — 15(3). — P. 589–596. <https://doi.org/10.2478/v10181-012-0090-7>
- 59 Strazdaitė-Žielenė Ž. Molecular Identification of Parasitic Protozoa *Sarcocystis* in Water Samples / Ž. Strazdaitė-Žielenė, A. Baranauskaitė, D. Butkauskas, E. Servienė, P. Prakas // Veterinary Sciences. — 2022. — 9(8). — 412. <https://doi.org/10.3390/vetsci9080412>
- 60 Dameshghi F. RFLP Analysis of Fragments of the 18S rRNA and Cox1 Genes to Identify *Sarcocystis cruzi* in Water Buffalo in Guilan Province, Iran / F. Dameshghi, S. Shirali, P. Shayan, B. Shemshadi // Iranian Journal of Parasitology. — 2023. — 18(4). — P. 464–473. <https://doi.org/10.18502/ijpa.v18i4.14255>
- 61 Hoeve-Bakker B.J.A. Molecular identification targeting *cox1* and 18S genes confirms the high prevalence of *Sarcocystis* spp. in cattle in the Netherlands / B.J.A. Hoeve-Bakker, J.W.B. van der Giessen, F.F.J. Franssen // International Journal for Parasitology. — 2019. — 49(11). — P. 859–866. <https://doi.org/10.1016/j.ijpara.2019.05.008>

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***Sarcocystis* биоалуантүрлілігін және олардың экожүйелердегі рөлін зерттеудің заманауи бағыттары**

Шолуда *Sarcocystis* туысына жататын паразиттердің биоалуантүрлілігі және олардың экожүйелер, ветеринария және қоғамдық денсаулық үшін маңызы туралы заманауи деректер жинақталған. Саркоцистоздар айқын ветеринариялық және зооноздық мәні бар аурулар ретінде қарастырылады, өйткені олар ауыл шаруашылығы жануарларының өнімділігінің төмендеуіне, ет өнімдерінің сапасының нашарлауына әкеледі және адамда патологиялық өзгерістер туындатуы мүмкін. Туыс өкілдерінің таксономиялық және географиялық әртүрлілігі, аралық және түпкілікті иелерінің ерекшеліктері, сондай-ақ паразиттің айналымына экологиялық факторлардың әсері туралы мәліметтер талданды. *Sarcocystis*-тің нақты түрлік алуантүрлілігі морфологиялық тұрғыдан сипатталған формалар санынан едәуір жоғары екені атап өтілді, бұл молекулалық-генетикалық сәйкестендіру әдістерінің белсенді енгізілуімен байланысты. Заманауи диагностикалық тәсілдер қарастырылды, оның ішінде морфологиялық және гистологиялық зерттеулер, сондай-ақ 18S рРНҚ, *cox1* және ITS-1 маркерлерін қолданатын молекулалық әдістер, олар таксономиялық шекараларды нақтылауға, криптикалық түрлерді анықтауға және филогенетикалық байланыстарды талдауға мүмкіндік береді. Диагностиканың дәлдігін арттыру, мониторингті жетілдіру және профилактикалық шараларды әзірлеу үшін классикалық паразитологиялық және молекулалық әдістерді біріктірудің қажеттілігі атап көрсетілді. Паразитологияны, эпизоотологияны, экологияны және молекулалық биологияны біріктіретін пәнаралық тәсілдің орындылығы туралы қорытынды жасалды, бұл паразит пен иесінің эволюциялық өзара қатынастарын тереңірек түсінуге мүмкіндік береді және зооноздық саркоцистозды тиімді бақылау мен алдын алудың ғылыми негізін қалыптастырады.

Кілт сөздер: *Sarcocystis*, биоалуантүрлілік, экология, паразиттер, морфология, молекулалық идентификация, зооноздар, биоиндикаторлар.

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Современные исследования биоразнообразия *Sarcocystis* и их роли в экосистемах

В обзоре обобщены современные данные о биоразнообразии паразитов рода *Sarcocystis* и их значении для экосистем, ветеринарии и общественного здоровья. Саркоцистозы рассматриваются как заболевания с выраженной ветеринарной и зоонозной значимостью, поскольку они приводят к снижению продуктивности сельскохозяйственных животных, ухудшению качества мясной продукции и могут вызывать патологические изменения у человека. Проанализированы сведения о таксономическом и географическом разнообразии представителей рода, специфике промежуточных и окончательных хозяев, а также о влиянии экологических факторов на циркуляцию паразита. Отмечено, что реальное видовое разнообразие *Sarcocystis* существенно превышает число морфологически описанных форм, что связано с активным внедрением молекулярно-генетических методов идентификации. Рассмотрены современные диагностические подходы, включающие морфологические и гистологические исследования, а также молекулярные методы с использованием маркеров 18S рРНҚ, *cox1* и ITS-1, позволяющих уточнять таксономические границы, выявлять криптические виды и анализировать филогенетические связи. Подчеркнута необходимость интеграции классических паразитологических и молекулярных мето-

дов для повышения точности диагностики, совершенствования мониторинга и разработки профилактических мероприятий. Сделан вывод о целесообразности междисциплинарного подхода, объединяющего паразитологию, эпизоотологию, экологию и молекулярную биологию, что обеспечивает более глубокое понимание эволюционных взаимоотношений паразита и хозяина, а также формирует научную основу для эффективного контроля и профилактики зоонозного саркоцистоза.

Ключевые слова: Sarcocystis, биоразнообразие, экология, паразиты, морфология, молекулярная идентификация, зоонозы, биоиндикаторы.

References

- 1 Cawthorn, R.J., & Speer, C.A. (2019). Sarcocystis: *Infection and disease of humans, livestock, wildlife, and other hosts*. In P.L. Long (Ed.), *Coccidiosis of man and domestic animals* (2nd ed., pp. 145–172). CRC Press. <https://doi.org/10.1201/9781351070744-6>
- 2 Prakas, P., & Butkauskas, D. (2012). Protozoan parasites from genus Sarcocystis and their investigations in Lithuania. *Ekologija*, 58(1), 9–17. <https://doi.org/10.6001/EKOLOGIJA.V58I1.2349>
- 3 Wieser, S.N., & Giuliano, S.M. (2024). Sarcocystis spp. of New and Old World camelids: Ancient origin, present challenges. *Pathogens*, 13(3), 196. <https://doi.org/10.3390/pathogens13030196>
- 4 Castro-Forero, S.P., et al. (2022). Sarcocystis spp., a parasite with zoonotic potential. *Bulgarian Journal of Veterinary Medicine*, 25(4), 550–559. <https://doi.org/10.15547/bjvm.2019-0129>
- 5 Korpysa-Dzirba, W., Bilska-Zajac, E., Różycki, M., Belcik, A., Karamon, J., Gontarczyk, A., et al. (2024). Sarcocystis spp. — An underestimated parasite with zoonotic potential associated with food of animal origin. *Medycyna Weterynaryjna*, 80(1), 12–20. <https://doi.org/10.21521/mw.6838>
- 6 Fayer, R., Dubey, J.P., & Rosenthal, B.M. (2015). Human infections with Sarcocystis species. *Clinical Microbiology Reviews*, 28(2), 295–311. <https://doi.org/10.1128/CMR.00113-14>
- 7 Gjerde, B. (2014). Molecular characterisation of Sarcocystis rileyi from a common eider (Somateria mollissima) in Norway. *Parasitology Research*, 113(9), 3501–3509. <https://doi.org/10.1007/s00436-014-4025-1>
- 8 Chhabra, M.B., & Samantaray, S.R. (2013). Sarcocystis and sarcocystosis in India: Status and emerging perspectives. *Journal of Parasitic Diseases*, 37(1), 1–10. <https://doi.org/10.1007/s12639-012-0135-y>
- 9 Tenter, A.M. (1995). Current research on Sarcocystis species of domestic animals. *International Journal for Parasitology*, 25(11), 1311–1330. [https://doi.org/10.1016/0020-7519\(95\)00068-D](https://doi.org/10.1016/0020-7519(95)00068-D)
- 10 Stojceki, K., Sroka, J., & Cencek, T. (2012). Molecular diagnostics of Sarcocystis spp. infections. *Polish Journal of Veterinary Sciences*, 15(3), 589–596. <https://doi.org/10.2478/V10181-012-0090-7>
- 11 Swar, S.O., & Shnawa, B.H. (2021). Recent advances in molecular characterization of Sarcocystis species in some meat-producing animals: An updated review. *Asian Journal of Agriculture and Biology*, 9(1), 12–25. <https://doi.org/10.35495/ajab.2020.09.502>
- 12 Gjerde, B. (2013). Phylogenetic relationships among Sarcocystis species in cervids, cattle, and sheep inferred from the mitochondrial cytochrome c oxidase subunit I gene. *International Journal for Parasitology*, 43(7), 579–591. <https://doi.org/10.1016/j.ijpara.2013.02.004>
- 13 Fayer, R. (2004). Sarcocystis spp. in human infections. *Clinical Microbiology Reviews*, 17(4), 894–902. <https://doi.org/10.1128/CMR.17.4.894-902.2004>
- 14 Dubey, J. P., Calero-Bernal, R., Rosenthal, B. M., Speer, C. A., & Fayer, R. (2016). *Sarcocystosis of animals and humans* (2nd ed.). CRC Press.
- 15 Zeng, H., Van Damme, I., Kabi, T.W., et al. (2021). Sarcocystis species in bovine carcasses from a Belgian abattoir: A cross-sectional study. *Parasites & Vectors*, 14, 271. <https://doi.org/10.1186/s13071-021-04788-1>
- 16 Shams, M., Shamsi, L., Asghari, A., Motazedian, M. H., Mohammadi-Ghalehbin, B., Omidian, M., Nazari, N., & Sadrebazzaz, A. (2022). Molecular epidemiology, species distribution, and zoonotic importance of the neglected meat-borne pathogen Sarcocystis spp. in cattle (Bos taurus): A global systematic review and meta-analysis. *Acta Parasitologica*, 67(3), 1055–1072. <https://doi.org/10.1007/s11686-022-00563-z>
- 17 Baranauskaitė, A., Strazdaitė-Žielenė, Ž., Servienė, E., Butkauskas, D., & Prakas, P. (2023). Molecular identification of protozoan Sarcocystis in different types of water bodies in Lithuania. *Life*, 13(1), 51. <https://doi.org/10.3390/life13010051>
- 18 Moré, G.A. (2021, rev. 2024). Sarcocystosis in animals. *MSD Veterinary Manual*. Retrieved from <https://www.msdsvetmanual.com>
- 19 Marandykina-Prakienė, A., Butkauskas, D., Gudiškis, N., et al. (2023). Sarcocystis species richness in sheep and goats from Lithuania. *Veterinary Sciences*, 10(8), 520. <https://doi.org/10.3390/vetsci10080520>
- 20 da Rosa, G., Roman, I.J., Gressler, L.T., Cargnelutti, J.F., & Vogel, F.S.F. (2024). Molecular identification of Sarcocystis species in wild boar (Sus scrofa) and pigs (Sus scrofa domesticus) in Brazil. *Veterinary Parasitology: Regional Studies and Reports*, 50, 101020. <https://doi.org/10.1016/j.vprsr.2024.101020>

- 21 Moré, G.A. (2021, rev. 2024). Sarcocystosis in animals. Immunoparasitology Laboratory, National University of La Plata, Buenos Aires, Argentina. www.msdivetmanual.com. Retrieved from <https://www.msdivetmanual.com/musculoskeletal-system/sarcocystosis/sarcocystosis-in-animals>
- 22 Prakas, P., Calero-Bernal, R., & Dubey, J.P. (2025). Sarcocystis infection in domestic and wild avian hosts: Inseparable flight partners. *Veterinary Parasitology*, 335, 110413. <https://doi.org/10.1016/j.vetpar.2025.110413>
- 23 Juozaitytė-Ngugu, E., & Prakas, P. (2023). The richness of Sarcocystis species in the common gull (*Larus canus*) and black-headed gull (*Larus ridibundus*) from Lithuania. *Parasitologia*, 3(2), 172–180. <https://doi.org/10.3390/parasitologia3020018>
- 24 Prakas, P., Strazdaitė-Žielienė, Ž., Januškevičius, V., Chiesa, F., Baranauskaitė, A., Rudaitytė-Lukošienė, E., et al. (2020). Molecular identification of four Sarcocystis species in cattle from Lithuania, including *S. hominis*, and development of a rapid molecular detection method. *Parasites & Vectors*, 13(1), 610. <http://dx.doi.org/10.1186/s13071-020-04490-3>
- 25 Baranauskaitė, A., Prakas, P., Petrauskas, M., Rubiola, S., Servienė, E., & Strazdaitė-Žielienė, Ž. (2025). Detection of Sarcocystis parasites in environmental samples from Lithuanian farms. Food and Waterborne. *Parasitology*, 39, e00267. <https://doi.org/10.1016/j.fawpar.2025.e00267>
- 26 Epidemiologija i modeli sistem «khozaiin-parazit» [Epidemiology and models of host-parasite systems]. Pavlodar: Toraigyrov universitet. textbook.tou.edu.kz. Retrieved from <https://textbook.tou.edu.kz/books/009/7.html> [in Russian].
- 27 Pradhan, A.K., & Karanth, S. (2023). Zoonoses from animal meat and milk. In M.E. Knowles, L.E. Anelich, A.R. Boobis, & B. Popping (Eds.). *Present knowledge in food safety* (pp. 394–411). Academic Press. <https://doi.org/10.1016/B978-0-12-819470-6.00029-9>
- 28 Maky, M.A., & Mohammed, E.S. (2020). Molecular identification of Sarcocystis spp. in meat and meat products in Qena, Upper Egypt. *Journal of Animal Health and Production*, 9(1), 88–93. <http://dx.doi.org/10.17582/journal.jahp/2020/9.1.88.93>
- 29 Obadiyah, H.I., Wieser, S.N., Nzelu, I.N., Olaolu, O.S., Jagab, H.S., Obishakin, E.T., et al. (2024). First molecular detection of Sarcocystis suihominis in a domestic pig of Nigeria. *Parasitology Research*, 123(2), 367–375. <http://dx.doi.org/10.1007/s00436-024-07901-2>
- 30 Tang, K., Lamu, D., Qin, T., Liao, Z., Zhang, M., Wu, Z., Deng, S., Tao, J., & Hu, J. (2023). Prevalence and genetic characterization of morphologically indistinguishable sarcocysts of *Sarcocystis cruzi* in cattle and *Sarcocystis poephagicanis* in yaks. *Diversity*, 15(11), 1136. <https://doi.org/10.3390/d15111136>
- 31 Bermukhametov, Z.Zh., Tomaruk, O.V., Suleymanova, K.U., & Rychshanova, R.M. (2023). Bovine sarcocystosis in Kostanay region. *Herald of Science of S. Seifullin Kazakh Agrotechnical Research University: Veterinary Sciences*, 2(002), 14–19. [https://doi.org/10.51452/kazatuvc.2023.2\(002\).1428](https://doi.org/10.51452/kazatuvc.2023.2(002).1428)
- 32 Bermukhametov, Z., Suleimanova, K., Prakas, P., Tomaruk, O., Shevtsov, A., Abdygulov, B., Mustafin, B., Baimenov, B., Sokharev, Y., & Rychshanova, R. (2025). Identification of *Sarcocystis* species in cattle muscles: Experience of Kazakhstan. *International Journal of Veterinary Science*, 14(1), 32–38. <https://doi.org/10.47278/journal.ijvs/2024.206>
- 33 Feng, Y., Guo, R., Sang, X., Zhang, X., Li, M., Li, X., Yang, N., & Jiang, T. (2023). A systematic meta-analysis of global *Sarcocystis* infection in sheep and goats. *Pathogens*, 12, 902. <https://doi.org/10.3390/pathogens12070902>
- 34 Orazgaliyev, S.M., Zaykovskaya, O.N., Nurzhumanova, Zh.M., Koigeldinova, A.S., & Amantai, G.A. (2025). Patomorfologicheskaya diagnostika pri sarkotsistoze ovets [Pathomorphological Diagnosis of Sarcocystosis in Sheep]. *Nauchno-prakticheskii zhurnal Zapadno-Kazakhstanskogo agrarno-tekhnicheskogo universiteta imeni Zhangir khana. Nauka i obrazovanie — Scientific and practical journal of Zhangir Khan West Kazakhstan Agrarian-Technical University. Science and education*, 3-2(80), 87–95. <https://doi.org/10.52578/2305-9397-2025-3-2-87-95> [in Russian].
- 35 Gastón, M., Carlotta, F., Oehm, A.W., Maja, R., Andrew, H., Frey, C.F., & Walter, B. (2025). *Sarcocystis* spp. and *Toxoplasma gondii* in muscles from wild boars (*Sus scrofa*) consumed in Switzerland. *International Journal for Parasitology: Parasites and Wildlife*, 27, 101114. <https://doi.org/10.1016/j.ijppaw.2025.101114>
- 36 Bermukhametov, Z., Suleimanova, K., Tomaruk, O., Baimenov, B., Shevchenko, P., Batyrbekov, A., Mikniene, Z., Girisgin, A. O., & Rychshanova, R. (2024). Equine sarcocystosis in the northern region of the Republic of Kazakhstan. *Animals*, 14(16), 2299. <https://doi.org/10.3390/ani14162299>
- 37 Prakas, P., Oksanen, A., Butkauskas, D., Sruoga, A., Kutkienė, L., Švažas, S., et al. (2014). Identification and intraspecific genetic diversity of *Sarcocystis rileyi* from ducks (*Anas* spp.) in Lithuania and Finland. *Journal of Parasitology*, 100(5), 657–661. <https://doi.org/10.1645/13-493.1>
- 38 Prakas, P., Valkiūnas, G., Žalakevičius, M., Lazutka, J.R., Stonis, J.R., & Paulauskas, A. (2011). Diversity and ecology of *Sarcocystis* in Lithuanian game fauna. *Acta Zoologica Lituanica*, 21(2), 157–165.
- 39 Abe, N., Matsuo, K., Moribe, J., Takashima, Y., Irie, T., Baba, T., & Gjerde, B. (2019). Morphological and molecular characteristics of seven *Sarcocystis* species from sika deer (*Cervus nippon centralis*) in Japan, including three new species. *International Journal for Parasitology: Parasites and Wildlife*, 10, 252–262. <https://doi.org/10.1016/j.ijppaw.2019.10.002>
- 40 Rudaitytė-Lukošienė, E., Prakas, P., Butkauskas, D., Kutkienė, L., Vepštaitė-Monstavičė, I., & Servienė, E. (2018). Morphological and molecular identification of *Sarcocystis* spp. from sika deer (*Cervus nippon*), including two new species *Sarcocystis frondea* and *Sarcocystis nipponi*. *Parasitology Research*, 117(5), 1305–1315. <https://doi.org/10.1007/s00436-018-5816-8>
- 41 Hu, J., Zhang, M., Wu, Z., Zeng, H., & Tao, J. (2023). Description of *Sarcocystis platyrhynchoi* n. sp. from domestic ducks (*Anas platyrhynchos*) in China. *Parasites & Vectors*, 16(1), 1–12. <https://doi.org/10.1186/s13071-023-05710-8>
- 42 Nimri, L. (2014). Unusual case presentation of intestinal *Sarcocystis hominis* infection in a healthy adult. *JMM Case Reports*, 1(4), e004069. <https://doi.org/10.1099/jmmcr.0.T00019>

- 43 Rathish, B. (2022). *Sarcocystis*. In *StatPearls*. StatPearls Publishing. www.ncbi.nlm.nih.gov. Retrieved from <https://www.ncbi.nlm.nih.gov/books/NBK574577/>
- 44 Juozaitytė-Ngugu, E., Švažas, S., Šneideris, D., Rudaitytė-Lukošienė, E., Butkauskas, D., & Prakas, P. (2021). The role of birds of the family Corvidae in transmitting *Sarcocystis* protozoan parasites. *Animals*, *11*(11), 3258. <https://doi.org/10.3390/ani11113258>
- 45 Dubey, J.P. (1976). A review of *Sarcocystis* of domestic animals and of other coccidia of cats and dogs. *Journal of the American Veterinary Medical Association*, *169*(10), 1061–1078.
- 46 Zhu, Z., Ying, Z., Feng, Z., Liu, Q., & Liu, J. (2023). The occurrence and meta-analysis of investigations on *Sarcocystis* infection among ruminants in mainland China. *Animals*, *13*, 149. <https://doi.org/10.3390/ani13010149>
- 47 Barrows, P.L., Prestwood, A.K., & Green, C.E. (1982). Experimental *Sarcocystis suicanis* infections: Disease in growing pigs. *American Journal of Veterinary Research*, *43*(8), 1409–1412.
- 48 Shvedova, G.I., & Rystsova, E.O. (2024). Muscular sarcocystosis in dogs. *Innovative Processes in Agriculture*, 145–149. Retrieved from <https://repository.rudn.ru/ru/records/article/record/167453>
- 49 Chapman, J., Mense, M., & Dubey, J.P. (2005). Clinical muscular sarcocystosis in a dog. *Journal of Parasitology*, *91*(1), 187–190. <https://doi.org/10.1645/GE-406R>
- 50 Šukytė, T., Butkauskas, D., Juozaitytė-Ngugu, E., Švažas, S., & Prakas, P. (2023). Molecular confirmation of *Accipiter* birds of prey as definitive hosts of numerous *Sarcocystis* species, including *Sarcocystis* sp. closely related to pathogenic *S. calchasi*. *Pathogens*, *12*(6), 752. <https://doi.org/10.3390/pathogens12060752>
- 51 Pagano, T.B., Prisco, F., De Biase, D., Piegari, G., Maurelli, M.P., Rinaldi, L., Cringoli, G., Papparella, S., & Paciello, O. (2020). Muscular sarcocystosis in sheep associated with lymphoplasmacytic myositis and expression of major histocompatibility complex class I and II. *Veterinary Pathology*, *57*(2), 272–280. <https://doi.org/10.1177/0300985819891257>
- 52 Glamazdin, I.G., Rutaganira, Y., Panova, O.A., Sysoeva, N.Yu., & Khalim, D. (2024). Visual and molecular-serological diagnosis of sarcocystosis in cattle. *Russian Journal of Parasitology*, *18*(2), 163–169. <https://doi.org/10.31016/1998-8435-2024-18-2-163-169>
- 53 Tenter, A.M. (1988). Comparison of dot-ELISA, ELISA and IFAT for the detection of IgG antibodies to *Sarcocystis muris* in experimentally infected and immunized mice. *Veterinary Parasitology*, *29*(2-3), 89–104. [https://doi.org/10.1016/0304-4017\(88\)90119-7](https://doi.org/10.1016/0304-4017(88)90119-7)
- 54 Dalir Ghaffari, A., Dalimi, A., & Pirestani, M. (2022). Microscopic and molecular detection of *Sarcocystis cruzi* in the heart muscle of cattle. *Iranian Journal of Parasitology*, *17*(4), 535–542. <https://doi.org/10.18502/ijpa.v17i4.11281>
- 55 Abdolahi, N., Heidari, A., Bairami, A., Miahipour, A., Sezavar, M., Teimuri, A., & Bahadory, S. (2025). Prevalence and molecular analysis of *Sarcocystis* species infection in slaughtered cattle in Alborz, Iran. *Veterinary and Animal Science*, *27*, 100431. <https://doi.org/10.1016/j.vas.2025.100431>
- 56 Hamidinejat, H., Moetamedi, H., Alborzi, A., & Hatami, A. (2014). Molecular detection of *Sarcocystis* species in slaughtered sheep by PCR-RFLP from south-western Iran. *Journal of Parasitic Diseases*, *38*(2), 233–237. <https://doi.org/10.1007/s12639-012-0231-z>
- 57 Chen, Y., Peng, J., Zhu, Z., Zhang, W., Wang, L., Xu, J., Liu, Q., & Liu, J. (2024). Development of a highly specific LAMP assay for detection of *Sarcocystis tenella* and *Sarcocystis gigantea* in sheep. *Parasitology Research*, *123*(9), 324. <https://doi.org/10.1007/s00436-024-08349-0>
- 58 Stojceki, K., Karamon, J., Sroka, J., & Cencek, T. (2012). Molecular diagnostics of *Sarcocystis* spp. infections. *Polish Journal of Veterinary Sciences*, *15*(3), 589–596. <https://doi.org/10.2478/v10181-012-0090-7>
- 59 Strazdaitė-Žielenė, Ž., Baranauskaitė, A., Butkauskas, D., Servienė, E., & Prakas, P. (2022). Molecular identification of parasitic protozoa *Sarcocystis* in water samples. *Veterinary Sciences*, *9*(8), 412. <https://doi.org/10.3390/vetsci9080412>
- 60 Dameshghi, F., Shirali, S., Shayan, P., & Shemshadi, B. (2023). RFLP analysis of fragments of the 18S rRNA and *cox1* genes to identify *Sarcocystis cruzi* in water buffalo in Guilan Province, Iran. *Iranian Journal of Parasitology*, *18*(4), 464–473. <https://doi.org/10.18502/ijpa.v18i4.14255>
- 61 Hoeve-Bakker, B.J.A., van der Giessen, J.W.B., & Franssen, F.F.J. (2019). Molecular identification targeting *cox1* and 18S genes confirms the high prevalence of *Sarcocystis* spp. in cattle in the Netherlands. *International Journal for Parasitology*, *49*(11), 859–866. <https://doi.org/10.1016/j.ijpara.2019.05.008>

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Phytochemical and Elemental Characterization of *Rheum tataricum*

This study presents a phytochemical and elemental characterization of *Rheum tataricum* L. collected in the Almaty region of Kazakhstan, aimed at describing its compositional features as a potential source of plant secondary metabolites. Elemental analysis revealed high levels of calcium, magnesium, phosphorus, sulfur, and zinc in the leaves, whereas the stems contained elevated levels of rubidium and comparable amounts of potassium, sodium, and chlorine. Quantitative phytochemical screening demonstrated a generally stable accumulation of major metabolite groups, including anthraquinones, flavonoids, tannins, triterpenoids, and phenolic acids, across vegetative stages, with noticeable seasonal variation observed primarily for carbohydrates and tannins. The stems were characterized by higher contents of tannins and triterpenoids, whereas the leaves accumulated greater amounts of phenolic acids and micronutrients. These organ-specific and stage-dependent patterns reflect ecological adaptation to semi-desert conditions and suggest complex regulation of secondary metabolism in *R. tataricum*. The results highlight the phytochemical richness of this species; however, its biological and pharmacological activities cannot be inferred from the present data and require confirmation through dedicated bioassays.

Keywords: *Rheum tataricum*, phytochemical analysis, elemental composition, secondary metabolites, Almaty region.

Introduction

The genus *Rheum* (*Polygonaceae*) comprises several species of high ethnopharmacological and practical importance due to their content of bioactive compounds such as anthraquinones, flavonoids, and tannins [1]. Many representatives of the genus are used in traditional medicine as laxative, choleric, astringent, and antispasmodic agents [2, 3]. In Kazakhstan, *Rheum tataricum* L., commonly known as Tatar rhubarb (*Tüyezhapsyraq* in Kazakh), is one of the most prominent and widespread species of this genus [4, 5].

The current state of knowledge on *Rheum* species in Kazakhstan indicates that at least seven of the nine known rhubarbs possess medicinal properties, while *Rheum altaicum* Losinsk. and *Rheum wittrockii* Lundstr. are listed in the Red Book of Kazakhstan as protected species [6, 7]. Experimental introduction studies have been carried out on four native species, *R. compactum* (syn. *R. altaicum*), *R. maximovichii*, *R. tataricum*, and *R. wittrockii*, at the Altai and Main Botanical Gardens [5, 7, 8]. Among them, *R. tataricum* has shown good adaptation under local conditions, although flowering and fruiting occur irregularly, and the species exhibits an introduction success index (ISI) of 4 [9].

Morphologically, *R. tataricum* is a perennial herb (ephemeroid) characteristic of desert and semi-desert zones, forming dense stands on saline and gray-brown soils. The plant has a strong upright rhizome covered with brownish-yellow scales and 2-3 grooved, hollow, branched stems reaching 2-3 m in height. The leaves are large (up to 35×50 cm), rounded, heart-shaped at the base, and supported by three prominent veins; their undersides are slightly pubescent [10, 11]. The inflorescence is paniculate-spherical, consisting of small (approximately 3 mm) cream-colored flowers with brown veins. The fruits are triangular or heart-shaped, dark brown to black, with narrow red-brown wings about 1-1.5 mm wide. The species flowers in April-May and produces fruits in May-June [4, 12].

Geographically, *R. tataricum* is distributed across many regions of Kazakhstan, including the Caspian, Bokeev, Aktobe, Torgay, Kyzyl-Orda, Ulytau, Karatau, and Chu-Ili mountain ranges, extending through the Balkhash-Alakol and Kyzylkum areas [4, 13]. The rhizomes and fruit pericarp are rich in tannins,

while the fresh leaves are grazed by sheep and camels, giving the plant both ecological and economic importance [9, 10].

In folk medicine, *R. tataricum* has been used in both Eastern and Western traditions for its anti-tumor, febrifuge, and hemostatic properties [14]. However, scientific validation of these pharmacological effects through systematic phytochemical and elemental analysis remains limited. Despite its long-standing traditional use and successful acclimatization, *R. tataricum* remains insufficiently studied with respect to its detailed phytochemical profile and elemental composition [15]. Therefore, this study aims to conduct a botanical, phytochemical, and elemental characterization of *Rheum tataricum* L. (Polygonaceae Juss.) from the Balkhash region of Almaty Province as a basis for further evaluation of its biological activity in future studies.

Experimental

2.1. Study Site and Plant Material

Plant material of *Rheum tataricum* L. was collected in April 2023 in the Balkhash district of Almaty region, Kazakhstan, at an altitude of 381 m above sea level (45°35'28.3" N, 77°19'55.5" E). The area is characterized by an arid climate with saline gray-brown soils typical of semi-desert ecosystems. Taxonomic identification of the species was performed using the generic and species keys of the family Polygonaceae for the flora of Kazakhstan. A voucher specimen of *Rheum tataricum* L.fil. is deposited in the Herbarium of the Institute of Botany and Phytointroduction, Almaty (Herbarium AA), voucher No. 2197/25-*Rheum tataricum* L.fil., identified by Zh.Zh. Karzhaubekova and R.B. Arysbayeva and confirmed by N.G. Gemejiyeva.

Plant material was collected from a single natural population within one sampling site. A total of 16 individual plants were sampled to represent four vegetative phases (four plants per phase).

2.2. Preparation of Plant Material

Fresh plant material was separated into stems and leaves. The aerial parts were air-dried in the shade at 25–30 °C with periodic turning until constant weight was achieved, corresponding to a residual moisture content of 10–12 %. The dried material was ground to a fine powder using a stainless-steel mill and stored in airtight containers protected from light and moisture until further analysis.

2.3. Determination of Elemental Composition

The mineral composition of the stems and leaves was determined using atomic absorption spectroscopic (AAS) analysis following ashing at 450 °C. Samples (1 g) were digested in a mixture of HNO:HCl (3:1, v/v) and filtered. Elemental concentrations (Na, K, Mg, Fe, Zn and other elements) were quantified using a PerkinElmer AAnalyst 400 spectrophotometer. Calibration was performed using certified standard solutions. All elemental determinations were performed in triplicate for each plant sample (n = 3). Results were expressed as a percentage of dry weight.

2.4. Phytochemical Screening

Qualitative tests for major groups of biologically active substances, alkaloids, flavonoids, anthraquinones, tannins, coumarins, triterpenoids, polysaccharides, phenolic acids, amino acids, catechins, organic acids, and carbohydrates, were conducted using standard phytochemical procedures [16–18]. The following reactions were applied: Dragendorff's test for alkaloids, Bornträger's reaction for anthraquinones, ferric chloride test for phenolic compounds and tannins, Shinoda reaction for flavonoids, and Molisch test for carbohydrates. Results were expressed qualitatively as "present" or "absent."

2.5. Quantitative Determination of Bioactive Compounds

Quantitative analyses of key phytochemical groups were performed spectrophotometrically using reported procedures [19–22]. Flavonoid content was determined by the aluminum chloride colorimetric method ($\lambda=415$ nm) and expressed as milligrams of quercetin equivalents per gram of dry weight (mg QE/g DW). Tannin concentration was measured by the Folin-Denis assay ($\lambda = 760$ nm, mg GAE/g DW). Anthraquinones were quantified using the modified Bornträger reaction, while total polysaccharides were determined by the phenol-sulfuric acid method. For ease of comparison across compound classes, quantitative results were sub-

sequently converted and presented as percentage of dry weight. Values obtained from calibration curves (mg equivalents per g DW) were recalculated assuming 1 g of dry plant material per extraction, using the relationship: 1 % DW = 10 mg/g DW. All measurements were performed in triplicate (n = 3) using a Shimadzu UV-1800 UV-Vis spectrophotometer.

2.6. Comparative Analysis by Vegetative Phase

To evaluate the dynamic accumulation of bioactive compounds, analyses were conducted across four vegetative stages: (1) bud formation, (2) flowering, (3) fruiting, and (4) dormancy. For each vegetative phase, samples from four independent individual plants were analyzed (n = 4 per phase). Comparative analysis was carried out separately for stems and leaves.

2.7. Statistical Analysis

All data were expressed as mean \pm standard deviation (SD) of at least three replicates. Statistical comparisons among vegetative stages were performed using one-way ANOVA followed by Šidák's multiple comparisons test ($p < 0.05$) in GraphPad Prism 10.0. For two-group comparisons, an unpaired t-test was used ($p < 0.05$).

Results

3.1 Elemental Composition of *Rheum tataricum*

The elemental analysis of *Rheum tataricum* revealed distinct differences between stems and leaves in mineral composition (Table 1). The total mineral content of stems accounted for approximately 3.0 % of dry weight, while leaves showed a higher accumulation of macro- and microelements. Calcium (Ca) and magnesium (Mg) were the most abundant macronutrients, with significantly higher concentrations in leaves (0.83 ± 0.03 % and 0.55 ± 0.02 %, respectively) compared to stems (0.49 ± 0.02 % and 0.46 ± 0.01 %; $p < 0.0001$). Similar trends were observed for phosphorus (P) and sulfur (S), which were also significantly elevated in leaves ($p = 0.0004$ and $p < 0.0001$, respectively). In contrast, rubidium (Rb) content was higher in stems (0.32 ± 0.02 %) than in leaves (0.11 ± 0.01 %; $p < 0.0001$). Potassium (K), sodium (Na), and chlorine (Cl) did not differ significantly between organs ($p = 0.7889$). Among trace elements, zinc (Zn) was notably enriched in leaves (0.78 ± 0.04 %), whereas iron (Fe) was undetected in stems but present in leaves (0.21 ± 0.01 %; $p < 0.0001$). The relatively high Zn concentration observed in leaves should be interpreted with caution, as it may reflect local soil geochemistry and site-specific environmental conditions rather than species-level hyperaccumulation.

Table 1

Elemental composition of *Rheum tataricum* stems and leaves (mean \pm SD, % dry weight)

| Element | Stems (% \pm SD) | Leaves (% \pm SD) | p-value |
|----------------|--------------------|---------------------|---------|
| Calcium (Ca) | 0.49 \pm 0.02 | 0.83 \pm 0.03 | <0.0001 |
| Potassium (K) | 0.40 \pm 0.01 | 0.38 \pm 0.01 | 0.7889 |
| Sodium (Na) | 0.29 \pm 0.01 | 0.31 \pm 0.01 | 0.7889 |
| Magnesium (Mg) | 0.46 \pm 0.01 | 0.55 \pm 0.02 | <0.0001 |
| Phosphorus (P) | 0.17 \pm 0.01 | 0.23 \pm 0.01 | 0.0004 |
| Sulfur (S) | 0.24 \pm 0.01 | 0.35 \pm 0.01 | <0.0001 |
| Chlorine (Cl) | 0.40 \pm 0.01 | 0.38 \pm 0.01 | 0.7889 |
| Silicon (Si) | 0.18 \pm 0.01 | 0.29 \pm 0.02 | <0.0001 |
| Rubidium (Rb) | 0.32 \pm 0.02 | 0.11 \pm 0.01 | <0.0001 |
| Iron (Fe) | ND | 0.21 \pm 0.01 | <0.0001 |
| Zinc (Zn) | 0.07 \pm 0.01 | 0.78 \pm 0.04 | <0.0001 |

Note. Values are expressed as mean \pm SD (n=3). ND = not detected. Statistical significance was determined using an unpaired t-test.

Overall, leaves exhibited a greater accumulation of essential elements, reflecting their active metabolic role, while stems contained relatively higher levels of Rb and comparable concentrations of K, Na, and Cl.

3.2. Dynamics of Biologically Active Compounds in the Stem of *Rheum tataricum* during Vegetative Phases

The quantitative composition of the main groups of biologically active substances in stem of *Rheum tataricum* varied slightly across vegetative phases (Table 2). Carbohydrates dominated the extractive fraction throughout all growth stages, accounting for approximately 20–22 % of the dry weight, followed by tannins (2–4 %), triterpenoids (4–5 %), and anthraquinones (3–4 %). Minor constituents included amino acids (1–2 %), flavonoids (2–3 %), polysaccharides (1–2 %), and trace levels of alkaloids, catechins, and organic acids (<1 %).

Table 2

Quantitative composition of the main groups of biologically active substances in stem of *Rheum tataricum* during different vegetative phases (mean±SD, % of dry weight)

| Bioactive compound group | Budding period (mean±SD) | Flowering period (mean±SD) | Fruiting period (mean±SD) | Dormant period (mean±SD) |
|--------------------------|--------------------------|----------------------------|---------------------------|--------------------------|
| Alkaloids | 0.38±0.03 | 0.41±0.04 | 0.42±0.03 | 0.44±0.02 |
| Amino acids | 2.03±0.10 | 1.88±0.09 | 1.81±0.09 | 1.69±0.08 |
| Anthraquinones | 3.82±0.19 | 3.91±0.20 | 3.97±0.20 | 4.08±0.21 |
| Tannins | 4.26±0.21 | 3.93±0.20 | 3.68±0.18 | 2.11±0.11 |
| Catechins | 0.29±0.02 | 0.28±0.02 | 0.28±0.02 | 0.26±0.02 |
| Coumarins | 1.14±0.06 | 0.96±0.05 | 0.91±0.05 | 0.83±0.04 |
| Organic acids | 0.18±0.01 | 0.16±0.01 | 0.15±0.01 | 0.13±0.01 |
| Polysaccharides | 1.72±0.09 | 1.83±0.09 | 1.94±0.11 | 2.11±0.10 |
| Triterpenoids | 4.16±0.21 | 4.39±0.22 | 4.52±0.23 | 4.73±0.24 |
| Carbohydrates | 20.82±1.14 | 21.14±1.06 | 21.30±1.27 | 21.75±1.09 |
| Phenolic acids | 0.32±0.02 | 0.28±0.02 | 0.28±0.02 | 0.26±0.02 |
| Flavonoids | 2.49±0.12 | 2.32±0.12 | 2.27±0.11 | 2.20±0.11 |

Note. Values are presented as mean±SD (n = 4). Statistical significance was evaluated using Šidák's multiple comparisons test.

Statistical analysis using Šidák's multiple comparisons test confirmed significant variation in several compound groups among developmental stages ($p < 0.05$). A decrease in tannin content was observed in dormant period (2.11±0.11 %; $p < 0.0001$) compared to the budding phase (4.26±0.21 %), while intermediate values were recorded during flowering (3.93±0.20 %) and fruiting (3.68±0.18 %). Similarly, carbohydrates showed a modest but statistically significant decrease from the dormant (21.75±1.09 %) period to the budding (20.82±1.14 %) phase, comparing to the ($p = 0.0173$).

Other compound classes, including alkaloids, amino acids, anthraquinones, catechins, coumarins, organic acids, polysaccharides, triterpenoids, phenolic acids, and flavonoids, exhibited no statistically significant fluctuations across vegetative phases ($p > 0.05$).

Overall, the phytochemical profile of stem of *R. tataricum* remained relatively stable throughout the growing cycle, with the highest variability observed in the concentrations of tannins and carbohydrates, reflecting potential shifts in metabolic allocation during active and dormant stages.

3.3. Dynamics of Biologically Active Compounds in the Leaves of *Rheum tataricum* during Vegetative Phases

The quantitative composition of the main groups of biologically active substances in the leaves of *Rheum tataricum* varied minimally across vegetative phases (Table 3). Carbohydrates remained the predominant component throughout all stages, accounting for approximately 17–18 % of dry weight, followed by tannins (3–4 %), triterpenoids (3–4 %), and anthraquinones (3–4 %). Minor components included amino acids (1–2 %), flavonoids (1–2 %), and polysaccharides (1–2 %), whereas alkaloids, catechins, coumarins, organic acids, and phenolic acids were present in trace amounts (<1 %).

Quantitative composition of the main groups of biologically active substances in leaves of *Rheum tataricum* during different vegetative phases (mean±SD, % of dry weight)

| Bioactive compound group | Budding period (mean±SD) | Flowering period (mean±SD) | Fruiting period (mean±SD) | Dormant period (mean±SD) |
|--------------------------|--------------------------|----------------------------|---------------------------|--------------------------|
| Alkaloids | 0.43±0.03 | 0.41±0.03 | 0.39±0.02 | 0.34±0.02 |
| Amino acids | 1.70±0.09 | 1.63±0.08 | 1.55±0.08 | 1.42±0.07 |
| Anthraquinones | 3.23±0.16 | 3.35±0.17 | 3.46±0.18 | 3.62±0.18 |
| Tannins | 3.82±0.19 | 3.74±0.18 | 3.55±0.17 | 3.38±0.16 |
| Catechins | 0.98±0.05 | 0.93±0.05 | 0.87±0.04 | 0.75±0.04 |
| Coumarins | 1.08±0.05 | 1.03±0.05 | 0.99±0.05 | 0.94±0.05 |
| Organic acids | 0.24±0.02 | 0.22±0.02 | 0.21±0.02 | 0.19±0.02 |
| Polysaccharides | 1.39±0.07 | 1.45±0.07 | 1.58±0.08 | 1.74±0.08 |
| Triterpenoids | 3.25±0.16 | 3.42±0.17 | 3.57±0.18 | 3.69±0.18 |
| Carbohydrates | 17.11±0.85 | 17.32±0.87 | 17.68±0.88 | 18.02±0.90 |
| Phenolic acids | 0.42±0.03 | 0.45±0.03 | 0.46±0.03 | 0.49±0.03 |
| Flavonoids | 2.01±0.10 | 1.88±0.09 | 1.76±0.09 | 1.63±0.08 |

Note. Values are presented as mean±SD (n = 4). Statistical significance was evaluated using Šidák's multiple comparisons test.

Statistical analysis using Šidák's multiple comparisons test confirmed that carbohydrate content exhibited significant variation among the vegetative phases ($p=0.0004$ and $p=0.0265$). Specifically, a notable decrease was observed from the dormant to the budding stage (from 18.02 ± 0.90 % to 17.11 ± 0.85 %). However, differences between intermediate stages (flowering and fruiting) were not statistically significant ($p>0.05$).

All other compound classes, including alkaloids, amino acids, anthraquinones, tannins, catechins, coumarins, organic acids, polysaccharides, triterpenoids, phenolic acids, and flavonoids, showed no statistically significant differences ($p > 0.05$) across vegetative phases, indicating overall biochemical stability in leaf composition.

Overall, the phytochemical profile of the leaves of *R. tataricum* remained relatively stable throughout the growing cycle, with minor fluctuations primarily observed in carbohydrate content. This stability suggests that the leaf metabolic composition is largely conserved across vegetative phases, with only slight adjustments in primary metabolite levels during seasonal transitions.

3.4 Comparative Analysis of Stems and Leaves

To better illustrate organ-specific accumulation patterns, the content of the main classes of biologically active substances in the stems and leaves of *Rheum tataricum* was compared across all vegetative stages (Fig. 1). Both organs exhibited a similar qualitative composition dominated by carbohydrates, tannins, triterpenoids, and anthraquinones, yet their quantitative ratios differed significantly.

At all growth phases, stems accumulated higher levels of tannins and triterpenoids ($p < 0.05$), confirming their role as major storage tissues for secondary metabolites. Conversely, leaves contained significantly higher levels of phenolic acids during each developmental period ($p < 0.0001$), likely reflecting their active participation in photosynthesis-associated oxidative processes and stress responses. Minor but consistent differences were also detected for catechins and carbohydrates in some phases ($p = 0.015-0.0363$).

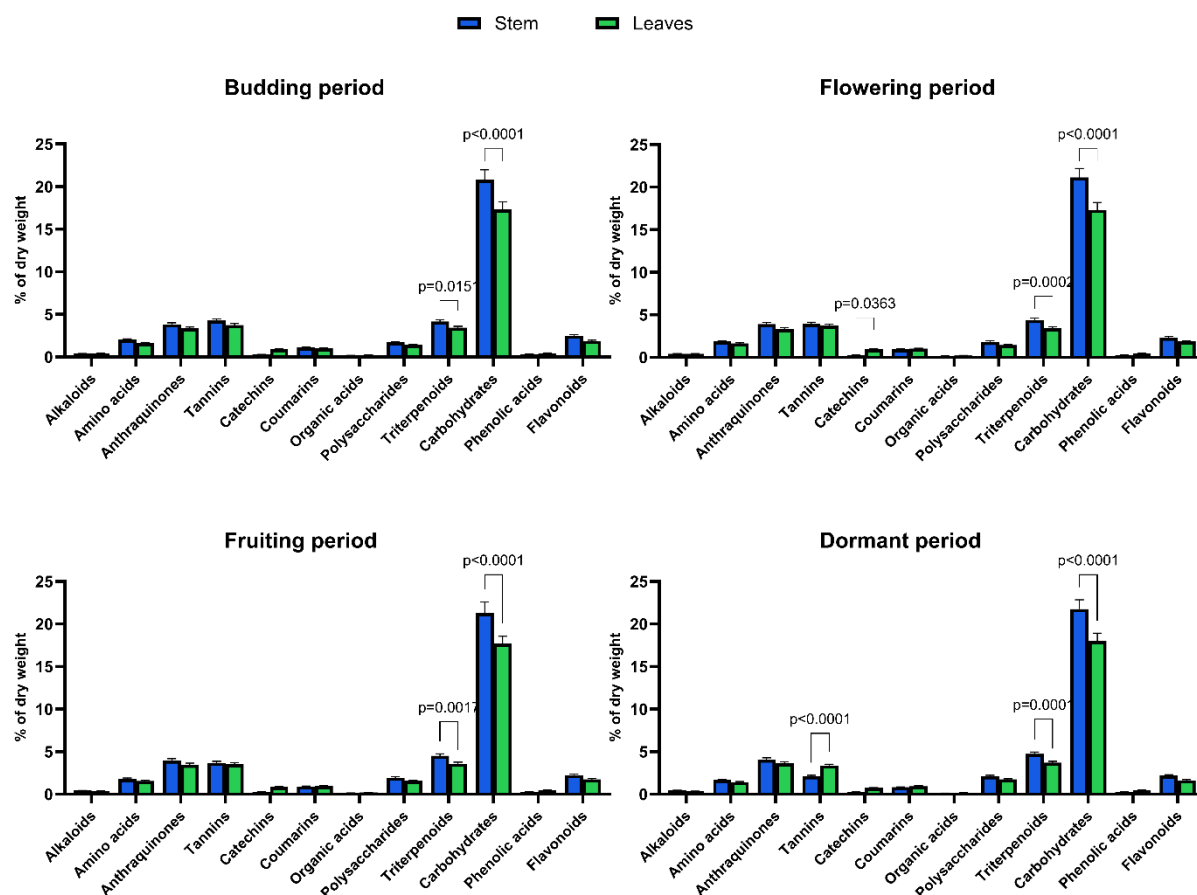


Figure 1. Comparative content of major groups of biologically active compounds in stems and leaves of *Rheum tataricum* during the budding, flowering, fruiting, and dormant periods

Data represent mean \pm SD (n=4). Significant differences between plant organs within each phase were determined using Šidák's multiple comparisons test ($p < 0.05$).

Overall, while the qualitative composition remained stable, the quantitative distribution of metabolites demonstrated clear tissue-specific specialization. Stems primarily served as reservoirs of condensed phenolic compounds, whereas leaves maintained higher proportions of readily oxidized phenolics and primary metabolites.

Discussion

This study delivers an organ- and stage-resolved profile of *Rheum tataricum* under semi-desert conditions, showing leaves enriched in Ca, Mg, P, S and Zn relative to stems, while stems retain more Rb and similar K/Na/Cl, and most phytochemical classes remain stable across the season except for tannins and carbohydrates. These patterns align with prior ecological work showing *Rheum tataricum* efficient mineral translocation and stress adaptation in arid habitats, including high foliar accumulation of several macro-/microelements and evidence of element hyperaccumulation under semi-desert soils [10]. Together, these findings suggest functional differentiation between organs, with leaves acting as metabolically active tissues and stems serving as storage compartments for condensed phenolic compounds.

Our leaf-dominant Ca/Mg/Zn profile concurs with Golubkina et al. (2022), who reported higher Mn/Fe/Co/B and other trace elements in wild *Rheum tataricum* and discussed soil-to-plant transfer influencing antioxidant status [10]. Moreover, similar mineral enrichment in leaves has been observed in *R. officinale* [23] and in rhubarb stalks/leaves more broadly [24], supporting the idea that leaf tissues of the *Rheum* genus preferentially accumulate these macro- and micro-elements as part of their adaptive and antioxidant metabolism. Environmental control over *Rheum* secondary metabolism is also emphasized in a review on the rhubarb value chain, noting climate/soil/altitude effects on anthraquinones, coumarins and stilbenes, consistent with our site-specific findings [25]. This study assessed only macro- and microelements

(Ca, K, Na, Mg, P, S, Cl, Si, Rb, Fe and Zn). Although elevated Zn levels were detected in leaf tissues, the present study does not aim to classify *R. tataricum* as a Zn hyperaccumulator. Such interpretation would require targeted soil–plant transfer analyses, larger population sampling, and controlled comparisons, which were beyond the scope of this work. Toxic heavy metals (Pb, Cd, As and Hg) were not determined and should be addressed in future studies prior to pharmaceutical application.

Across stages, carbohydrates and tannins showed the clearest shifts, while anthraquinones, flavonoids, amino acids and most minor classes were largely constant. This metabolic stability mirrors reports that *Rheum* maintains a robust phenolic/anthraquinone baseline across environments, with quantitative differences driven more by extraction and processing than by growth stage alone. Recent LC–MS/MS work on *Rheum tataricum* roots quantified 53 phytochemicals and demonstrated that supercritical CO₂, subcritical ethanol and ultrasound extractions markedly shift yields and bioactivity profiles, an important methodological caveat when comparing studies [9].

Our stem-greater tannins/triterpenoids and leaf-greater phenolic acids suggest tissue specialization: stems as reservoirs of astringent/antimicrobial phenolics and leaves as sites of redox-active phenolic acids. Such distributions are relevant from a phytochemical perspective, as the *Rheum* genus is known to contain anthraquinones (e.g., emodin, chrysophanol, rhein) and polyphenolic compounds that have been associated with various biological activities in previous studies. Current reviews summarize a broad range of biological activities that have been reported for anthraquinones and related compounds isolated from various *Rheum* species, including discussions of underlying molecular pathways and metabolism-related effects [26, 27]. In parallel, compound-level data for *R. tataricum* continue to expand. For example, a study from Kazakhstan reported the isolation of several metabolites from *R. tataricum* (e.g., stilbenes, phenylbutanoids, gallotannin) and evaluated their cytotoxic effects using in vitro cell line models [12]. Another review provides a comprehensive overview of anthraquinones, stilbenes, and related compound classes across the *Rheum* genus, highlighting their structural diversity and biological relevance in systems biology studies [28]. However, it should be emphasized that such findings originate from independent investigations employing targeted bioassays and purified compounds and cannot be directly extrapolated to the compositional data presented in the present study.

Strengths include standardized qualitative/quantitative assays and phase-matched organ comparisons. Limitations include single-region sampling and spectrophotometric class-level quantification rather than targeted LC–MS per class in all organs/stages. Future work should: (i) couple our design with targeted metabolomics (anthraquinones, triterpenoids, tannins) and bioassays; (ii) benchmark extraction-method effects explicitly (supercritical vs. hydroalcoholic) given their strong impact on yields and antibacterial/antioxidant readouts; and (iii) integrate safety/toxicity profiling, since dose-dependent adverse effects are reported for crude *Rheum* extracts and for rhein at higher exposures despite favorable therapeutic signals. Moreover, future studies should include parallel soil elemental analysis and expanded sampling to clarify the mechanisms underlying elevated Zn accumulation and to exclude site-specific effects.

Collectively, the results of this study characterize *Rheum tataricum* as a species with a diverse and stable phytochemical composition. The consistent presence of anthraquinones, triterpenoids, tannins, and phenolic acids across vegetative stages reflects a sustained capacity for secondary metabolite biosynthesis, while organ-specific accumulation patterns highlight pronounced chemical differentiation between stems and leaves. The enrichment of essential elements such as Ca, Mg, and Zn further contributes to understanding the metabolic and ecological features of this species under semi-desert conditions. Taken together, these compositional characteristics, along with the ecological adaptability and availability of *R. tataricum* in Kazakhstan, provide a descriptive basis for future investigations integrating targeted metabolomics, bioassays, and safety assessment to evaluate potential applied uses.

Conclusion

Rheum tataricum demonstrates stable biosynthesis of key secondary metabolites and a pronounced accumulation of essential elements, reflecting its adaptation to semi-desert environments. The consistent presence of anthraquinones, tannins, triterpenoids, and phenolic acids indicates that this species is characterized by a rich and diverse phytochemical composition. However, the present study is limited to elemental and phytochemical characterization, and no conclusions regarding biological or pharmacological activity can be drawn. Evaluation of antioxidant, anti-inflammatory, anticancer, or other bioactivities requires dedicated bioassays and should be addressed in future studies.

Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Korganbayeva Z.S.** — conceptualization, methodology, investigation, data curation, writing — original draft; **Pernebekova R.K.** — formal analysis, validation, investigation, writing — original draft, writing — review & editing; **Kirgizbayeva A.A.** — investigation, resources, visualization, data curation, writing — review & editing; **Bekmurzaeva E.K.** — supervision, project administration, writing — review & editing. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Yang, X., Li, Y., Zhang, L., Wang, J., & Chen, H. (2024). The phytochemistry and pharmacology of three *Rheum* species: A comprehensive review with future perspectives. *Phytomedicine*, *131*, 155772. doi:10.1016/j.phymed.2024.155772
- 2 Kolodziejczyk-Czepas, J., & Liudvytska, O. (2021). *Rheum rhaponticum* and *Rheum rhabarbarum*: A review of phytochemistry, biological activities and therapeutic potential. *Phytochemistry Reviews*, *20*(3), 589–607. doi:10.1007/s11101-020-09715-3
- 3 Tabin, S., Gupta, R., Kamili, A., & Parray, J. (2022). Medical and medicinal importance of *Rheum* spp. collected from different altitudes of the Kashmir Himalayan range. *Cellular and Molecular Biomedical Reports*, *2*(3), 187–201. doi:10.55705/cmbr.2022.349901.1050
- 4 Salmukhanbetova, Z., & Dimeyeva, L. (2025). Phytocenotic and resource characteristics of *Rheum tataricum* L. f. in the Northern Aral region. *Fundamental and Experimental Biology*, *11830*(2), 34–43. doi:10.31489/2025feb2/34-43
- 5 Aitzhan, M., Aimenova, Z., & Sumbembayev, A. (2024). Studying the species distribution of rhubarbs (*Rheum* L.) in Kazakhstan. *BIO Web of Conferences*, *100*, 04034. doi:10.1051/bioconf/202410004034
- 6 Sumbembayev, A. A., Lagus, O. A., & Nowak, S. (2023). Seed morphometry of *Rheum* L. (Polygonaceae) species from Kazakhstan and its implications in taxonomy and species identification. *Biodiversitas: Journal of Biological Diversity*, *24*(9). doi:10.13057/biodiv/d240908
- 7 Dagarova, S. (2025). Research the seed surface of *Rheum wittrockii* Lundstr. from the flora of Kazakhstan. *Discover Plants*, *2*(1), 299. doi:10.1007/s44372-025-00383-1
- 8 Sitpayeva, G. T., Otradnykh, I. G., & Syedina, I. A. (2021). Collection of rare plant species of Kazakhstan in the conditions of the botanical garden of Almaty. *Problems of Botany of Southern Siberia and Mongolia*, *20*(1), 404–408. doi:10.14258/pbssm.2021081
- 9 Amangeldinova, M., et al. (2024). Simultaneous quantitative screening of 53 phytochemicals from *Rheum tataricum* L. roots: A comparative study of supercritical CO₂, subcritical ethanol, and ultrasound-assisted extraction for enhanced antioxidant and antibacterial activities, and molecular docking study. *Frontiers in Plant Science*, *15*, 1513875. doi:10.3389/fpls.2024.1513875
- 10 Golubkina, N., et al. (2022). Biochemical characteristics and elemental composition peculiarities of *Rheum tataricum* L. in semi-desert conditions and of European garden rhubarb. *International Journal of Plant Biology*, *13*(3), 368–380. doi:10.3390/ijpb13030031
- 11 Terletskeya, N., et al. (2024). Comparative analysis of the anatomical and morphological features of *Rheum tataricum* L. plants from different ecopopulations. *Eurasian Journal of Ecology*, *79*(2), 127–134. doi:10.26577/EJE.2024.v79.i2-012
- 12 Turgunbayeva, A. A., et al. (2025). Isolation and identification of secondary metabolites in *Rheum tataricum* L. growing in Kazakhstan and surveying of its anticancer potential. *Molecules*, *30*(14), 2978. doi:10.3390/molecules30142978
- 13 Sagyndykova, M. S., Imanbayeva, A. A., Lukmanov, A. B., & Gassanova, G. G. (2021). Resources of *Rheum tataricum* on the territory of Atyrau region. *Bulletin of Karaganda University. Biology, Medicine and Geography Series*, *103*(3), 119–124. doi:10.31489/2021bmg3/119-124
- 14 Khaja, U. M., Chopra, C., Sehgal, A., Singh, R., & Ganie, S. A. (2025). Unveiling the cancer-fighting potential of *Rheum* species (rhubarb): Phytochemistry, ethnopharmacology, and mechanistic insights into the anticancer effects of key anthraquinones. *Phytomedicine Plus*, *5*(3), 100831. doi:10.1016/j.phyplu.2025.100831
- 15 Minkayeva, A. A., et al. (2025). Comparative investigation of *Rheum tataricum* and *Rheum palmatum*. *International Journal of Biology and Chemistry*, *18*(1). doi:10.26577/IJBCh202518113
- 16 Singh, P. K., Singh, J., Medhi, T., & Kumar, A. (2022). Phytochemical screening, quantification, FT-IR analysis, and in silico characterization of potential bio-active compounds identified in HR-LC/MS analysis of the polyherbal formulation from Northeast India. *ACS Omega*, *7*(37), 33067–33078. doi:10.1021/acsomega.2c03117

- 17 Nortjie, E., Basitere, M., Moyo, D., & Nyamukamba, P. (2022). Extraction methods, quantitative and qualitative phytochemical screening of medicinal plants for antimicrobial textiles: A review. *Plants*, *11*(15), 2011. doi:10.3390/plants11152011
- 18 Youl, O., et al. (2023). Phytochemical screening, polyphenol and flavonoid contents, and antioxidant and antimicrobial activities of *Opilia amentacea* Roxb. (Opiliaceae) extracts. *Applied Biosciences*, *2*(3), 493–512. doi:10.3390/applbiosci2030031
- 19 Das, B., Saha, P., & Maity, N. (2023). Quantitative estimation of quercetin of some selected edible plants of West Bengal by high-performance thin-layer chromatography densitometry method. *Asian Journal of Pharmaceutical Research and Health Care*, *15*(3), 254–261. doi:10.4103/ajprhc.ajprhc_70_23
- 20 Sarr, A., et al. (2022). Role of condensed tannins in the antioxidant activity of seeds of *Cola nitida* (Vent.) Schott & Endl. (Malvaceae). *European Journal of Medicinal Plants*, 26–33. doi:10.9734/ejmp/2022/v33i121111
- 21 Yue, F., Zhang, J., Xu, J., Niu, T., Lü, X., & Liu, M. (2022). Effects of monosaccharide composition on quantitative analysis of total sugar content by phenol-sulfuric acid method. *Frontiers in Nutrition*, *9*, 963318. doi:10.3389/fnut.2022.963318
- 22 Godlewska, K., Pacyga, P., Najda, A., & Michalak, I. (2023). Investigation of chemical constituents and antioxidant activity of biologically active plant-derived natural products. *Molecules*, *28*(14), 5572. doi:10.3390/molecules28145572
- 23 Dai, L., et al. (2024). Changes in the nutrients, phytochemical profile and antioxidant activity of *Rheum officinale* Baill. leaf blades during different growth periods. *Frontiers in Nutrition*, *11*, 1387947. doi:10.3389/fnut.2024.1387947
- 24 Korus, A., & Korus, J. (2024). Enhancing nutritional value of rhubarb (*Rheum rhaponticum* L.) products: The role of fruit and vegetable pomace. *Agriculture*, *14*(10), 1784. doi:10.3390/agriculture14101784
- 25 Zou, J., Wu, W., Wang, F., & Hou, K. (2024). The foundation of the rhubarb industry economy: Investigating metabolite disparities of rhubarb between varieties and growing environments on the Tibetan Plateau. *Frontiers in Pharmacology*, *15*, 1461523. doi:10.3389/fphar.2024.1461523
- 26 Deng, T., et al. (2023). Rhein for treating diabetes mellitus: A pharmacological and mechanistic overview. *Frontiers in Pharmacology*, *13*, 1106260. doi:10.3389/fphar.2022.1106260
- 27 Zhao, L., & Zheng, L. (2023). A review on bioactive anthraquinone and derivatives as the regulators for ROS. *Molecules*, *28*(24), 8139. doi:10.3390/molecules28248139
- 28 Miao, H., Wang, K., -E., Li, P., & Zhao, Y. -Y. (2025). Rhubarb: Traditional uses, phytochemistry, multiomics-based novel pharmacological and toxicological mechanisms. *Drug Design, Development and Therapy*, *19*, 9457–9480. doi:10.2147/DDDT.S557114

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***Rheum tataricum* фитохимиялық және элементтік сипаттамасы**

Мақалада Қазақстанның Алматы облысында жиналған *Rheum tataricum* L. фитохимиялық және элементтік, сонымен қатар оның құрамдас құрамын қайталама метаболиттердің әлеуетті көзі ретінде сипаттау мақсатында зерттеу ұсынылған. Элементтік талдау жапырақтарда кальций, магний, фосфор, күкірт және мырыштың жоғары деңгейде жинақталуын анықтады, ал сабақтарда рубидий мөлшерінің жоғарырақ болуы және калий, натрий мен хлордың салыстырмалы деңгейлері байқалды. Сандық фитохимиялық скрининг вегетациялық кезеңдерде антрахинондар, флавоноидтар, таниндер, тритерпеноидтар және фенол қышқылдарын қоса алғанда, метаболиттердің негізгі топтарының жалпы тұрақты жинақталуын көрсетті, негізінен көмірсулар мен таниндер үшін маусымдық өзгеріштік байқалды. Сабақтар таниндер мен тритерпеноидтардың жоғары мөлшерімен сипатталса, жапырақтарда фенол қышқылдары мен микроэлементтердің жинақталуы басым болды. Анықталған органға тән және кезеңге тәуелді заңдылықтар жартылай шөлейт экожүйелер жағдайына экологиялық бейімделуді көрсетеді және *R. tataricum* өсімдігіндегі екіншілік метаболизмнің күрделі реттелуін айқындайды. Алынған нәтижелер бұл түрдің фитохимиялық байлығын көрсеткенімен, оның биологиялық және фармакологиялық белсенділігін осы деректер негізінде бағалау мүмкін емес және оны растау үшін арнайы биологиялық сынақтар жүргізу қажет.

Кілт сөздер: *Rheum tataricum*, фитохимиялық талдау, элементтік құрам, екіншілік метаболиттер, Алматы облысы.

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Фитохимическая и элементная характеристика *Rheum tataricum*

В настоящем исследовании представлена фитохимическая и элементная характеристика *Rheum tataricum* L., собранного в Алматинской области Казахстана, с целью описания его компонентного состава как потенциального источника вторичных метаболитов. Элементный анализ выявил высокое содержание кальция, магния, фосфора, серы и цинка в листьях, тогда как стебли характеризовались более высоким содержанием рубидия и сопоставимыми уровнями калия, натрия и хлора. Количественный фитохимический скрининг показал в целом стабильное накопление основных групп метаболитов,

включая антрахиноны, флавоноиды, танины, тритерпеноиды и фенольные кислоты, на протяжении вегетационных стадий, при этом заметная сезонная вариабельность наблюдалась преимущественно для углеводов и танинов. Стебли отличались более высоким содержанием танинов и тритерпеноидов, тогда как листья накапливали повышенные уровни фенольных кислот и микроэлементов. Выявленные органоспецифические и фазозависимые закономерности отражают экологическую адаптацию к условиям полупустынных экосистем и указывают на сложную регуляцию вторичного метаболизма у *R. tataricum*. Полученные результаты свидетельствуют о фитохимическом богатстве данного вида; однако его биологическая и фармакологическая активность не может быть оценена на основании представленных данных и требует подтверждения в специализированных биологических тестах.

Ключевые слова: *Rheum tataricum*, фитохимический анализ, элементный состав, вторичные метаболиты, Алматинская область.

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Ecological and anatomical features of the structure and adaptations of *Sibiraea altaiensis* (L.) Schneid. in the East Kazakhstan context

Sibiraea altaiensis (L.) Schneid. is a characteristic species of high-mountain ecosystems in Eastern Kazakhstan, *Sibiraea altaiensis* experiences intense solar radiation, sharp temperature fluctuations, low humidity, and nutrient-poor soils. This study presents a comprehensive ecological–anatomical analysis of the leaves and stems of *S. altaiensis* from natural populations of the Katon-Karagay National Park. Anatomical parameters were examined using classical microtechnical methods, morphometry, and statistical approaches. The leaf of *S. altaiensis* demonstrates a pronounced combination of xeromorphic and oromorphic traits. The leaf blade has a stable thickness, a well-developed cuticle, and a hypostomatic epidermis. A thickened palisade layer and a moderately variable spongy layer, reflecting adaptation to high insolation and limited moisture, characterize the dorsiventral mesophyll. The vascular bundles are reinforced with sclerenchyma, providing mechanical stability under strong winds. The stem is characterized by well-developed xylem, stable dimensions of vascular elements, and a thick periderm, which performs protective and mechanical functions. Correlation analysis revealed coherence among the main anatomical parameters, including leaf thickness, mesophyll structure, vascular bundle size, and xylem development. The weakly acidic, low-mineral soils of the habitats correspond to the moderate plasticity in mesophyll and conducting tissues. Thus, *S. altaiensis* exhibits a complex of anatomical and morphological adaptations enabling survival under extreme high-mountain conditions of the Kazakh Altai. These findings contribute to a better understanding of the adaptive evolution of Rosaceae taxa in Central Asia and are relevant for further taxonomic and conservation research.

Keywords: *Sibiraea altaiensis*, leaf anatomy, stem anatomy, high-altitude adaptations, ecological-anatomical analysis, East Kazakhstan, Katon-Karagay.

Introduction

Plants growing in the mountainous ecosystems of Central Asia form complex adaptive complexes, allowing them to successfully exist in conditions of extreme and highly variable climate. The Kazakhstan Altai is one of the most biodiverse regions of the country, characterized by high relief contrast, landscape mosaicism, and pronounced climatic zonation. These natural features create a wide range of ecological niches, which contributes to the formation of specific morphological and anatomical adaptations in plants inhabiting various altitudinal levels. The study of such adaptive mechanisms is key to understanding the evolution of high-mountain flora, assessing its resistance to climatic changes, and developing scientifically sound strategies for the conservation of the region's natural heritage [1].

Representatives of the genus *Sibiraea* Maxim. (Rosaceae Juss.) are typical inhabitants of mountainous regions of Eurasia and are characterized by high resistance to unfavorable environmental factors [2]. Special attention is given to *Sibiraea altaiensis* (L.) Schneid., which is widespread in Eastern Kazakhstan, including the territories of the Katon-Karagay State National Nature Park [3, 4]. This region is distinguished by a complex geomorphological structure, pronounced elevation gradients, the presence of glaciers, and intensive exogenous processes that create unique conditions for plant growth. The degree of terrain dissection, slope exposure, types of soil substrates, and moisture regimes determine the variety of ecological stresses experienced by vegetation—from sharp temperature fluctuations to low air humidity, strong winds, short periods of drought, and high solar radiation levels [5].

The conditions of mountain ecosystems impose strict requirements on the anatomical organization of plant leaves and shoots. It is at the anatomical level that key mechanisms of adaptation to moisture deficit,

excessive insolation, mechanical stress, and low-temperature conditions are manifested. The thickness of the epidermis, the development of the cuticle, the degree of mesophyll differentiation, the density of venation, and the structural features of conducting and mechanical tissues all reflect the adaptive strategies of a species and determine its viability under extreme conditions. Moreover, anatomical traits often possess high diagnostic value and are widely used in the systematics of the Rosaceae family. For the genus *Sibiraea*, such data are particularly important, since morphological differences between closely related species are weakly expressed, whereas anatomical features can serve as additional informative criteria in taxonomic and phylogenetic studies [6].

Despite the ecological significance of *S. altaiensis* and its wide distribution in the mountainous regions of Eastern Kazakhstan, anatomical studies of this species remain limited. Previous descriptions have mainly focused on general morphology and did not address detailed aspects of leaf blade structure in relation to the natural conditions of the region. Meanwhile, current climate change, accompanied by shifts in temperature and moisture regimes, necessitates an in-depth analysis of the adaptive mechanisms of endemic and rare mountain flora species, among which *S. altaiensis* holds an important position [7].

Thus, conducting a comprehensive ecological–anatomical analysis of the leaves of *S. altaiensis* under the conditions of Eastern Kazakhstan is a relevant scientific task, allowing the identification of structural and functional features shaped by the specificity of the environment. The results of this study will help clarify the taxonomic position of the species, reveal its adaptive potential, and enhance our understanding of plant survival strategies in extreme mountain landscapes. In addition, the obtained data have practical value for monitoring natural populations and developing measures to conserve the biological diversity of the Kazakh Altai amid ongoing climatic transformations [8].

Experimental

The material for the study consisted of leaves and stems of *S. altaiensis* collected from natural wild populations in the East Kazakhstan within the Kazakh Altai. The main sampling site was located on the Sarymsakty Ridge (Southern Altai), in the open right-bank valley of the Taldybulak River and on the southeastern slope of Mount Zhumsak-Asu (coordinates: N 49°06.355', E 086°07.890', elevation 1816 m). The area is characterized by a sharply continental climate with cold winters, short summers, significant daily temperature fluctuations, and high insolation. The soils are well-drained alluvial rocky loam substrates with moderate moisture, determined by precipitation and seasonal snowmelt. The vegetation of the territory belongs to mountain meadow–shrub communities, which correspond to the typical habitats of *S. altaiensis* in Eastern Kazakhstan (Fig. 1).



Figure 1. General view of *S. altaiensis* in its natural habitat (East Kazakhstan)

Leaf and young shoot samples were collected during the period of active growth (June–August). For each plant, 3–5 fully developed leaves from the middle canopy and segments of current-year stems were harvested. For anatomical analysis, the material was immediately fixed in FAA solution (formalin–acetic acid–70 % ethanol, 90:5:5 v/v/v) for 24–48 hours at room temperature, following the classical protocols of Johansen [9] and Sass [10]. After fixation, samples were rinsed with distilled water and stored in 70 % ethanol, in

accordance with the recommendations of Berlyn & Miksche [11]. Transverse sections of leaves and stems were prepared using a Leica RM2125 RTS rotary microtome and manual microtomes, with section thickness maintained at 15–30 μm . For the differential identification of tissue complexes, a double staining with Safranin O and Astra Blue (Safranin O + Astra Blue) was applied following the protocols of Ruzin [12] and Kiernan [13]. In this procedure, lignified elements were stained red, whereas cellulose-rich tissues appeared bluish-green. After staining, the specimens were sequentially dehydrated in ethanol of increasing concentrations (70 %, 90 %, 96 %), cleared in xylene, and mounted in Canada balsam. Microscopic observations were performed using a Leica DM500 light microscope at magnifications of $\times 100$ – $\times 400$. Photo documentation was carried out with a Leica DFC290 HD digital camera using the Leica Application Suite software. Scale calibration was conducted using eyepiece and stage micrometers (100–500 μm). Image processing and morphometric analysis were performed in Image J 1.54f [14], without applying algorithms that distort tissue geometry. Morphometric analysis included measurements of leaf blade thickness, upper and lower epidermis thickness, palisade and spongy mesophyll thickness, main vascular bundle diameter, periderm thickness, phloem and xylem thickness, and the diameter of primary cortex and pith cells. For each parameter, 15–20 measurements were performed, and results were expressed in micrometers as mean \pm standard error. Anatomical terminology follows Evert [15] and Kaplan [16]. Key tissue elements were annotated on micrographs, including epidermis, mesophyll, vascular bundles, xylem and phloem elements, cambium, periderm, collenchyma, and parenchyma.

To characterize the soil conditions of *S. altaiensis* habitats, soil (pH) and electrical conductivity (EC) were measured. Soil samples were collected from the upper root-inhabited horizon (0–20 cm) at the sites where the studied plants were growing. Composite samples were air-dried at room temperature, with large fragments of plant debris and stones removed. Soil pH was determined potentiometrically in a 1:2.5 (soil-to-distilled water suspension), following standard soil analytical procedures [17]. Measurements were performed using a portable pH meter with automatic temperature compensation. Prior to measurements, the instrument was calibrated with buffer solutions at pH 4,00, 7,00, and 10,00 according to the international ISO 10390 protocol [18]. pH values were recorded after stabilization of readings, and each analysis was performed in triplicate. Soil solution electrical conductivity (EC) was measured using a conductometric method in a 1:5 (soil-to-distilled water suspension), according to Rhoades et al. [19]. Values were expressed in millisiemens per centimeter (mS/cm), providing an estimate of soil salinity and overall ionic load. Temperature correction was applied automatically at 25 °C. All measurements were repeated at least three times, and mean values \pm standard deviations were reported. The obtained pH and EC values were used to correlate the anatomical features of *S. altaiensis* with the soil conditions of its habitats. Soil parameters were interpreted based on the USDA Soil Survey classification [20], allowing assessment of soil acidity and mineralization levels in the context of the species' ecological adaptations.

For the analysis of anatomical traits of *S. altaiensis*, statistical processing of the data was performed, including the assessment of overall variability, testing for normality of distribution, and evaluation of relationships among the measured morphometric characteristics. All measurements were initially screened for outliers and assessed for normality using the [21], test, a standard approach for small biological datasets. When distributions deviated from normality, non-parametric methods were applied to evaluate differences between groups [22].

Correlation analyses were conducted to examine the relationships among epidermal thickness, mesophyll structure, vascular tissue parameters, and other anatomical features. Pearson's correlation coefficients were calculated for variables with normal distributions, while Spearman's rank correlation coefficients were applied for non-normally distributed data [23]. The strength of the observed correlations was interpreted following the classification of Evans (1996) [24], a standard reference widely used in biological research. To assess inter- and intra-population variability of morphometric traits, variance, standard deviation, and the coefficient of variation (CV) were calculated, enabling comparison of the degree of variability in tissue structural parameters [25]. Mean values between samples were compared using one-way analysis of variance ANOVA when assumptions of normality and homogeneity of variances were met. Homogeneity of variances was tested using Levene's test [26]. All statistical analyses were performed using RStudio (version 4.3.1) and Statistica 13.0, as well as ImageJ plugins for image analysis. This statistical approach not only quantitatively confirmed differences in anatomical parameters but also identified key structural relationships reflecting the adaptive mechanisms of *S. altaiensis* to the environmental conditions of Eastern part of Kazakhstan.

Results and Discussion

The analysis of *S. altaiensis* leaves from natural populations of Eastern Kazakhstan revealed a pronounced set of xeromorphic and oromorphic traits characteristic of high-mountain plants of Central Asia. Leaf blade thickness varied within a narrow range (447–512 μm), which is consistent with reported data on stable morphological characteristics of montane Rosaceae species (Table 1). Under the environmental conditions of Katon-Karagay National Park, plants are exposed to intense solar radiation, sharp diurnal temperature fluctuations, and periodic moisture deficits (Fig. 2–5). In such conditions, a compact and weakly variable leaf blade serves as a key adaptive mechanism that helps maintain turgor and reduce transpirational water loss. Similar patterns have been documented in species of the genera *Dasiphora* Raf., *Rosa* L., and *Spiraea* L., supporting the shared adaptive strategies of Rosaceae in response to extreme mountain environments [27].

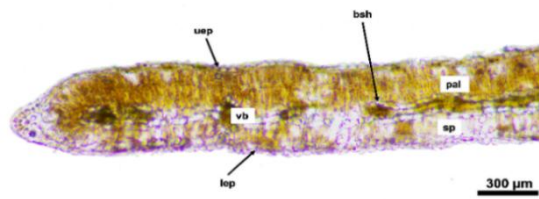


Figure 2. Marginal part of the leaf blade (*Margo folii*) in cross-section: uep — upper epidermis; lep — lower epidermis; pal — palisade parenchyma; sp — spongy parenchyma; bsh — bundle of sclerenchyma; vb — vascular bundle

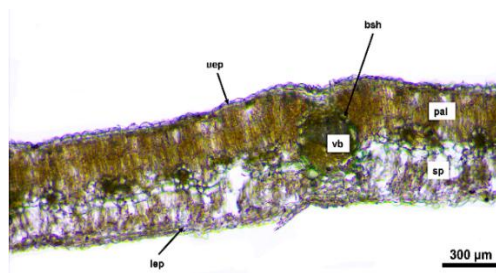


Figure 3. Central part of the leaf blade (*Pars centralis laminae folii*) in cross-section: uep — upper epidermis; lep — lower epidermis; pal — palisade parenchyma; sp — spongy parenchyma; bsh — bundle of sclerenchyma; vb — vascular bundle

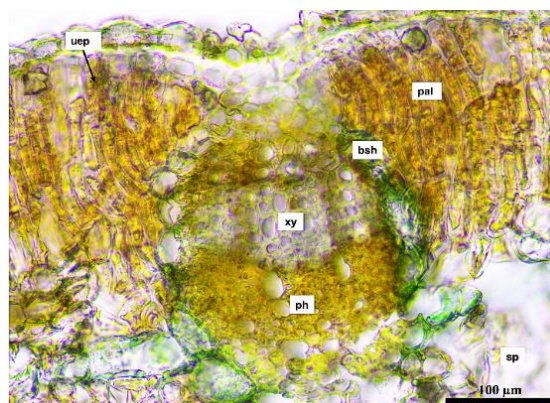


Figure 4. Central vein of the leaf blade (*Vena media laminae folii*) in cross-section: uep — upper epidermis; pal — palisade parenchyma; sp — spongy parenchyma; bsh — bundle of sclerenchyma; xy — xylem; ph — phloem

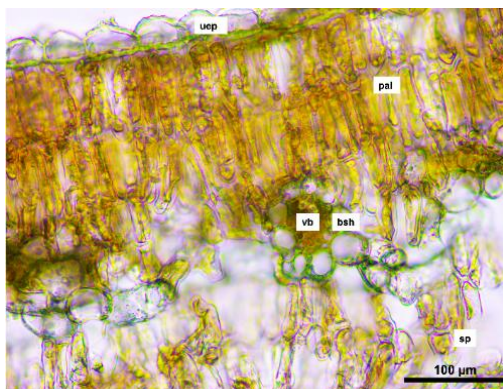


Figure 5. Upper part of the leaf blade (*Pars superior laminae folii*) in cross-section: uep — upper epidermis; pal — palisade parenchyma; sp — spongy parenchyma; bsh — bundle of sclerenchyma; vb — vascular bundle

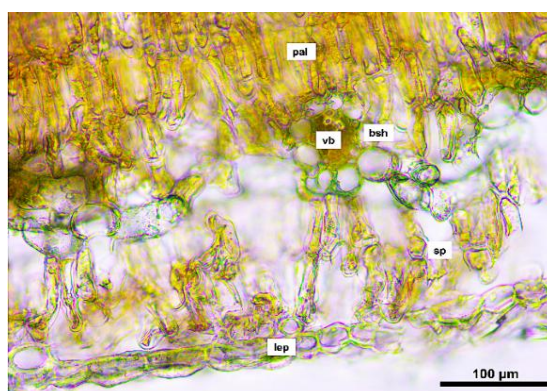


Figure 6. Lower part of the leaf blade (*Pars inferior laminae folii*) in cross-section: lep — lower epidermis; pal — palisade parenchyma; sp — spongy parenchyma; bsh — bundle of sclerenchyma; vb — vascular bundle

Table 1

Anatomical characteristics of the leaf (μm)

| Indicator | Average | Standard deviation | Minimum | 25 % | Median | 75 % | Maximum |
|--|---------|--------------------|---------|--------|--------|--------|---------|
| Leaf blade thickness (TLP) | 476,55 | 19,79 | 447,10 | 461,91 | 473,53 | 491,94 | 511,65 |
| Thickness of the upper epidermis (TVE) | 22,66 | 2,08 | 20,20 | 21,09 | 22,59 | 23,27 | 27,23 |
| Thickness of the lower epidermis (TLE) | 24,12 | 2,78 | 19,81 | 21,76 | 24,93 | 26,45 | 27,40 |
| Thickness of the palisade mesophyll (TPM) | 194,62 | 23,18 | 164,61 | 170,48 | 201,67 | 208,62 | 227,34 |
| Thickness of the spongy mesophyll (TGM) | 126,49 | 18,09 | 94,66 | 114,33 | 128,26 | 135,23 | 153,77 |
| Diameter of the main vascular bundle (DVB) | 244,43 | 16,49 | 215,25 | 239,08 | 246,94 | 255,49 | 264,93 |

A thickened upper epidermis (up to 27 μm) and the formation of a dense cuticle are reliable barrier structures that, combined with the hypostomatic leaf type, limit water loss and protect tissues from photodestructive effects. Similar adaptations have been observed in species such as *Juniperus sabina* L., *Betula fruticosa* Pall., and *Spiraea alpina* Pall., which grow on rocky substrates in the East Kazakhstan and the Altai [28].

The palisade mesophyll of *S. altaiensis* was considerably thick (up to 227 μm), indicating a high level of photosynthetic activity. In mountain xeromorphic plants, an increase in the volume of palisade tissue is considered a key mechanism for enhancing photosynthetic efficiency under bright but often intermittent light [29]. A thick palisade mesophyll ensures effective light absorption and maintains high productivity of the photosynthetic apparatus, despite frequent cloud cover, fog, and daytime shading, which are typical for the Sarymsakty Ridge (Fig. 6–12).

The high variability in spongy mesophyll thickness (94–153 μm) may reflect the sensitivity of the aerenchyma structure to soil moisture and macronutrient availability. Comparative studies on *Tilia cordata* Mill. [30], *Caragana pygmaea* (L.) DC., and *Populus suaveolens* Fisch. have shown that the spongy mesophyll is the most plastic element of leaf anatomy, changing in response to fluctuations in water availability. The presence of mucilage canals and calcium oxalate druses corresponds to high metabolic activity of the tissues and specialized protective mechanisms against excess ions or herbivory.

The low variability in xylem thickness ($\text{CV} < 3\%$) confirms the structural stability. This is consistent with data from resilient oromorph species such as *J. sabina*, *Spiraea chamaedryfolia* L., and *Dasiphora fruticosa* (L.) O. Schwarz, whose secondary xylem also demonstrates stability regardless of environmental variability [31].

The diameter of the main vascular bundle (215–265 μm) shows low variability, which is consistent with patterns observed in *Spiraea media* Schmidt. and *Prunus fruticosa* Pall. [32]. On mountain slopes, water transport is limited not only by moisture deficiency but also by sharp temperature fluctuations that can disrupt the continuity of transport pathways.

The stability of the vascular system parameters indicates a conservative water transport mechanism and a high degree of adaptation to stressful conditions. A pronounced sclerenchymatous sheath around the veins confirms the mechanical reinforcement of the leaf. The dense mechanical framework provides resistance to bending and tearing caused by strong winds typical of the montane-meadow regions of the Southern Altai. Similar traits have been observed in steppe and subalpine species such as *Rosa acicularis* Lindl. and *Cotoneaster melanocarpus* Ledeb., indicating common oromorph adaptations of Rosaceae to physical stress (Table 2). In the stems of *S. altaiensis*, this represents one of the most important adaptive traits. Such reinforcement of the conductive xylem (778–854 μm) is typical for plants growing under conditions of cold nights, frost, and sharp temperature fluctuations, in which xylem is susceptible to cavitation. According to the works of Esau and Fahn, compensatory expansion of xylem elements is a typical response to the risk of disruption in the water column.

Table 2

Anatomical parameters of the stem (μm)

| Indicator | Average | Standard deviation | Minimum | 25 % | Median | 75 % | Maximum |
|---|---------|--------------------|---------|--------|--------|--------|---------|
| Periderm thickness (TPR) | 74,29 | 2,78 | 69,35 | 73,31 | 74,37 | 75,76 | 78,86 |
| Diameter of primary cortex parenchyma cells (DPC) | 43,25 | 5,42 | 36,07 | 38,83 | 43,56 | 47,92 | 51,35 |
| Phloem thickness (TFL) | 432,17 | 137,80 | 44,73 | 462,84 | 474,96 | 481,89 | 517,85 |
| Xylem thickness (TXL) | 820,82 | 21,58 | 778,77 | 812,52 | 822,41 | 833,85 | 853,72 |
| Diameter of pith cells (DPCe) | 39,61 | 7,50 | 29,57 | 34,97 | 39,51 | 44,62 | 53,12 |

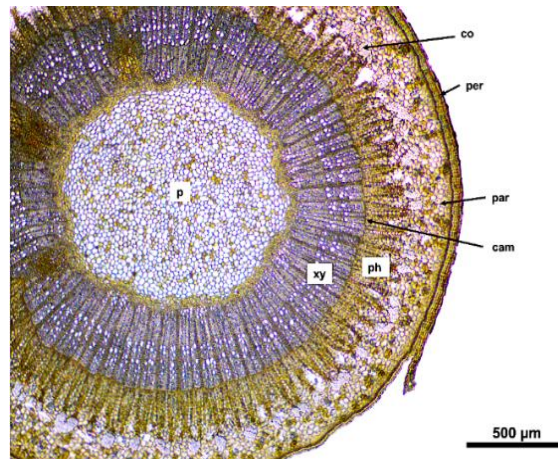


Figure 7. Cross-section of the stem (caulis): co — protective tissue (cuticle and epidermis); per — primary cortex; par — parenchyma tissue; cam — cambium; ph — phloem; xy — xylem; p — pith

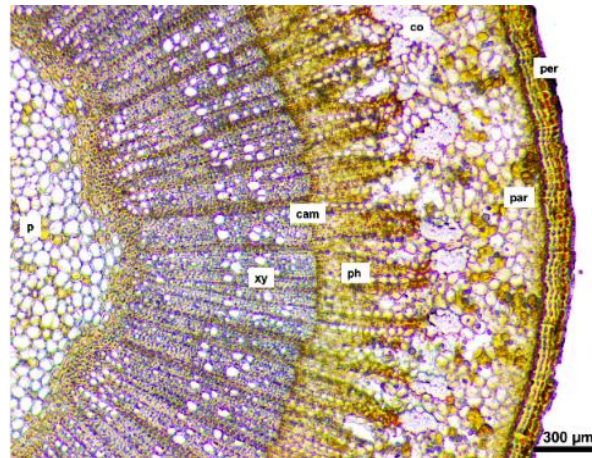


Figure 8. Right half of the stem (pars dextra caulis) in cross-section: co — protective cortex; par — parenchyma; cam — cambium; ph — phloem; xy — xylem; p — pith

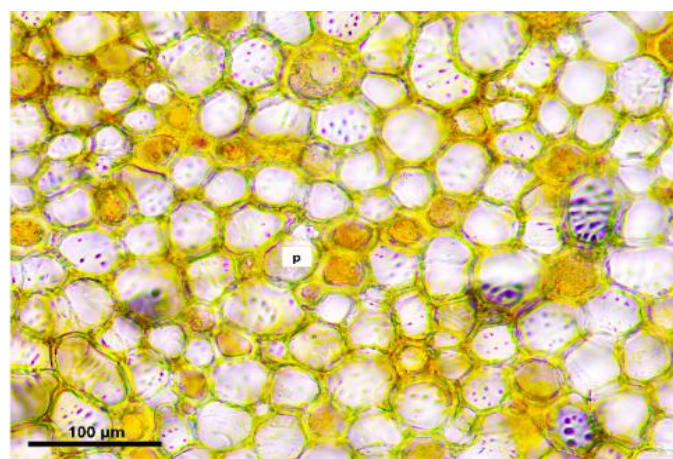


Figure 9. Pith of the stem (medulla caulis) in cross-section: p — pith parenchyma

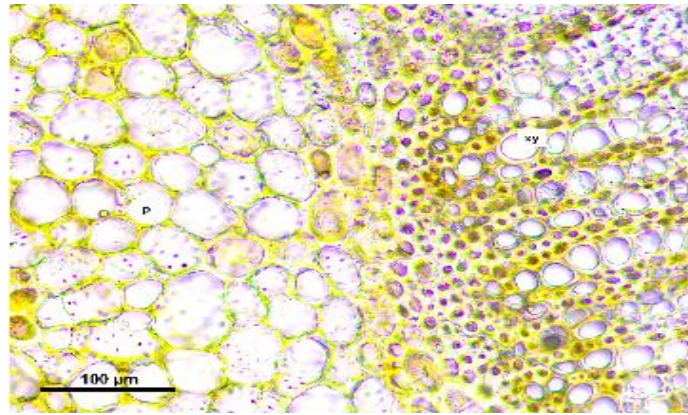


Figure 10. Transitional zone between the pith and the vascular system of the stem (zona transitionis inter medullam et systema vascularium caulis) in cross-section: p — pith parenchyma; xy — xylem

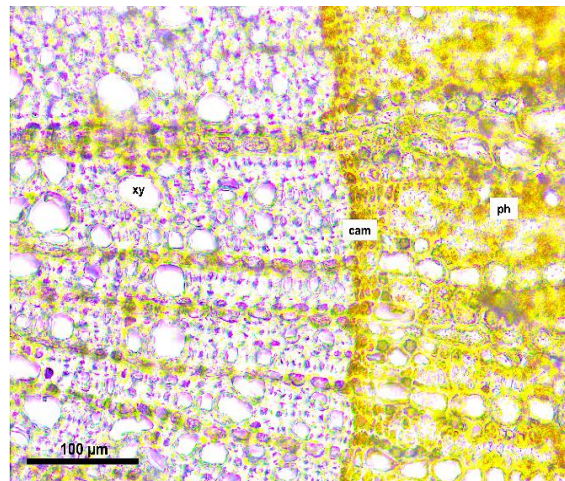


Figure 11. Cambial zone of the stem (zona cambialis caulis) in cross-section: xy — xylem; cam — cambium; ph — phloem



Figure 12. Peripheral part of the stem (margo caulis) in cross-section: co — protective tissue (cuticle and epidermis); per — primary cortex; par — parenchyma

The phloem and primary cortex exhibited higher variability, which may reflect seasonal fluctuations in assimilate flow and carbohydrate redistribution. Similar fluctuations have been described in *T. cordata*, confirming general trends in woody plants of temperate-cold regions.

Soils at the studied sites were slightly acidic (pH 4.95–5.13) with moderate electrical conductivity (49–84 mV). These conditions are typical of high-mountain meadow soils, which are prone to leaching and base deficiency [33]. It was found that in areas with higher electrical conductivity, mesophyll thickening and reinforcement of vascular tissues were observed. This is consistent with models of soil ionic composition effects on the photosynthetic apparatus of plants.

The correlation matrix (Fig. 13) showed that leaf blade thickness is closely related to the diameter of the vascular bundle ($r = 0.91$); pith cell diameters negatively correlate with mesophyll thickness ($r = -0.64$); and stem xylem parameters correlate with phloem ($r > 0.7$).

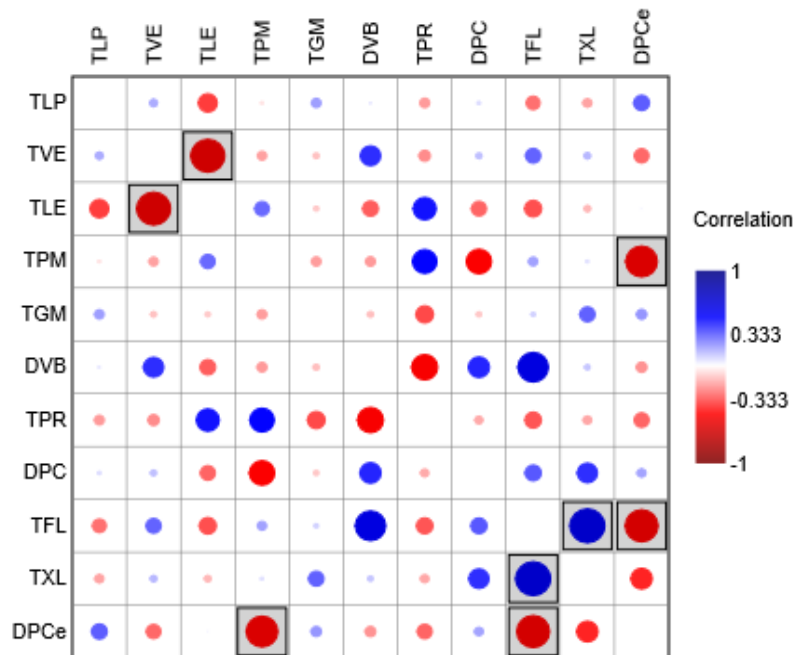


Figure 13. Correlation matrix of morpho-anatomical parameters of leaves and stems *S. altaiensis*

The strong correlation between leaf blade thickness and palisade mesophyll thickness ($r = 0.88$) highlights the structural integration of the photosynthetic apparatus. A similar relationship has been reported in arcto-alpine species such as *Salix glauca* L. and *Betula nana* L., where photosynthetic tissues form a stable adaptive module that enables plants to withstand extreme environmental conditions [34].

Such correlations indicate the presence of an interconnected anatomical system optimized for the mountain climate. Comparable structural linkages among anatomical modules have been documented in many high-mountain species, including *Betula rotundifolia* Spach, *S. glauca*, and various *Caragana* spp.

Anatomical and morphological analyses demonstrated that *S. altaiensis* develops a unique set of adaptive structures that ensure resilience under the high-altitude landscapes of Eastern Kazakhstan. The combination of a thickened palisade mesophyll, consistently developed xylem, a robust sclerenchymatous framework, and a hypostomatic leaf surface reflects an integrated survival strategy aimed at maintaining water balance, reducing transpiration, and enhancing mechanical strength of tissues. These features make *S. altaiensis* a valuable model species for understanding the adaptive responses of Central Asian flora to climate change and extreme ecological conditions.

Conclusion

Anatomical and morphological investigations of *S. altaiensis* revealed a set of stable structural features reflecting the species' profound adaptation to the extreme conditions of high-mountain ecosystems in Eastern Kazakhstan. The leaf blade exhibits pronounced xeromorphic traits, including a thick upper epidermis with a well-developed cuticle, a hypostomatic leaf type, and a compact mesophyll organization. The thick palisade

mesophyll ensures high photosynthetic efficiency under intense solar radiation, whereas the spongy mesophyll regulates gas exchange and contributes to maintaining water balance under limited moisture availability.

The presence of a robust sclerenchymatous sheath surrounding the veins and the stable dimensions of vascular bundles indicate high mechanical resistance of the leaf—an essential adaptation to withstand wind exposure and mechanical stress typical of mountainous landscapes. Stem anatomy, characterized by a well-developed xylem, stable wood parameters, and moderately variable phloem, further supports the adaptive strategy of the species, ensuring efficient water transport and structural stability of shoots under sharp temperature fluctuations and periodic water deficits.

Correlation analysis of morphometric traits revealed strong relationships among leaf blade thickness, mesophyll parameters, vascular bundle diameter, and the development of stem xylem. These interconnections confirm the presence of an integrated anatomical system capable of optimizing plant functions in response to abiotic conditions. Such structural coherence is typical of high-mountain species of Central Asia and reflects an evolutionarily established survival strategy in extreme environments.

Thus, *S. altaiensis* represents a highly adapted species with well-defined anatomical and morphological features that confer resilience to climatic and edaphic stresses of the Kazakh Altai. The findings expand current scientific understanding of ecological–anatomical adaptations in Rosaceae under mountain conditions, refine the diagnostic characteristics of the species, and may serve as a basis for future taxonomic, floristic, and ecological research. The results are also significant for monitoring natural populations of *S. altaiensis* and for developing biodiversity conservation strategies under intensifying climate change.

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Author Contributions

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Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Dolezal, J. et al. (2019). Disentangling evolutionary, environmental and morphological drivers of plant anatomical adaptations to drought and cold in Himalayan graminoids. *Oikos*, 128(11), 1576–1587. <https://doi.org/10.1111/oik.06451>
- 2 Shirmanov, M. V., & Polyakova, T. A. (2020). Historical Overview of Research on the Genus *Spiraea* L. (Rosaceae Juss.). *Problems of Botany in Southern Siberia and Mongolia*, 19(2), 140–145.
- 3 Killov, V. Yu., Stikhareva, T. N., Serafimovich, M. V., & Terekhova, S. V. (2014). *Sibiraea altaiensis* — A Promising Object for Forest Biotechnology and Phytochemistry in Kazakhstan. *Editorial Board*, 18, 105 p.
- 4 Orazayeva, M. K. (2018). Study of the endemic *Sibiraea altaiensis* in the West Altai State Nature Reserve. *Master's Bulletin*, 5–3 (80), 13–14.

- 5 Krykbayeva, R. N. (2022). The history of formation and development prospects of Katon-Karagay State National Natural Park. In *Proceedings of Katon-Karagay State National Natural Park*, 10–29.
- 6 Song, J. H., Oak, M. K., & Hong, S. P. (2024). Leaf micromorphology in Rosaceae tribe Spiraeae (subfamily Amygdales) and its systematic and ecological implications. *Botanical Journal of the Linnean Society*, 205(2), 116–131. <https://doi.org/10.1093/botlinnean/boae002>
- 7 Kotukhov, Yu. A., Danilova, A. N., & Anufrieva, O. A. (2017). *Sibiraea Altaiensis* (Laxm.) Schneid. — a rare species of the flora of Kazakhstan. *Botanical Research of Siberia and Kazakhstan*, 23, 50–74.
- 8 Serafimovich, M. V., & Efimova, M. V. (2024). Altai endemic *Sibiraea altaiensis* (Laxm.) Schneid: possible uses and conservation methods. *Biotechnology and Plant Breeding*, 7(1), 35–42.
- 9 Woo, J. Y. (1970). Techniques for Sectioning and Staining Tissue Cultures of Western White Pine (Vol. 116). *US Department of Agriculture, Forest Service, Intermountain Forest & Range Experiment Station*.
- 10 Brooks, J. H. (1969). *Cytotaxonomy of the genus Echinochloa in Louisiana*. Louisiana State University and Agricultural & Mechanical College.
- 11 Berlyn, G. P., & Miksche, J. P. (1976). *Botanical microtechnique and cytochemistry* (pp. viii+326).
- 12 Ruzin, S. E. (1999). *Plant microtechnique and microscopy* (Vol. 198, p. 322). New York: Oxford University Press.
- 13 Kiernan, J. (2015). *Histological and histochemical methods*. Scion publishing Ltd.
- 14 Schneider, C. A., Rasband, W. S., & Eliceiri, K. W. (2012). NIH Image to ImageJ: 25 years of image analysis. *Nature methods*, 9(7), 671–675.
- 15 Evert, R. F. (1992). Commentary: The Contributions of Katherine Esau. *International Journal of Plant Sciences*, 153(3, Part 2), v–ix.
- 16 Kaplan, D., & Specht, C. D. (2022). *Kaplan's principles of plant morphology*. CRC Press.
- 17 Arinushkina, E. V. (1970). *Handbook for soil chemical analyses*. Moscow State University.
- 18 Noble, T. L., Lottermoser, B., & Parbhakar-Fox, A. (2016). pH testing methods for sulfidic mine wastes. In *Environmental Indicators in Metal Mining* (pp. 199–210). Cham: Springer International Publishing.
- 19 Rhoades, J. D., Chanduvi, F., & Lesch, S. M. (1999). *Soil salinity assessment: Methods and interpretation of electrical conductivity measurements* (Vol. 57). Food & Agriculture Org.
- 20 Galbraith, J. M. (2018). Human-altered and human-transported (HAHT) soils in the US soil classification system. *Soil science and plant nutrition*, 64(2), 190–199.
- 21 Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika*, 52(3–4), 591–611.
- 22 Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *The annals of mathematical statistics*, 50–60.
- 23 Zar, J. H. (1999). *Biostatistical analysis*. Pearson Education India.
- 24 Evans, J. D. (1996). *Straightforward statistics for the behavioral sciences*. Thomson Brooks/Cole Publishing Co.
- 25 Sokal, R. R. (1995). *The principles and practice of statistics in biological research*. Biometry, 451–554.
- 26 Levene, H. (1960). *Robust tests for equality of variances*. *Contributions to probability and statistics*, 278–292.
- 27 Crang R., Lyons-Sobaski Sh., & Wise R. (2018). *Plant Anatomy. A concept-based approach to the structure of seed plants* Springer Nature, 250 p.
- 28 Gibadulina, I. I., Larionov, M. V., & Maslennikova, N. N. (2022). Anatomical and Morphological Features of the Leaves of *Tilia Cordata* Mill. As an Indicator of the Adaptive Capabilities of the Species to the Conditions of the Urban Environment *IOP Conference Series: Earth and Environmental Science*, 988(3), Article ID 032082.
- 29 Fahn, A. (1988). Secretory tissues in vascular plants. *New phytologist*, 108(3), 229–257.
- 30 Ramírez-Díaz, M., Gutiérrez, J., & Terrazas, T. (2024). Leaf architecture and anatomy of eight species of *Tilia* (Malvaceae). *Acta botánica mexicana*, 131.
- 31 Crang R., Lyons-Sobaski, & Wise R. (2018). *Plant Anatomy. A concept-based approach to the structure of seed plants* Springer Nature, 250 p.
- 32 Kulawik, P., Jamróz, E., Kruk, T., Szymkowiak, A., Tkaczewska, J., Krzyściak, P., & Milosavljević, V. (2023). Active edible multi-layer chitosan/furcellaran micro/nanoemulsions with plant essential oils and antimicrobial peptides: Biological properties and consumer acceptance. *Food Control*, 150, 109767.
- 33 Arinushkina, E. V. (1970). *Handbook for soil chemical analyses*. Moscow State University.
- 34 Strelnikov, B. G., & Gürdal, B. (2024). Anatomy and micromorphology of *Tilia* species from Turkey and its taxonomic implication. *Microscopy Research and Technique*, 87(11), P. 2625–2635.

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***Sibiraea altaiensis* (L.) Schneid. өсімдігінің Шығыс Қазақстан жағдайындағы экологиялық-анатомиялық ерекшеліктері мен бейімделуі**

Sibiraea altaiensis (L.) Schneid. өсімдіктері қарқынды күн радиациясының, температураның күрт ауытқуының, төмен ылғалдылықты және топырақтың әсерін нашар сезінетін Шығыс Қазақстанның биік таулы экожүйелеріне тән түр. Бұл зерттеуде Катонқарағай ұлттық паркінің табиғи популяцияларынан *S. altaiensis* жапырақтары мен сабақтарына кешенді экологиялық-анатомиялық талдау жасалды. Анатомиялық параметрлер классикалық микротехникалық әдістерді, морфометрияны және статистиканы қолдана отырып зерттелген. *S. altaiensis* жапырағы ксеро- және ороморфты белгілердің айқын кешенін көрсетеді. Жапырақ тактасының қалыңдығы тұрақты, қабығы жақсы дамыған, эпидермисі гипостоматты және бірнеше типті. Дорсивентральды мезофилл қалың палисадты қабатымен және орташа өзгермелі борпылдақ қабатымен сипатталып, бұл жоғары инсоляция мен шектеулі ылғал жағдайына бейімделгенін көрсетеді. Өткізгіш шоқтар склеренхимамен нығайтылған, бұл қатты желдерге механикалық төзімділікті арттырады. Сабағы жақсы дамыған ксилемамен, өткізгіш элементтердің тұрақты өлшемдерімен және қалың перидерма қабатымен ерекшеленеді, бұл құрылым су транспортының тиімді жүйесін қалыптастырады. Корреляциялық талдау негізгі анатомиялық параметрлердің дәйектілігін көрсетті, олар: жапырақ қалыңдығы, мезофилл құрылымы, өткізгіш сәулелердің мөлшері және ксилеманың дамуы. Тіршілік ету ортасының топырағы аздап қышқыл, минералдануы төмен-мезофилл мен өткізгіш тіндердің орташа икемділігіне сәйкес келеді. Осылайша *S. altaiensis* қазақстандық Алтайдың биік тауларының экстремалды жағдайларында өмір сүруді қамтамасыз ететін анатомиялық-морфологиялық бейімделулердің бірегей кешеніне ие. Алынған мәліметтер Орталық Азиядағы *Rosaceae* тұқымдасының өкілдерінің бейімделу эволюциясын тереңірек түсінуге мүмкіндік береді және таксономиялық әрі табиғат қорғау зерттеулері үшін маңызды.

Кілт сөздер: *Sibiraea altaiensis*, жапырақ анатомиясы, сабақ анатомиясы, биіктаулы бейімделулер, экологиялық-анатомиялық талдау, Шығыс Қазақстан, Катонқарағай.

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Эколого-анатомические особенности строения и адаптаций *Sibiraea altaiensis* (L.) Schneid. в условиях Восточного Казахстана

Sibiraea altaiensis (L.) Schneid. — характерный вид высокогорных экосистем Восточного Казахстана, где растения испытывают воздействие интенсивной солнечной радиации, резких температурных колебаний, низкой влажности и бедных почв. В данном исследовании выполнен комплексный эколого-анатомический анализ листьев и стеблей *S. altaiensis* из природных популяций Катон-Карагайского национального парка. Анатомические параметры изучены с использованием классических микротехнических методик, морфометрии и статистики. Лист *S. altaiensis* демонстрирует выраженный комплекс ксеро- и ороморфных признаков. Листовая пластинка имеет стабильную толщину, хорошо развитую кутикулу, гипостоматический эпидермис. Дорсивентральный мезофилл характеризуется утолщённым палисадным слоем и умеренно варьируемым губчатым слоем, что отражает адаптацию к высокой инсоляции и ограниченной влаге. Проводящие пучки усилены склеренхимой, обеспечивая механическую устойчивость при сильных ветрах. Стебель отличается развитой ксилемой, стабильными размерами сосудистых элементов и толстой перидермой, формирующими эффективную систему водного транспорта. Корреляционный анализ показал согласованность основных анатомических параметров — толщины листа, структуры мезофилла, размеров проводящих пучков и развития ксилемы. Почвы местообитаний — слабокислые, с низкой минерализацией — соответствуют умеренной пластичности мезофилла и проводящих тканей. Таким образом, *S. altaiensis* обладает уникальным комплексом анатомо-морфологических адаптаций, обеспечивающих выживание в экстремальных условиях высокогорий Казахского Алтая. Полученные данные углубляют понимание адаптивной эволюции представителей *Rosaceae* Центральной Азии и важны для дальнейших таксономических и природоохранных исследований.

Ключевые слова: *Sibiraea altaiensis*, анатомия листа, анатомия стебля, высокогорные адаптации, эколого-анатомический анализ, Восточный Казахстан, Катон-Карагай.

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Current state and ecological assessment of flora in man-made areas of industrial enterprises in the East Kazakhstan region

The article presents the results of a floristic study of technogenically disturbed territories associated with industrial enterprises in the East Kazakhstan Region (EKR) and assesses the current ecological state of vegetation in these areas. The aim of the study was to evaluate the ecological features and current condition of flora in disturbed industrial territories based on an analysis of species composition and the ecological structure of plant communities at seven major non-ferrous metallurgy enterprises in the East Kazakhstan Region. The object of the study was the flora of technogenically disturbed industrial sites. The research was based on field botanical surveys using floristic and ecological-cenotic analysis methods. The disturbed flora was found to comprise 253 species of woody and herbaceous plants belonging to 171 genera and 53 families. Three leading families were identified: Asteraceae Bercht. & J.Presl — 41 species (16.1%), Poaceae Barnhart — 24 species (9.4%), and Rosaceae Juss. — 23 species (9.0%), which are characteristic of the boreal-temperate flora of the Holarctic region. The study includes an ecological and morphological assessment of plant adaptation to environmental conditions and analyzes patterns of vegetation recovery in disturbed habitats. Ecological characteristics of the phytocenoses are presented, the distribution of species among ecological-cenotic groups is examined, and a botanical-geographical analysis of the flora of technogenically disturbed territories is conducted. The obtained results expand current understanding of vegetation formation under technogenic impact and provide insight into the present state and ecological organization of technogenic flora.

Keywords: flora, ecosystem, phytocenosis, population, community, species, plants, technogenically disturbed areas, environmental assessment, succession.

Introduction

Intensive industrial development plays a leading role in the economic development of any country. Its growth has a negative impact on the environment, leading to changes in the integrity of the biogeocenotic cover and the degradation of natural landscapes, air, water, and soil pollution, increased waste, and a reduction in plant biodiversity. These processes give rise to anthropogenically disturbed lands, where secondary successions of biological communities occur spontaneously [1]. One such source of environmental destabilization in Eastern Kazakhstan is large industrial enterprises extracting and processing minerals. The region is a flagship for the development of non-ferrous metallurgy, the leading economic sector in the eastern part of the Republic. The region is home to large complexes for the extraction and processing of polymetallic ores: copper, zinc, magnesium, titanium, precious metals, and other minerals. The operations of these enterprises impact the environmental situation in the region, worsening the environment. Moreover, the environmental consequences of indirect impacts on the environment are often more extensive and often exceed the direct impact of mining enterprises on the environment.

The increasing area of technogenic land necessitates the identification and objective assessment of the current state of soil and vegetation cover at the region's major industrial enterprises. Scientific literature emphasizes the importance of studying technogenic flora, as such research allows for the assessment of the ecological state of disturbed areas, the identification of plant adaptations to extreme conditions [2], and the development of effective measures to restore and protect disturbed ecosystems [3, 4].

The aim of the work is to assess the current state and ecological characteristics of flora in man-made areas based on the analysis of species composition and ecological structure of populations at seven leading non-ferrous metallurgy enterprises in the East Kazakhstan region (EKR).

The main objective is to study the issues of degradation of plant communities and the study of the features of the formation of technogenic flora for further monitoring, planning and development of environmen-

tal measures, as well as conducting a geographic analysis of industrial flora, which will provide an understanding of the processes of formation of phytocenoses under conditions of technogenic impact and the patterns of plant distribution on the territory of industrial facilities.

Experimental

The study of vegetation cover in the zone of man-made pollution was carried out at 7 industrial enterprises in the East Kazakhstan region (Fig. 1).



Figure 1. Study of vegetation cover at industrial enterprises in East Kazakhstan region
 1 — Ridder Metallurgical Plant; 2 — Ust-Kamenogorsk Titanium and Magnesium Plant;
 3 — Ulba Metallurgical Plant; 4 — Belousovsky Mining and Processing Plant; 5 — Irtysch Copper Smelter;
 6 — Irtysch Rare Earth Company; 7 — Kazmineral

The study focused on natural and anthropogenically transformed plant communities located within the mountain forest, forest-steppe, and steppe zones near large industrial enterprises. Phytocenoses were studied using a route-reconnaissance method in areas adjacent to industrial enterprises in the East Kazakhstan region. A GARMIN GPS navigator was used to accurately determine the location of the monitoring zones (Etrex 22 X). During the research, the species composition of vascular plants was described, herbarium specimens were collected, and plant communities were identified taking into account the terrain and patterns of vertical zonation.

The species composition of herbarium specimens was clarified using plant identification guides [5–11] and the GBIF information system (<https://www.gbif.org/>).

The life forms of plants were established according to the ecological-morphological classification of I.G. Serebryakov [12]. The structural-dynamic analysis of life forms, taking into account the characteristics of the habitat and the nature of growth, was carried out according to the classification of G.M. Zozulin [13, 14]. The ecological conditions of plants were determined using the ecological scales of G.Ya. Stepanyuk, L.A. Zhukova and others, reflecting the distribution of species in anthropogenically disturbed areas based on the analysis of the species composition of plants, their taxonomic, morphological and ecological-geographical characteristics [15–19]. The identification of the structure of the flora by the belonging of species to ecological-cenotic groups, the assessment of the ratio of natural and anthropogenic components that determine the degree of transformation of ecosystems were carried out using ecological scales and methods of analyzing floristic diversity in accordance with the approaches developed by R.V. Kamelin for comparative floristic studies [20, 21].

The geographical analysis was conducted using the quantitative flora characterization method of A.I. Tolmachev et al. [22–27]. Species were distributed according to longitudinal and latitudinal geographic elements, which made it possible to identify patterns of their spatial distribution under conditions of anthro-

pogenic transformation of vegetation cover. Statistical processing of primary and secondary data from the comparative analysis of industrial phytocenosis systems was carried out using Microsoft Office Excel 2010.

Results and Discussion

The distribution of plant species in phytocoenoses was recorded at 132 locations across key sites of seven regional enterprises (Fig. 2). All areas are characterized by a high degree of anthropogenic impact due to the long-term development of the mining industry. The flora of the study areas includes apophytes, native, ruderal, synanthropic, and adventitious species that form secondary successional communities in disturbed areas.

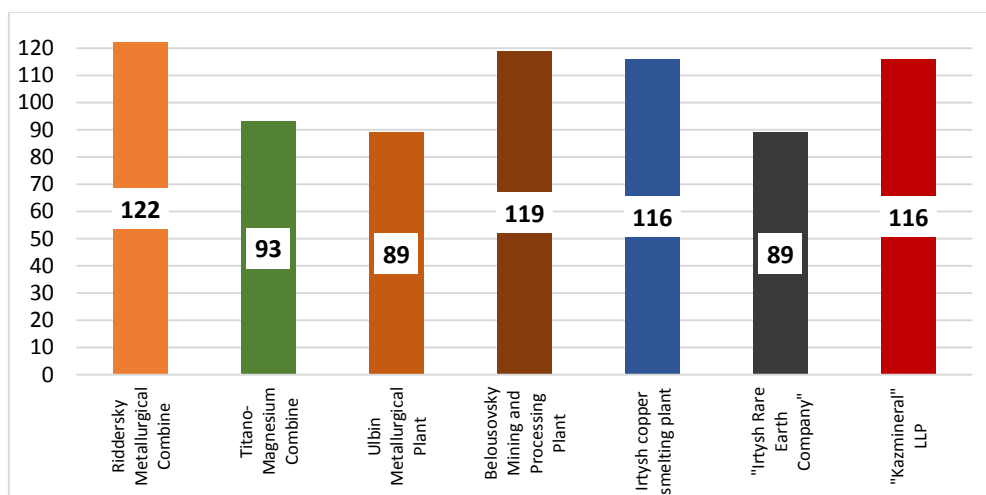


Figure 2. Distribution of the number of species by industrial sites in the East Kazakhstan region

According to the botanical and geographical zoning, the study area belongs to the Altai–Sayan mountain–taiga region, which is part of the South Siberian mountain forest vegetation region. The natural vegetation cover is located in two provinces [28, 29]:

– The Irtysh forest–steppe province of the Eurasian steppe region. Its territory is home to mining enterprises and large population centers, forming an independent type of urban phytocenosis vegetation. Natural vegetation is formed in the steppe and forest–steppe zones of the right bank of the Irtysh River. The natural vegetation type includes forest–steppe feather–grass–grass and fescue steppes, mixed forests, aspen–birch groves, floodplain forests, and shrub thickets. In flat areas, natural phytocenoses give way to arable lands and pastures with anthropogenic agrocenoses and associated weed vegetation. The relief is represented by a hilly surface, in places smoothed and indented by a moderate river network. The difference in altitude reaches up to 120 m (from 80 to 200 m). The climate is sharply continental. Winters are cold and with little snow. Precipitation ranges from 280 to 450 mm. Soils are predominantly a combination of light and dark chestnut soils.

– West Altai mountain forest province. The main enterprises of the non–ferrous metallurgy mining and processing industry are concentrated in the city of Ridder. The surrounding area belongs to the mountain–taiga zone and is characterized by high–altitude and mid–altitude terrain with characteristic vertical zonation. The natural vegetation type is coniferous and mixed forests. Due to intensive agriculture near populated areas, plant communities have been transformed by human economic activity. Degradation of the soil structure and a decrease in overall biodiversity are observed, accompanied by an increased number of adventitious species. The relief is a geomorphological depression with elevations of 700–900 meters above sea level. The climate is moderately cold due to the moderate altitudinal climatic zonation of the mountainous terrain. Precipitation ranges from 600 to 800 mm. The soils are soddy–podzolic.

Vegetation is one of the most sensitive biological components to human anthropogenic influence and, therefore, is becoming a key indicator of industrial pollution. The flora of the Kazakhstan Altai remains understudied. The total floristic diversity of the region comprises approximately 2,500 species of higher vascular plants from 531 genera and 108 families [5]. The studied provinces represent a limited portion of the Rudny Altai, experiencing significant anthropogenic influence from industrial zones. During route reconnaissance surveys in key flora areas, we noted 253 species of woody and herbaceous plants from 171 genera

and 53 families (Table 1). Species analysis showed that the proportion of flora represented at industrial sites reaches 10 % of the total species diversity of the Kazakhstan Altai.

Table 1

**Leading flora families near industrial enterprises in the northeastern part of Rudny Altai,
East Kazakhstan region**

| Families | Number of species | % of total |
|--------------------------------------|-------------------|------------|
| <i>Asteraceae</i> Bercht. & J. Presl | 49 | 19.3 |
| <i>Poaceae</i> Barnhart | 24 | 9.4 |
| <i>Rosaceae</i> Juss. | 23 | 9.0 |
| <i>Fabaceae</i> Lindl. | 17 | 6.7 |
| <i>Salicaceae</i> Mirb. | 13 | 5.1 |
| <i>Lamiaceae</i> Martinov | 12 | 4.7 |
| <i>Caryophyllaceae</i> Juss. | 9 | 3.6 |
| <i>Apiaceae</i> Lindl. | 8 | 3.2 |
| <i>Ranunculaceae</i> Juss. | 7 | 2.8 |
| <i>Plantaginaceae</i> Juss. | 7 | 2.8 |
| <i>Polygonaceae</i> Juss. | 6 | 2.4 |

In disturbed ecosystems, the leading families are *Asteraceae* (491 species, 19.3 %), *Poaceae* (24 species, 9.4 %), and *Rosaceae* (23 species, 9.0 %), which is typical of the boreal–temperate flora of the Holarctic. Due to their high ecological plasticity, they inhabit a variety of habitats, including disturbed natural complexes, and become dominant in ecosystems for a given climate.

The dominant components of the Irtysh region’s phytocenoses are typical meadow–steppe and shrub–meadow communities. In the Ridder mountain basin, meadow and forb–grass communities predominate, developing in the moderately cold and humid conditions of the low relief. Human activity has led to significant changes in the structure and composition of the mountain taiga forests around the city. Species like *Artemisia vulgaris* L., *Tanacetum vulgare* L., *Achillea millefolium* L., *Dactylis glomerata* L., *Lolium pratense* (Huds.) Darbysh., *Alopecurus pratensis* L., *Trifolium hybridum* L. and others are found in natural and anthropogenically disturbed areas. Among them, the overwhelming majority of the noted species (229, or 90.4 %) are native plants of the Kazakh Altai. Adventitious species make up a significant proportion of the cultivated flora near populated areas of the region (24, or 9.5 %). Due to their ecological plasticity, they are able to survive under stressful conditions and undergo a full cycle of ontogenetic development. Among them, predominantly tree species are traditionally used in landscaping cities and towns in the region: *Acer negundo* L., *Ulmus laevis* Pall., *Populus balsamifera* L., *Malus baccata* (L.) Borkh., *Fraxinus pennsylvanica* Marshall, *Syringa vulgaris* L., *Ribes aureum* Pursh. Some species are invasive (*Acer negundo* L.) or potentially invasive plants in natural communities and in the vicinity of populated areas (*Echinocystis lobata* (Michx.) Torr. et A. Gray, *Amaranthus retroflexus* L., *Xanthium strumarium* L. and etc.).

Plants in the surveyed area represent a diverse range of life forms. The overwhelming majority of 106 species (42 %) are perennial herbaceous plants of the genus *Elymus*. *repens* (L.) Gould, *Agropyron cristatum* (L.) Gaertn., *Artemisia austriaca* Jacq., *Cichorium intybus* L., *Senecio vulgaris* L., *Heracleum dissectum* Ledeb., *Origanum vulgare* L. and etc. They have a developed root system, are highly adaptable, and are capable of vegetative propagation, which ensures population stability in a variety of habitats. A relatively high proportion of annuals (57 %, or 22 %) and biennials (43 %, or 17 %) are found, occupying open and unstable areas lacking dense vegetation cover on industrial sites, along roads, in settlements, and in vacant lots (*Setariaviridis* (L.) P. Beauv., *Carduus nutans* L., *Sonchus oleraceus* L., *Chenopodium album* L., *Amaranthus retroflexus* L. etc.). Dendroflora is represented by 47 taxa (18.5 %). Among them, adventitious species are noted—6 %, which have a high proportion of participation in the composition of cultivated plantings. Some of them act as “pioneers”, becoming the basis of these formations with the gradual overgrowth of man–made objects—*Populus tremula* L., *Betula* L., *Rosaspinosissima* L., *Spiraea hypericifolia* L., *Lonicera tatarica* L., *Caragana frutex* (L.) K. Koch, *Atraphaxis frutescens* (L.) Eversm., etc. Subshrubs and vines (2 species each) are minimally represented in the industrial flora, accounting for 1.6 % (Fig. 3). It has

been noted that in disturbed areas, the presence of native woody flora ensures natural succession processes during the restoration of anthropogenic ecosystems.

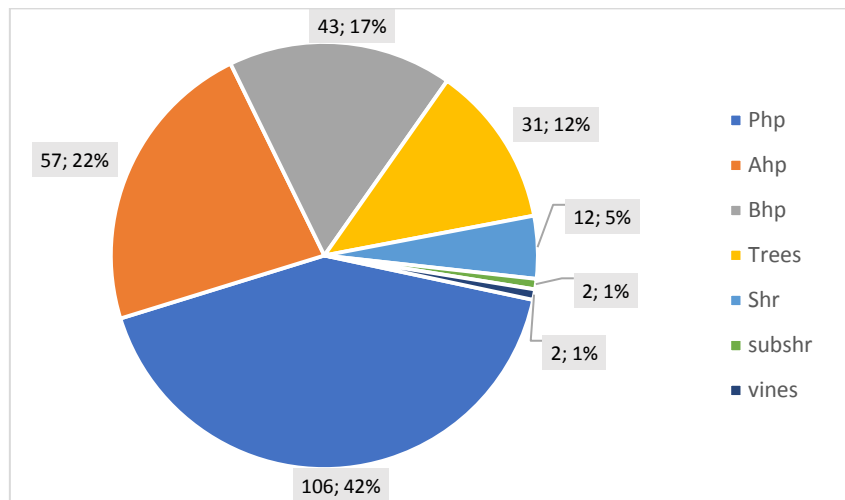


Figure 3. Life forms noted in plant populations in the areas of industrial pollution in East Kazakhstan region: Mtr — herbaceous perennials; Odn — annuals; Dv — biennials; D — trees; K — shrubs; Pk — subshrubs; L — vines

A structural and dynamic analysis of plant species was conducted to determine the stability of vegetation cover, the degree of disturbance, the stages of succession, and assess biodiversity. According to G.M. Zazulin's classification, the development of phytocenoses in disturbed ecotopes was determined by the ratio of restative, irruptive, and vagative plant groups, reflecting their adaptation and spatial distribution. The composition of plant groups in populations in the study areas varies depending on a range of factors related to the nature of industrial impact on the surrounding area (intensity of technogenic pollution, production characteristics, distance from the pollution source, the degree of accumulation of harmful substances in the soil, etc.).

In the disturbed areas of industrial enterprises in the region, the vegetation cover is dominated by restorative species (127 species, 50 %), indicating a pronounced ability of the community to maintain its occupied area and stabilize its spatial structure. The significant proportion of irruptive species (89 species, 35 %) indicates active dispersal and the development of vacant ecological niches, which is typical of anthropogenically transformed habitats. The smaller proportion of vagative species (38 species, 15 %) reflects their limited role in long-term population succession (Fig. 4).

Populations with different types of groups in disturbed areas located near an operating industrial enterprise and the enterprise after its shutdown and reduction of technogenic impact are presented in Figure 3. At sites with intense and constant pollution (Ust-Kamenogorsk "TMK"), irruptive species predominate in the technogenic flora — *Acer negundo* L., *Calamagrostis epigeios* (L.) Roth., *Cichorium intybus* L., *Cirsium vulgare* (Savi) Ten., *Convolvulus arvensis* L. Their share in the flora is 114 (45 %), indicating high ecological instability of plant populations under constant anthropogenic pressure. The proportion of stable regenerative populations decreases to 41 % (104 species), preventing the formation of a stable biocenosis. Among the existing species, plants with high ecological plasticity and resistance to environmental pollution are noted: *Artemisia absinthium* L., *Salvia dumetorum* Andr. ex Besser, *Verbascum songaricum* Schrenkex Fisch. et C.A. Mey., *Origanum vulgare* L., etc. The low value of variable species 35 (14 %) indicates that plants do not tolerate active pollution well — *Melilotus albus* Medik., *Berteroa incana* (L.) DC., *Echium vulgare* L., *Erigeron canadensis* L. et al. Thus, the ecosystem is in a state of chronic stress, where slow successional processes are observed.

A somewhat opposite picture of technogenic flora development is observed at the former Irtysh Chemical and Metallurgical Plant, which began operations in 1958. The plant's production activities were gradually suspended from 2008 to 2015. In fact, the plant's impact on the surrounding flora and ecosystem during this period was minimized. Active technogenic impact on the flora decreased, and successional processes gradually began to develop toward the formation of resilient and stable plant communities characteristic of natural ecosystems. The current composition of the vegetation reflects this dynamic, manifested in the predominance of regenerative species: 46 (51 %) of the total 89 species noted. *Festuca rubra* L., *Artemisia sericea* Weber

(Besser), *Achillea millefolium* L., *Gypsophila paniculata* L., *Dianthus ramosissimus* Pall.ex Poir et al. The proportion of irruptive taxa is still high, amounting to 29 (33 %). The ecosystem has not yet stabilized, and active successional changes are underway. Many expansive species continue to maintain their numbers and play a significant role in plant communities, indicating the impact of environmental pollution. Among them are ruderal, synanthropic, and pioneer species: *Elymus repens* (L.) Gould, *Malva thuringiaca* subsp. *thuringiaca*, *Sonchus arvensis* L., *Rumex confertus* Willd., and *Leonurus glaucescens* Bunge. The low proportion of variable species (14; 16%) indicates that the ecosystem has not yet reached maturity and remains unstable. These species include *Carduus crispus* L., *Cannabis sativa* var. *ruderalis* (Janisch.) S.Z. Liou, *Senecio vulgaris* L., and *Amaranthus retroflexus* L. Overall, this area reflects a post-technogenic character. Successional processes are at the early and middle stages of development.

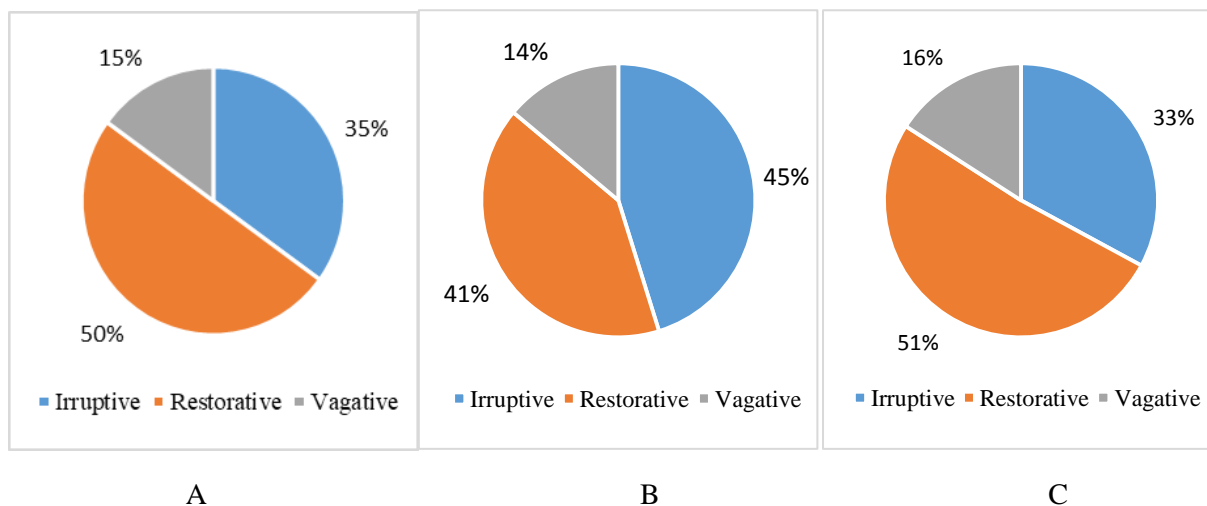


Figure 4. Distribution of plant groups in populations according to G.M. Zazulina in disturbed areas of East Kazakhstan region: A — Average data for all sites, B — Operating Ust-Kamenogorsk Titanium and Magnesium Plant, C — Mothballed Irtysh Rare Earth Company LLC

Plants growing in man-made landscapes differ in their ecological characteristics, including their relationship to moisture conditions, light conditions, and soil fertility (Fig. 5, 6).

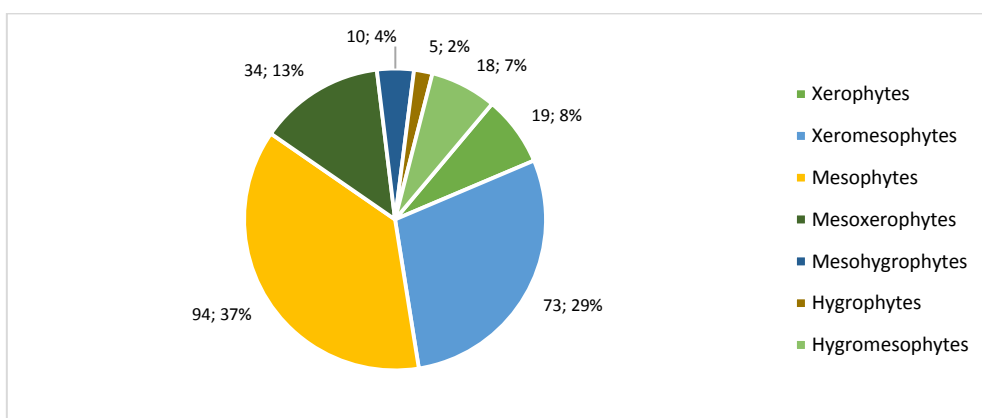


Figure 5. The ratio of ecological groups by the moisture factor of plants growing in man-made disturbed landscapes

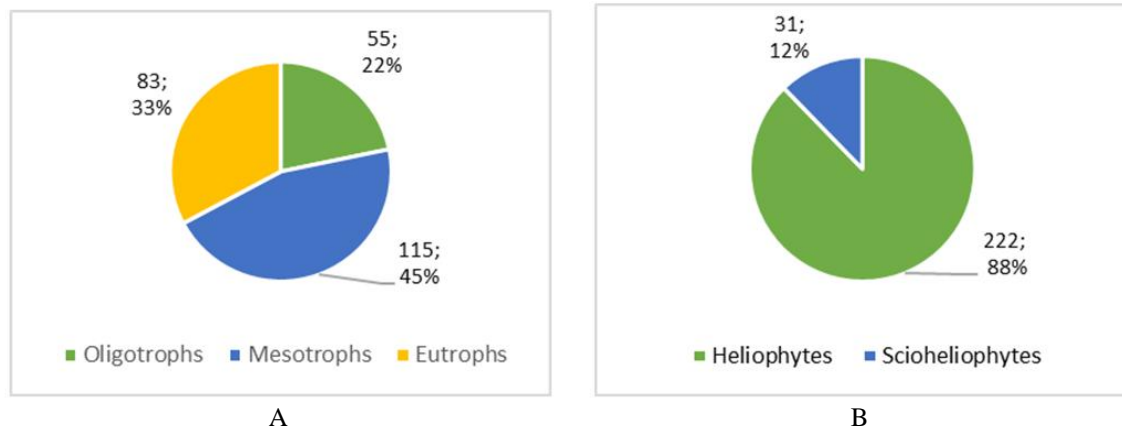


Figure 6. The ratio of ecological groups by the illumination factor (A) and soil fertility (B) of plants growing on man-made disturbed landscapes of the East Kazakhstan region

In terms of moisture requirements, plants adapted to moderate moisture predominate—mesophytes 94 (37 %), mesoxerophytes 13 %, xerophytes 19 (8 %), xeromesophytes 73 (29 %). Such types, like *Agrimonia pilosa* Ledeb., *Poa pratensis* L., *Lolium pratense* (Huds.) Darbysh., *Senecio vulgaris* L., *Veronica spicata* L., *Phleum phleoides* (L.) H. Karst., *Bromus inermis* Leyss., etc. reflect dry and moderately dry character conditions growth on violated territories. Marked moisture-loving types from groups hygrophytes with intermediate subgroups—33 (13 %) species, predominantly encountered on territories mountain taiga zones (Ridder): *Salix viminalis* L., *Rubus caesius* L., *Sanguisorba officinalis* L., *Equisetum sylvaticum* L., *Angelica decurrens* (Ledeb.) B. Fedtsch., *Cirsium alatum* (SG Gmel.) Bobrov and in relation to light, the flora of disturbed areas of industrial zones is represented predominantly by heliophytes—222 (88 %) and, to a lesser extent, by scioheliophytes 31 (12 %). This distribution is due to the open nature of the territories of industrial zones, including the mountain-steppe landscape, where well-lit areas predominate and dense vegetation is absent. In the surveyed areas, the greatest number of species develop with average soil fertility — mesotrophs 115 (45 %) — *Lonicera Tatarica* L., *Alopecurus pratensis* L., *Bromus inermis* Leyss., *Echinops tricholepis* Schrenk, *Origanum vulgare* L., etc. The ecological group of plants that inhabit soils with low nutrient content includes 83 (33 %) taxa (oligotrophs) — *Pinus sylvestris* L., *Caragana frutex* (L.) K. Koch, *Filipendula vulgaris* Moench, *Agropyron desertorum* (Fisch. ex Link) Schult., *Artemisia gmelinii* Weber ex Stechm., etc., and 55 (22 %) plants from industrial zones prefer fertile soils with a high humus content (eutrophs).

The eco-coenotic spectrum of flora in disturbed areas is characterized by high mosaicism. Analysis of flora by ecological groups and habitat types reflects habitat conditions, allows evaluating their ecological confinement, functional role in the structure of plant communities, and identify anthropogenic impact. Flora of disturbed areas is divided into 5 eco-coenotic groups: steppe and semi-steppe 65 species or 26 %; forest, forest-shrub and forest-meadow formations (64 species or 25 % of the total composition); weed-ruderal (62 species or 25 %); meadow (51 taxa or 20 %); wetland (11 species or 4 %). The dominance of steppe and forest species reflects the ecotone nature of the territories, caused by the interaction of forest-steppe, steppe and mountain-taiga landscapes. Meadow groups are present as a background element, displaced by weed and steppe vegetation. The proportion of wetland species is minimal due to the relief features and the predominance of dry growing conditions (Fig. 7).

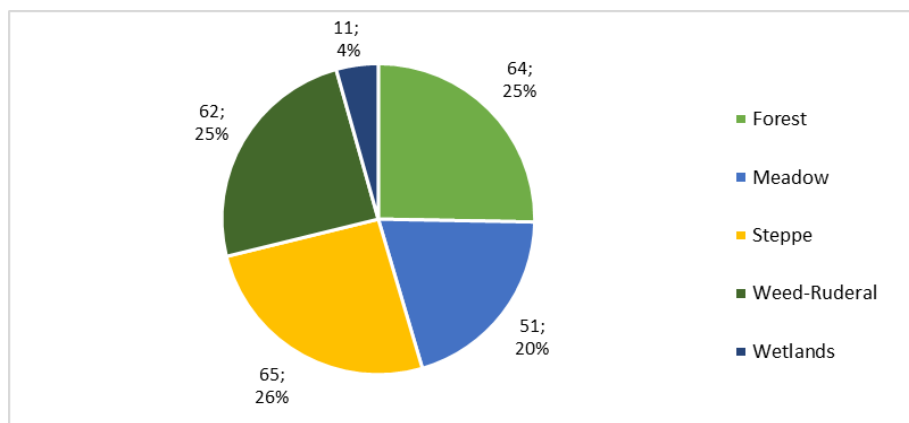


Figure 7. Spectrum of eco-cenotic groups of industrial flora of industrial enterprises of the East Kazakhstan region

An analysis of the spectrum of latitudinal elements of species, carried out on the basis of the classification of latitudinal elements according to A.I. Tolmachev [22], showed that the flora of the studied territories is almost entirely represented by species of the temperate zone (99 %), which corresponds to its physical and geographical position within the mountainous and foothill regions (Fig. 8).

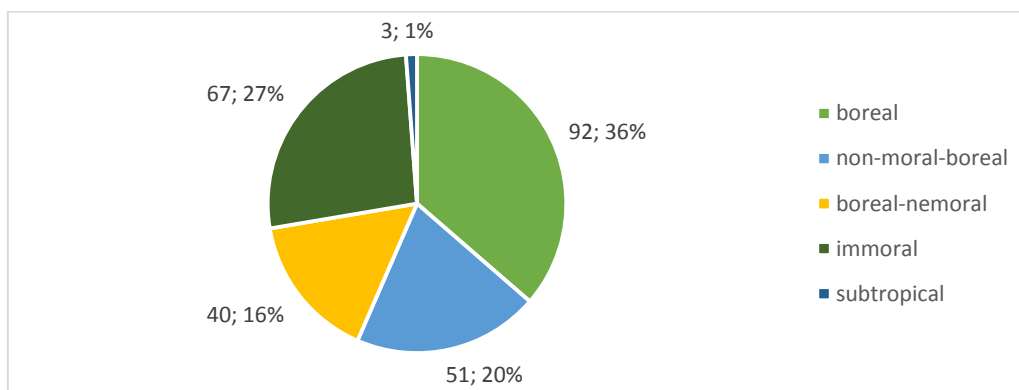


Figure 8. Spectrum of latitudinal elements of flora species of industrial enterprises of the East Kazakhstan region according to botanical and geographical zoning

The largest share in the urban flora is made up of temperate boreal elements 92 (36 %), characteristic of conditions with low temperatures and sufficient moisture—*Rosa acicularis* Lindl., *Potentilla chrysantha* Trevir., *Bromus inermis* Leyss., *Bunias orientalis* L., *Medicago falcata* L., and others. The predominance of this group reflects the significant influence of the mountain-taiga zone. A significant part of the flora is represented by temperate nemoral-boreal 51 (20 %) and boreal-nemoral elements 40 (16 %)—*Acer Tataricum* subsp. *ginnala* (Maxim.) Wesm., *Ulmus pumila* L., *Populus laurifolia* Ledeb., *Chamaenerion angustifolium* (L.) Scop., *Senecio nemorensis* L., *Veronica spicata* L., *Malva thuringiaca* subsp. *Thuringiaca*. These are ecologically flexible species, occupying transition zones between steppe and forest, with mountain-steppe and forest-steppe elements dominating. Moderately nemoral species account for 67 (27 %) of the studied species. The group includes species confined to warmer temperate climates associated with forest-steppe, meadow steppes, and anthropogenic species that form the basis of the vegetation cover of industrial zones and is represented by *Acer negundo* L., *Populus alba* L., *Ferula songarica* Pall. ex Willd., *Pulmonaria Mollis* Wulf. ex Hornem., *Dianthus ramosissimus* Pall. ex Poir., *Delphinium dictyocarpum* DC., and others. The subtropical element is insignificant, constituting 1.2 %, associated with introduced, anthropogenic alien and cultivated plants—*Echinochloa crus-galli* (L.) P. Beau., *Heliantus annuus* L. These species are not indicators of the natural conditions of the region.

An analysis of longitudinal flora groups reveals a distinct predominance of species with wide habitat ranges, a characteristic feature of anthropogenically transformed ecosystems. The Eurasian group dominates the vegetation structure, comprising 194 (77 %) species of the total flora of anthropogenically disturbed areas, forming the core of disturbed habitats. The proximity of their habitats and similar biogeographic origins

allows them to be considered a single Eurasian complex, possessing a broad ecological range and high resilience to anthropogenic impacts on the environment (Fig. 9).

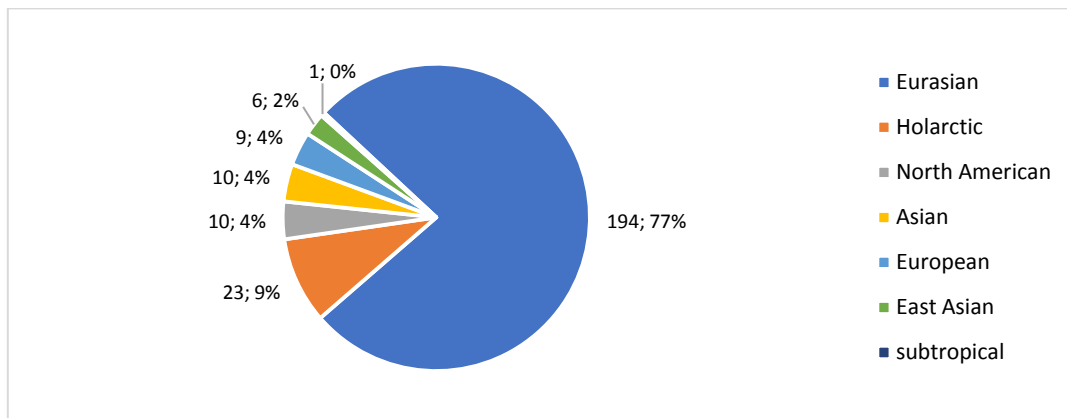


Figure 9. Distribution of industrial flora of industrial enterprises of East Kazakhstan region by geographical zoning

Among them *Acer tataricum* L., *Populus tremula* L., *Betula pendula* Roth, *Calamagrostis purpurea* (Trin.) Trin., *Poa pratensis* L., *Cirsium arvensis* (L.) Scop., *Plantago major* L., *Salvia dumetorum* Andr. ex Besser etc. Holarctic elements are playing significant role — 23 (9 %) types, characterized by extensive areas growth within Northern hemispheres — *Sanguisorba officinalis* L., *Festuca rubra* L., *Agrostis stolonifera* L., *Phragmites australis* (Gav.) Trin. ex Steud., *Equisetum hyemale* L. etc. Their presence highlights the ability of plants to adapt to various climatic conditions, including urbanized and man-made areas. The remaining longitudinal elements are represented in small proportions: North American and Asian species — 10 each (4 %) — *Populus balsamifera* L., *Fraxinus Pennsylvania* Marshal, *Solidago canadensis* L., *Ferula songarica* Pall. ex Willd., *Bupleurum longifolium* subsp. *aureum* and others; North American elements are represented by alien and naturalized species, widely distributed in disturbed and secondary habitats; Asian elements reflect continental floristic connections and adaptation to arid and mountain-steppe conditions; European elements make up 9 (4 %) species of the total number — *Salix daphnoides* Villa., *Syringa vulgaris* L., *Campanula rapunculoides* L. and other East Asian — 6 species or 2 % — *Acer Tataricum* subsp. *ginnala* (Maxim.) Wesm., *Salix integra* Thunb., *Malus baccata* (L.) Borkh. etc. Their participation reflects the historical and geographical connections of the region's flora with specific floristic regions and introduction processes. The tropical-subtopical element is represented by one species — *Portulaca oleracea* L., which indicates the absence of influence of southern floristic complexes.

The ecological–cenotic distribution of vegetation on the territory of industrial enterprises is formed under the influence of the degree of technogenic load, environmental conditions and biological characteristics of plant communities.

The conducted research has established that the structure of industrial phytocenoses reflects the adaptation of vegetation to disturbed ecotypes and combines elements of stabilization and active species dispersal with high ecological plasticity, taking into account zonal and climatic factors. The most favorable conditions for plant growth were also noted at the mothballed IREC LLC facility, where phytocenoses are in a state of restorative succession, compared to operating facilities, where natural plant communities are weakened due to constant anthropogenic impacts on the environment, with a predominance of ruderal species and a decrease in the diversity of natural vegetation.

Conclusion

Based on the results of the research, the floristic composition of key industrial flora sites comprises 253 species of woody and herbaceous plants from 171 genera in 53 families, accounting for 10 % of the total species diversity of the Kazakhstan Altai. The leading families of industrial flora are representatives of three families: Asteraceae—49 (19.3 %) species, Poaceae—24 (9.4 %) species; Rosaceae—23 (9.0 %) species, which is typical for the boreal–temperate flora of the Holarctic.

In terms of life forms, the overwhelming majority of plant species are perennial herbaceous plants—106 (42 %), followed by annuals—57 (22 %), and biennials—43 (17 %). Dendroflora is represented by 47

taxa (18.5 % of the total), including adventitious species (6 %): trees—31 (12 %), shrubs—12 (5 %), and subshrubs and vines—2 each (1 %).

Structural–dynamic analysis (the relationship between plant groups in populations) revealed that disturbed phytocenoses are in the recovery stage, with stabilization processes prevailing over active dispersal. Under conditions of intense environmental pollution from industrial enterprises, successional processes and the formation of stable plant communities are slowing down.

The ecological characteristics of phytocenoses in disturbed areas are represented by light–loving plants (heliophytes 88 %), adapted to moderate (mesophytes — 37 %, mesoxerophytes — 13 %) and limited moisture (xerophytes — 8 % and xeromesophytes — 29 %) with a predominance of species with average soil fertility (mesotrophs — 45 %), which corresponds to the ecological conditions of the steppe and mountain–steppe zones of the foothills.

The flora of the disturbed areas is divided into 5 ecological–cenotic groups: steppe and semi–steppe 65 species (26 %); forest, forest–shrub and forest–meadow — 64 species (25 %) of the total composition; weed–ruderal — 62 (25 %); meadow — 51 (20 %); wetland — 11 (4 %).

Botanical and geographical analysis shows that the latitudinal flora elements in disturbed areas are almost entirely represented by temperate zone species (99 %). It was established that the majority of the flora are temperate boreal species — 92 (36 %), nemoral–boreal species — 51 (20 %), and boreal–nemoral species — 40 (16 %). This indicates the dominance of temperate zone flora in the formation of plant communities in industrial ecotopes.

The longitudinal structure is characterized by the dominance of the Eurasian group—194 species (77 %), creating a unified Eurasian complex with high resilience to anthropogenic impacts in the technogenically disturbed areas of industrial enterprises. Other longitudinal elements are represented in minor proportions: North American and Asian species account for 10 each (4 %), European elements account for 9 (4 %), and East Asian species account for 6 (2 %). The presence of North American and Asian species indicates the introduction of introduced species and migration processes.

Thus, at present, industrial phytocenoses in the man–made territories of the enterprises of the East Kazakhstan region are in a state of restoration succession process.

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Author Contributions

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Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Jackowiak B. Man-made changes in the flora and vegetation of Poland: Current review / B. Jackowiak // *Diversity*. — 2023. — Vol. 15, No. 5. — P. 618. <https://doi.org/10.3390/d15050618>
- 2 Rakhimov G. Life forms of plants of natural and anthropogenic landscapes / G. Rakhimov et al. // *Scientific Horizons*. — 2023. — Vol. 26, No. 1. — P. 62–72. DOI:10.48077/scihor.26(1).2023.62–72
- 3 Третьякова А. С. Урбанофлористика в России: современное состояние и перспективы / А. С. Третьякова // *Turczaninowia*. — 2021. — Т. 24, № 1. — С. 125–144. <https://doi.org/10.14258/turczaninowia.24.1.15>
- 4 Козыбаева Ф. Е. Естественное восстановление растительного покрова, его видового состава в условиях самозарастания и рекультивации / Ф. Е. Козыбаева, Ю. А. Котухов, Г. Б. Бейсева и др. // *Почвоведение и агрохимия*. — 2018. — № 4. — С. 53–69.
- 5 Васильева А. Н. Флора Казахстана [в 9 т.] / А. Н. Васильева, А. П. Гамаюнова, В. П. Голоскоков и др. — Алма–Ата: Изд–во Акад. наук Казах. ССР, 1966. — Т. 9. — 640 с.

- 6 Куминов А.В. Растительный покров Алтая / А.В. Кумина. — Новосибирск: Изд-во Сиб. отд-ния Акад. наук СССР. — 1960. — 450 с.
- 7 Куприянов А.Н. Флора и растительность / А.Н. Куприянов // Биологическое разнообразие Алтае-Саянского региона. — Кемерово. — 2003. — С. 23–126.
- 8 Котухов Ю.А. Список сосудистых растений Казахского Алтая / Ю.А. Котухов // Ботанические исследования Сибири и Казахстана. — Кемерово. — 2016. — С. 67–124.
- 9 Котухов Ю.А. Злаки Восточного Казахстана Дополнение к «Флоре Казахстана» [Электронный ресурс] / Ю.А. Котухов // Turczaninowia. — 2021. — Т. 24, № 2. — С. 156–169. — Режим доступа: <https://cyberleninka.ru/article/n/dopolnenie-k-flore-kazahstana-zlaki-vostochnogo-kazahstana/viewer>
- 10 Маслова О. Синантропная флора западных низкогорий Алтая / О.М. Маслова, И.А. Хрусталева, Т.О. Стрельникова // Вестник Томского государственного университета. Биология. — 2019. — № 47. — С. 74–102.
- 11 Анькова Т.В. Конспект флоры Ульбинского хребта (Рудный Алтай) / Т.В. Анькова. — Новосибирск: ЦСБС СО РАН. — 2006. — 144 с. doi: 10.17223/19988591/47/5
- 12 Серебряков И.Г. Экологическая морфология растений. Жизненные формы покрытосеменных и хвойных / И.Г. Серебряков. — М.: Высшая школа, 1962. — 378 с.
- 13 Зозулин Г.М. Система жизненных форм высших растений / Г.М. Зозулин // Ботанический журнал. — 1961. — Т. 46, № 1. — С. 3–20.
- 14 Зозулин Г.М. Жизненные формы растений в аспекте учения о биосфере / Г.М. Зозулин // Ботанический журнал. — 1976. — Т. 61, № 11. — С. 1506–1514.
- 15 Степанюк Г. Я. Оценка развития растительности техногенного отвала / Г.Я. Степанюк и др. // Техника и технология пищевых производств. — 2022. — Т. 52, № 4. — С. 807–818. <https://doi.org/10.21603/2074-9414-2022-4-2407>
- 16 Жукова Л.А. Экологические шкалы и методы анализа экологического разнообразия / Л.А. Жукова, Ю.А. Дорогова и др. — Йошкар-Ола: МарГУ. — 2010. — 368 с.
- 17 Раменский Л.Р. Экологическая оценка кормовых угодий по растительному покрову / Л.Р. Раменский, Н.А. Антипов и др. — М.: Сельхозгиз. — 1956. — 472 с.
- 18 Ellenberg H. Zeigerwerte der Gefasspflanzen Mitteleuropas / H. Ellenberg. — Gottingen; Goltze. — 1974. — 97 с.
- 19 Назаренко Н.Н. Классификация эколого-ценотических групп флоры сосудистых растений (на примере Ханты-Мансийского автономного округа — Югра) / Н.Н. Назаренко, У.Ю. Пасечник // Acta Biologica Sibirica. — 2019. — Т. 5, № 2. — С. 119–133. doi: <https://doi.org/10.14258/abs.v5.i2.6194>
- 20 Камелин Р.В. Флорогенетический анализ естественной флоры горной Средней Азии / Р.В. Камелин. — Л.: Наука, Ленингр. отд-ние. — 1973. — 356 с.
- 21 Камелин Р.В. Материалы по истории флоры Азии (Алтайская горная страна): монография / Р.В. Камелин. — Барнаул: Изд-во Алтайского университета. — 1998. — 240 с.
- 22 Толмачев А.И. Методы сравнительной флористики и проблемы флорогенеза / А.И. Толмачев. — Новосибирск: Наука. — 1986 — С. 197.
- 23 Письмаркина Е.В. Бореальные элементы флоры на северо-западе Приволжской возвышенности / Е.В. Письмаркина, Т.Б. Силаева // Проблемы ботаники Южной Сибири и Монголии. — 2024. — Т. 23, № 1. — С. 218–227. DOI: 10.14258/pbssm.2024040
- 24 Антипова Е.М. Структура флоры евро-сибирского географического элемента лесостепи Средней Сибири / Е.М. Антипова // Samara Journal of Science. — 2018. — Т. 7, № 1. — С. 15–19. DOI:10.17816/SANV25336-19863
- 25 Гончаров А.Н. Географический анализ флоры антропогенно нарушенных горнолесных фитоценозов Северо-Западного Кавказа / А.Н. Гончаров, А.Ф. Щербатова // Проблемы ботаники Южной Сибири и Монголии. — 2025. — Т. 24, № 1. — С. 40–44. <https://doi.org/10.14258/pbssm.2025009>
- 26 Макарова Ю.В. Материалы к эколого-географическому анализу флоры сосудистых растений горы Кузнецова / Ю.В. Макарова, А.А. Головлев, Н.В. Прохорова // Самарский научный вестник. — 2019. — Т. 8, № 1. — С. 59–65. DOI 10.24411/2309-4370-2019-11109
- 27 Эбель А.Л. Флора северо-западной части Алтае-Саянской провинции: состав, структура, происхождение, антропогенная трансформация: автореф. ... дис. д-ра биол. наук / А.Л. Эбель. — Томск, 2011. — 40 с.
- 28 Бондаренко А.В. Видовое разнообразие биоресурсов трансграничной биосферной территории: Россия, Монголия, Казахстан, Китай / А.В. Бондаренко // Развитие территорий. — 2016. — № 1 (4). — С. 114–118.
- 29 Огуреева Г.Н. Ботаническая география Алтая / Г.Н. Огуреева. — М.: Наука, 1980. — 192 с.

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Шығыс Қазақстан облысындағы өнеркәсіптік кәсіпорындардың техногендік бұзылған аумақтарындағы флораның қазіргі жағдайы және экологиялық бағасы

Мақалада Шығыс Қазақстан облысындағы (ШҚО) өнеркәсіптік кәсіпорындардың техногендік аумақтарындағы флораны зерттеу нәтижелері келтірілген, бұзылған аумақтардағы техногендік әсерге ұшыраған флораның қазіргі жағдайына экологиялық бағалау негізінде баға берілген. Зерттеу жұмысының мақсаты — Шығыс Қазақстан облысындағы түсті металлургия саласындағы жеті жетекші кәсіпорында жүргізілген түрлік құрамды және популяциялардың экологиялық құрылымын талдау негізінде техногендік аумақтардағы флораның қазіргі жағдайы мен экологиялық ерекшеліктерін бағалау. Зерттеу нысаны — өнеркәсіптік кәсіпорындардың техногендік бұзылған аумақтарының флорасы. Жұмыс флористикалық және экологиялық-ценотикалық талдау әдістерін қолдана отырып жүргізілген далалық ботаникалық сипаттамалар негізінде орындалды. Өнеркәсіптік флораның түрлік құрамының ерекшеліктері анықталды. Ол 53 тұқымдас пен 171 туысқа жататын ағаш және шөптесін өсімдіктердің 253 түрінен тұрады. Негізгі үш жетекші тұқымдас айқындалды: Asteraceae Bercht. & J.Presl — 41 түр (16,1 %), Poaceae Barnhart — 24 түр (9,4 %) және Rosaceae Juss. — 23 түр (9,0 %). Бұл тұқымдастар Голарктиканың бореальды-қоңыржай флорасына тән. Жұмыста өсімдіктердің қоршаған орта жағдайларына бейімделуіне және техногендік флораның қайта қалпына келу ерекшеліктеріне экологиялық-морфологиялық баға берілген. Сонымен қатар фитоценоздарға экологиялық сипаттама жасалып, түрлердің экологиялық-ценотикалық топтар бойынша таралуы талданды, техногендік аумақтар флорасына ботаникалық-географиялық талдау жүргізілді. Алынған мәліметтер техногендік әсер жағдайында өсімдік жамылғысының қалыптасу заңдылықтары туралы түсінікті кеңейтіп, техногендік флораның қазіргі жағдайын сипаттауға мүмкіндік береді.

Кілт сөздер: флора, эокожүйе, фитоценоз, популяция, қауымдастық, түр, өсімдіктер, техногендік бұзылған аумақтар, экологиялық бағалау, сукцессия.

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Современное состояние и экологическая оценка флоры техногенно нарушенных территориях промышленных предприятий Восточно-Казахстанской области

В статье приводятся результаты исследования флоры на техногенных территориях промышленных предприятий Восточно-Казахстанской области (ВКО), дана оценка современного состояния техногенно нарушенной флоры на нарушенных территориях на основе экологической оценки. Цель работы — дать оценку современному состоянию и экологическим особенностям флоры на техногенных территориях на основе анализа видового состава и экологической структуры популяций на семи ведущих предприятиях цветной металлургии Восточно-Казахстанской области. Объект исследования — флора техногенно нарушенных территорий промышленных предприятий. Работа выполнена на основе полевых ботанических описаний с использованием методов флористического и эколого-ценотического анализа. Установлены особенности видового состава промышленной флоры, насчитывающей 253 вида древесных и травянистых растений из 171 рода, относящихся к 53 семействам. Выделены 3 ведущих семейства: Asteraceae Bercht. & J. Presl — 41 вид (16,1 %), Poaceae Barnhart — 24 вида (9,4 %) и Rosaceae Juss. — 23 вида (9,0 %), которые характерны для бореально-умеренной флоры Голарктики. В работе представлена эколого-морфологическая оценка адаптации растений к условиям среды и особенностям возобновления техногенных флор. Дана экологическая характеристика фитоценозов, проанализировано распределение видов по эколого-ценотическим группам, проведен ботанико-географический анализ флоры техногенных территорий. Полученные сведения расширяют представления о закономерностях формирования растительности в условиях техногенного воздействия и дают представление о современном состоянии техногенной флоры.

Ключевые слова: флора, экосистема, фитоценоз, популяция, сообщества, вид, растения, техногенно нарушенные территории, экологическая оценка, сукцессия.

References

- 1 Jackowiak, B. (2023). Man-made changes in the flora and vegetation of Poland: Current review. *Diversity*, 15(5). <https://doi.org/10.3390/d15050618>
- 2 Rakhimov, G. et al. (2023). Life forms of plants of natural and anthropogenic landscapes. *Scientific Horizons*, 26(1), 62–72. DOI:10.48077/scihor.26(1).2023.62–72
- 3 Tretyakova, A.S., et al. (2021). Urbanofloristika v Rossii: sovremennoe sostoianie i perspektivy [Urban floristry in Russia: current status and prospects]. *Turczaninowia*, 24(1), 125–144. <https://doi.org/10.14258/turczaninowia.24.1.15> [in Russian].
- 4 Kozybaeva, F.E., Kotuxov, Yu.A., & Bejseeva, G.B., et al. (2018). Estestvennoe vosstanovlenie rastitelnogo pokrova, ego vidovogo sostava v uslovii samozarastania i rekultivatsii [Natural restoration of vegetation cover, its species composition under conditions of self-overgrowth and reclamation]. *Pochvovedenie i agrokhimiiia — Soil Science and Agronomy*, 4, 53–69 [in Russian].
- 5 Vasil'eva, A.N., Gamayunova, A.P., Goloskokov, V.P., et al. (1966). *Flora Kazakhstana* [Flora of Kazakhstan]. Vols. 1–9. Vol. 9. Alma-Ata: Izdatelstvo Akademii Nauk Kazakhskoi SSR [in Russian].
- 6 Kuminov, A.V. (1960). *Rastitelnyi pokrov Altaia* [Plant cover of Altay]. Novosibirsk: Izdatelstvo Sibirnogo otdeleniia Akademii Nauk Kazakhskoi SSSR [in Russian].
- 7 Kupriyanov, A.N. (2003). Flora i rastitelnost [Flora and vegetation]. *Biologicheskoe raznoobrazie Altae-Saianskogo regiona — Biological diversity of the Altai-Sayan region*. Kemerovo [in Russian].
- 8 Kotuxov, Yu.A. (2016). Spisok sosudistykh rastenii Kazakhstanskogo Altaia [List of vascular plants of the Kazakh Altay]. *Botanicheskie issledovaniia Sibiri i Kazakhstana — Botanical studies of Siberia and Kazakhstan*, 67–124. Kemerovo [in Russian].
- 9 Kotuxov, Yu.A. (2021). Zlaki Vostochnogo Kazakhstana Dopolnenie k «Flore Kazakhstana» [Cereals of Eastern Kazakhstan. Supplement to the “Flora of Kazakhstan”]. *Turczaninowia*, 24(2). Retrieved from <https://cyberleninka.ru/article/n/dopolnenie-k-flore-kazahstana-zlaki-vostochnogo-kazahstana/viewer> [in Russian].
- 10 Maslova, O.M., Khrustaleva, I.A., & Strelnikova, T.O. (2019). Sinantropnaia flora zapadnykh nizkogorii Altaia [Synanthropic flora of the western lowlands of Altay]. *Vestnik Tomskogo gosudarstvennogo universiteta. Biologiya — Bulletin of Tomsk State University. Biology*, 47, 74–102 [in Russian].
- 11 Ankova, T.V. (2006). *Konspekt flory Ulbinskogo khrebtia (Rudnyi Altai)* [A summary of the flora of the Ulbinsky Range of the Rudny Altai]. Novosibirsk: TszSBS SO RAN. doi: 10.17223/19988591/47/5 [in Russian].
- 12 Serebryakov, I.G. (1962). *Ekologicheskaiia morfologia rastenii. Zhiznennye formy pokrytosemennykh i khvoinykh* [Ecological morphology of plants. Life forms of angiosperms of conifers]. Moscow: Vysshiaia shkola [in Russian].
- 13 Zozulin, G.M. (1961). Sistema zhiznennykh form vysshikh rastenii [System of life forms of higher plants]. *Botanicheskii zhurnal — Botanical journal*, 46(1), 3–20 [in Russian].
- 14 Zozulin, G.M. (1976). Zhiznennye formy rastenii v aspekte ucheniia o biosfere [Life forms of plants in the context of studying the biosphere]. *Botanicheskii zhurnal — Botanical journal*, 61(11), 1506–1514 [in Russian].
- 15 Stepanyuk, G.Ya., et al. (2022). Otsenka razvitiia rastitelnosti tekhnogenno otvala [Assessment of vegetation development of a man-made waste dump]. *Tekhnika i tekhnologiia pishchevykh proizvodstv — Technology of food production*, 52(4), 807–818. <https://doi.org/10.21603/2074-9414-2022-4-2407> [in Russian].
- 16 Zhukova, L.A., Dorogova, Yu.A., et al. (2010). *Ekologicheskie shkaly i metody analiza ekologicheskogo raznoobraziiia* [Ecological scales and methods of analysis of ecological diversity]. Yoshkar-Ola: Mariiskoi gosudarstvennyi universitet [in Russian].
- 17 Ramensky, L.R., Antipov, N.A. et al. (1956). *Ekologicheskaiia otsenka kormovykh ugodii po rastitelnomu pokrovu* [Ecological assessment of forage lands based on vegetation cover]. Moscow: Selkhozgiz [in Russian].
- 18 Ellenberg, H. (1974). *Zeigerwerte der Gefasspflanzen Mitteleuropas* [Indicator Values of the Vascular Plants of Central Europe]. Gottingen; Goltze [in German].
- 19 Nazarenko, N.N., & Pasechnyuk, U. Yu. (2019). Klassifikatsiia ekologo-tsenoticheskikh grupp flory sosudistykh rastenii (na primere Khanty-Mansiiskogo avtonomnogo okruga — Yugra) [Classification of ecological-cenotic groups of vascular plant flora (using the Khanty-Mansiysk Autonomous Okrug — Yugra as an example)]. *Acta Bijiigica Sibirica*, 5(2). doi: <https://doi.org/10.14258/abs.v5.i2.6194> [in Russian].
- 20 Kamelin, R.V. (1973). *Florogeneticheskii analiz estestvennoi flory gornoj Srednei Azii* [A florogenetic analysis of natural flora of the mountains of Central Asia]. Leningrad: Nauka, Leningradskoe otdelenie [in Russian].
- 21 Kamelin, R.V. (1998). *Materialy po istorii flory Azii (Altaiskaia gornaia strana): monografiia* [Materials on the history of Asian flora (Altay Mountain Country): monograph]. Barnaul: Altaiskii Universitet [in Russian].
- 22 Tolmachev, A.I. (1986). *Metody sravnitelnoi floristiki i problemy florogeneza* [Methods of comparative floristry and problems of florogenesis]. Novosibirsk: Nauka [in Russian].
- 23 Pismarkina, E.V., & Silaeva, T.B. (2024). Borealnye elementy flory na severo-zapade Privolzhskoi vozvyshechnosti [Boreal elements of flora in the northwest of the Volga Upland]. *Problemy botaniki Yuzhnyi Sibiri i Mongolii — Problems of botany in Southern Siberia and Mongolia*, 23(1). DOI: 10.14258/pbssm.2024040 [in Russian].
- 24 Antipova, E.M. (2018). Struktura flory evro-sibirskogo geograficheskogo elementa lesostepi Srednei Sibiri [Structure of the flora of the Euro-Siberian geographical element of the forest-steppe of Central Siberia]. *Samara Journal of Science*, 7(1), 15–19. DOI:10.17816/SANV25336-19863 [in Russian].
- 25 Goncharov, A.N., & Shherbatova, A.F. (2025). Geograficheskii analiz flory antropogenno naryshennykh gornolesnykh fitotsenozov Severo-Zapadnogo Kavkaza [Geographical analysis of flora of anthropogenically disturbed mountain forest

phytocoenoses of the Northwestern Caucasus]. *Problemy botaniki Yuzhnyi Sibiri i Mongolii — Problems of botany of Southern Siberia and Mongolia*, 24(1), 40–44. <https://doi.org/10.14258/pbssm.2025009> [in Russian].

26 Makarova, Yu.V., Golovlev, A.A., & Proxorova, N.V. (2019). Materialy k ekologo–geograficheskomu analizu flory sosudistykh rastenii gory Kuznetsova [Materials for the ecological and geographical analysis of the vascular plant flora of Mount Kuznetsov]. *Samarskii nauchnyi vestnik — Samara scientific bulletin*, 8(1), 59–65. DOI 10.24411/2309–4370–2019–11109 [in Russian].

27 Ebel, A.L. (2011). Flora severo-zapadnoi chasti Altae-Saianskoi provintsii: sostav, struktura, proiskhozhdenie, antropogennaia transformatsiia [Flora of the northwestern part of the Altae–Sayan province: composition, structure, origin, anthropogenic transformation]. *Extended abstract of Doctor's thesis* [in Russian].

28 Bondarenko, A.V. (2016). Vidovoe raznoobrazie bioresursov transgranichnoi biosfernoi territorii: Rossiia, Mongoliia, Kazakhstan, Kitai [Species diversity of bioresources of the transboundary biosphere territory: Russia, Mongolia, Kazakhstan, China]. *Ravitie territorii — Territory development*, 1(4), 114–118 [in Russian].

29 Ogureeva, G.N. (1980). *Botanicheskaia geografiia Altaia* [Botanical geography of Altaya]. Moscow: Nauka [in Russian].

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Altitudinal zonality and phytocenotic diversity of plant communities with participation of species of the genus *Allium* L. in the northern macroslope of the Kyrgyz Alatau mountains

The Kyrgyz Alatau is the westernmost range of the Northern Tien Shan. The western part of the northern macroslope of the range, with absolute heights of up to 3,700 metres above sea level, is located within Kazakhstan. This mountainous country is characterised by a "Kyrgyz type of altitudinal zonality", reflecting a connection with the vegetation of the Western Tien Shan. After identifying herbarium and expedition specimens, the revised checklist of the genus *Allium* L. includes 25 taxa, including the rare species *A. suworowii* and two subendemics (*A. margaritae*, *A. trachyscordum*). An analysis of the phytocenotic and altitudinal distribution of habitats of 19 species of the genus *Allium* L., identified during 2024-2025 in 14 gorges of the northern macroslope of the Kyrgyz Alatau range showed that their distribution in the mountains begins with the savannoid and meadow steppe subbelts, continues with the belt of juniper woodland belt, the belt of subalpine meadows and prostrate juniper thickets, and ends with the alpine belt of cryophytic meadows and communities of kobresia. The gorges of the western low- and mid-mountain part of the range are characterised by species diversity of onions: Sogety, Makpal, Ulken Almaly, Tastambek, Uzynbulak, as well as the Karakystak gorge located to the east, where 5 to 6 species of onions are found. Based on showing the locations of 19 identified wild species of the genus *Allium* L. on the northern macroslope of the studied range was created.

Keywords: altitudinal distribution, the genus *Allium* L., Kyrgyz Alatau range, phytocenotic diversity.

Introduction

The Kyrgyz Alatau range is the western most of the Northern Tien Shan ranges. The western part of the northern macro-slope of the range, with absolute heights of up to 3,700 metres above sea level, is located within Kazakhstan. This mountainous country is characterised by the "Kyrgyz type of altitudinal zonality" [1], which shows a connection with the vegetation of the Western Tien Shan, expressed in the abundance of ephemerals and ephemeroïds in the steppe zone on the foothill plains, in the appearance of a zone of juniper woodland and in the fragmentary nature of the forest zone. For the western part of the northern macroslope, patterns of zonal distribution of vegetation cover have been identified [2]. Within the highlands, there is an alpine belt of cryophytic low-grass meadows (2800–3500 m above sea level / asl) and a belt of subalpine meadows and prostrate juniper thickets (2200–2800 m asl). The middle mountains are characterised by a belt of juniper woodland (1600–2200 m asl). Within the low mountains, foothill plains and hills, there is a steppe belt with three sub-belts: meadow steppes (1200–1600 m asl), savannoid steppes (800–1200 m asl), and desert steppes (500–800 m asl). The foothill plain is home to a belt of foothill deserts (400–500 m asl).

For the territory of the Kyrgyz Alatau in Kazakhstan, based on analysis of herbarium and field research data, a preliminary list of 27 species of the genus *Allium* L. was compiled [3, 4]. To date, after the identification of expeditionary and herbarium specimens of the genus *Allium* L. of the western part of the Kyrgyz Range, the updated list includes 25 species: *Allium atosanguineum* Schrenk, *A. barszczewskii* Lipsky, *A. caeruleum* Pall., *A. caesium* Schrenk, *A. caricifolium* Kar. et Kir., *A. dasyphyllum* Vved., *A. fetisowii* Regel, *A. hymenorhizum* Ledeb., *A. karataviense* Regel, *A. leptomorphum* Vved., *A. longiradiatum* (Regel)

Vved., *A. margaritae* B. Fedtsch., *A. obliquum* L., *A. oreoprasoides* Vved., *A. oreoprasum* Schrenk, *A. parvulum* Vved., *A. platyspathum* Schrenk, *A. platystemon* Kar. & Kir. (syn. *A. oreophilum* C.A. Mey.), *A. polyphyllum* Kar. et Kir., *Allium sativum* L. (syn. *A. longicuspis* Regel), *A. semenovii* Regel, *A. suworowii* Regel, *A. taschkenticum* F.O. Khass. et R.M. Fritsch, *A. trachyscordum* Vved., *A. turkestanicum* Regel [5], including one endemic (*A. oreoprasoides*) [6], 2 sub-endemics (*A. margaritae*, *A. trachyscordum*), which are also found in Kyrgyzstan [7], and a rare species from the Red Book of Kazakhstan [8] — *A. suworowii*.

Comparison of the given list of onions from the western part of the Kyrgyz Alatau with the published regional lists of species of the genus *Allium* L. showed that, out of 42 onion species in the Zhetysu Alatau, 12 are found on both ranges under similar ecological conditions [9]. In the synopsis of onions of Eastern Kazakhstan, represented by 45 species, 5 species are common to these mountain regions (*A. hymenorhizum*, *A. obliquum*, *A. platyspathum*, *A. caeruleum*, *A. platystemon* (syn. *A. oreophilum*) [10]. For the flora of the studied and desert Aral-Balkhash regions, only 3 common species (*A. margaritae*, *A. turkestanicum*, *A. suworowii*) were noted [11], which generally indicates a wide ecological range of growth of species of the genus under study.

The purpose of these studies is to continue the analysis of the phytocenotic and altitudinal confinement of habitats of species of the genus *Allium* L., identified during field studies in 2024-2025 in the gorges of the western part of the Kyrgyz Alatau Range, which began in 2024.

Experimental

The material for the studies was the natural populations of onions identified during field studies in 2024-2025 in the gorges of the western part of the Kyrgyz Alatau Range, located within the Junggar-North Tien Shan Province, the Kyrgyz mountain subprovince [12].

When conducting field research, generally accepted methods of floristic, geobotanical and cartographic research were used. The determination of plant species was carried out on the basis of the 9-volume edition of “Flora of Kazakhstan” [13], “Illustrated Guide...” [14]. The taxonomy of species is consistent with the Internet resources Plantarium.ru and Plants of the World Online (POWO) [15, 16], but the authors adhere to their own view on the species affiliation of some taxa. To create maps of wild onion locations within the studied range, the coordinates obtained using the Garmin GPS navigator were plotted on a cartographic base and formatted in ESRI ArcGIS Desktop 10.8. On a cartographic basis, an updated digital geographical basis at a scale of 1:2500000 of the FSBI “VSEGEI” was used.

To characterize the vegetation of the high-altitude zones, the following stock materials collected during the implementation of the program: “Botanical diversity of wild relatives of cultivated plants of Kazakhstan as a source of enrichment and preservation of the gene pool of agrobio diversity for the implementation of the food program” (2013–2015) were also used, and the characteristics of the floristic composition of individual gorges (Merke, Karakystak) were supplemented by materials from the article by N.V. Nelina et al. [17].

The study of altitudinal-zonal patterns of vegetation cover was carried out using traditional methods of field geobotanical research [18], including landscape-ecological profiling and description of the main plant communities.

Results and Discussion

Field studies conducted during 2024-2025 have so far identified the localities of 19 species of the genus *Allium* L. in 14 surveyed gorges of the range and established that their distribution in the altitude range in the mountains begins from the subbelt of savannoid steppes, where, in the vegetation cover, in addition to typical steppe bunch grasses, savannoids are distributed. Steppes are combined with thickets of shrubs, rocks and screes with sparse aggregations of upland xerophytes and petrophytes, gallery forests with a layer of shrubs and grass-forb meadows. On the slopes with steppe vegetation and steppe meadows, species grow: *A. barsczewskii*, *A. caeruleum*, *A. karataviense*, *A. suworowii*, *A. caesium*, *A. fetisowii* (Table 1).

Altitudinal distribution of species of the genus *Allium* L. identified in the western part of the Kyrgyz Alatau Mountains

| Altitudinal belt | Height (m asl) | Floristic diversity of communities with participation of <i>Allium</i> L. species | Species |
|--|----------------|---|---|
| Cryophytic low-grass meadows | 2800–3500 | <i>Alchemilla retropilosa</i> Juz., <i>Bistorta vivipara</i> (L.) Delarbre, <i>Potentilla crantzii</i> (Crantz) Beck ex Fritsch, <i>Festuca kryloviana</i> Reverd., <i>Poa alpina</i> L., <i>Carex alatauensis</i> S.R. Zhang, <i>C. capillifolia</i> (Decne.) S.R. Zhang, <i>Thylacospermum caespitosum</i> (Cambess.) Schischk., <i>Rhodiola coccinea</i> (Royle) Boriss., <i>Saxifraga macrocalyx</i> Tolm., <i>Lonicera semenovii</i> Regel, <i>Ephedra regeliana</i> Florin, <i>Potentilla crantzii</i> (Crantz) Beck ex Fritsch, <i>Allardia tomentosa</i> Decne., <i>Saussurea gnaphalodes</i> (Royle ex DC.) Sch. Bip. [1]. | <i>A. atosanguineum</i> |
| Subalpine meadows and prostrate juniper thickets | 2200–2800 | <i>Juniperus pseudosabina</i> Fisch. & C.A. Mey., <i>J. semiglobosa</i> Regel, <i>Phlomoides oreophila</i> (Kar. & Kir.) Adylov, Kamelin & Makhm., <i>Bistorta elliptica</i> (Willd. ex Spreng.) V.V. Petrovsky, D.F. Murray & Elven, <i>Trifolium repens</i> L., <i>T. pratense</i> L., <i>Ziziphora clinopodioides</i> Lam., <i>Potentilla nivea</i> L., <i>Acantholimon fetissoyii</i> Regel, <i>A. purpureum</i> Korovin, <i>A. alberti</i> Regel, <i>Sibbaldianthe bifurca</i> (L.) Kurtto & T. Erikss.), <i>Rhodiola kirilowii</i> (Regel) Maxim., <i>Myosotis asiatica</i> (Vesterg.) Schischk. & Serg., <i>Iris ruthenica</i> Ker Gawl., <i>Alchemilla retropilosa</i> Juz., <i>A. sibirica</i> Zämelis, <i>Koenigia alpina</i> (All.) T.M. Schust. & Reveal, <i>Lamium album</i> L., <i>Achillea millefolium</i> L., <i>Artemisia stechmanniana</i> Besser, <i>Asperugo procumbens</i> L., <i>Alopecurus arundinaceus</i> Poir., <i>Helictochloa hookeri</i> (Scribn.) Romero Zarco, <i>Poa pratensis</i> L., <i>P. angustifolia</i> L., <i>Phleum phleoides</i> (L.) H. Karst., <i>Dactylis glomerata</i> L., <i>Festuca valesiaca</i> Schleich. ex Gaudin. | <i>A. atosanguineum</i> , <i>A. hymenorhizum</i> , <i>A. fedtschenkoanum</i> , <i>A. filifolium</i> , <i>A. polyphyllum</i> , <i>A. schoenoprasoides</i> |
| Juniper woodlands | 1600–2200 | <i>Juniperus pseudosabina</i> , <i>J. semiglobosa</i> , <i>Sorbus tianshanica</i> Rupr., <i>Lonicera microphylla</i> Willd. ex Schult., <i>Salix triandra</i> L., <i>Rosa platyacantha</i> Schrenk, <i>Spiraea lasiocarpa</i> Kar. & Kir., <i>Ephedra equisetina</i> Bunge, <i>Atraphaxis pyrifolia</i> Bunge, <i>Atragene sibirica</i> L., <i>Festuca valesiaca</i> , <i>Helictochloa hookeri</i> , <i>Stipa kirghisorum</i> P.A. Smirn., <i>Phleum phleoides</i> , <i>Phlomoides pratensis</i> (Kar. & Kir.) Adylov, Kamelin & Makhm., <i>Melica transsilvanica</i> Schur, <i>Catabrosa aquatica</i> (L.) P.Beauv., <i>Bromus inermis</i> Steven, <i>Lolium pratense</i> (Huds.) Darbysh., <i>Phleum phleoides</i> , <i>Patrinia intermedia</i> (Hornem.) Roem. & Schult., <i>Delphinium oreophyllum</i> Huth, <i>Hypericum perforatum</i> L., <i>Medicago falcata</i> L., <i>Potentilla inclinata</i> Vill., <i>Thalictrum minus</i> subsp. <i>saxatile</i> Gaudin, <i>Eremurus tianschanicus</i> Pazij & Vved. ex Pavlov | <i>A. caesium</i> , <i>A. fetisowii</i> <i>A. leptomorphum</i> , <i>A. renardii</i> , <i>A. talassicum</i> |

| Altitudinal belt | Height (m asl) | Floristic diversity of communities with participation of <i>Allium</i> L. species | Species |
|----------------------------|----------------|--|---|
| Steppes: Meadow steppes | 1200–1600 | <i>Prunus erythrocarpa</i> (Nevski) Gilli, <i>P. griffithii</i> var. <i>tianshanica</i> (Pojark.) Ingram, <i>Atraphaxis pyrifolia</i> , <i>A. virgata</i> (Regel) Krasn., <i>Spiraea hypericifolia</i> L., <i>Acer semenovii</i> Regel & Herder, <i>Crataegus chromorcarpa</i> Lenné & K. Koch, <i>C. sanguinea</i> Pall., <i>C. turkestanica</i> Pojark., <i>C. songarica</i> K. Koch, <i>Salix alba</i> L., <i>Rosa beggeriana</i> Schrenk ex Fisch. & C.A. Mey., <i>R. platyacantha</i> , <i>Rubus caesius</i> L., <i>Hippophae rhamnoides</i> L., <i>Festuca valesiaca</i> , <i>Stipa capillata</i> L., <i>Bothriochloa ischaemum</i> (L.) Keng, <i>Bromus lanceolatus</i> Roth, <i>Aegilops cylindrica</i> Host, <i>Taeniatherum caput-medusae</i> (L.) Nevski, <i>Hordeum murinum</i> subsp. <i>leporinum</i> (Link) Arcang., <i>Poa bulbosa</i> L., <i>Lolium pratense</i> (Huds.) Darbysh., <i>Elymus repens</i> (L.) Gould, <i>Thinopyrum intermedium</i> subsp. <i>intermedium</i> , <i>Cynodon dactylon</i> (L.) Pers., <i>Astragalus</i> L., <i>Calamagrostis pseudophragmites</i> (Haller f.) Koeler, <i>Bromus inermis</i> Leyss., <i>Eremurus tianschanicus</i> , <i>Acantholimon</i> Boiss., <i>Ziziphora clinopodioides</i> , <i>Hypericum scabrum</i> L., <i>H. perforatum</i> , <i>Mentha longifolia</i> (L.) L., <i>Glycyrrhiza uralensis</i> Fisch. ex DC., <i>Plantago lanceolata</i> L., <i>Inula britannica</i> L., <i>Galium aparine</i> L., <i>Medicago falcata</i> L., <i>Lathyrus pratensis</i> L., <i>Vicia cracca</i> L. | <i>A. barszczewskii</i> , <i>A. caeruleum</i> , <i>A. karataviense</i> , <i>A. suworowii</i> , <i>A. caesium</i> , <i>A. fetisowii</i> |
| Savannoid steppes | 800–1200 | <i>Pistacia vera</i> L., <i>Acer semenovii</i> Regel & Herder, <i>Pyrus regelii</i> Rehder, <i>Atraphaxis pyrifolia</i> , <i>Rosa platyacantha</i> , <i>Ephedra equisetina</i> , <i>Prunus griffithii</i> var. <i>tianshanica</i> , <i>Allochrysa gypsophilloides</i> (Regel) Schischk., <i>Thinopyrum intermedium</i> subsp. <i>intermedium</i> , <i>Festuca valesiaca</i> , <i>Stipa caucasica</i> Schmalh., <i>Galium verum</i> L., <i>Ziziphora clinopodioides</i> , <i>Crupina vulgaris</i> Pers. ex Cass., <i>Crambe cordifolia</i> subsp. <i>kotschyana</i> (Boiss.) Jafri, <i>Bromus japonicus</i> Houtt., <i>Taeniatherum caput-medusae</i> [19] | <i>A. barszczewskii</i> <i>A. caeruleum</i> <i>A. caesium</i> , <i>A. caricifolium</i> <i>A. fetisowii</i> , <i>A. karataviense</i> , <i>A. margaritae</i> , <i>A. sativum</i> , <i>A. suworowii</i> , <i>A. trachyscordum</i> |

Savannoid woodlands with pistachio and low trees of Semenov's maple and Regel's pear are found on the steep, stony, dry slopes of southwestern exposure. Shrubs (*Atraphaxis pyrifolia*, *Rosa platyacantha*, *Ephedra equisetina*, *Prunus griffithii* var. *tianshanica*) are sporadically noted. The grass layer is represented by wheatgrass, fescue, ephemeroideis, forbs and annual savannoid grasses (*Bromus japonicus*, *Taeniatherum caput-medusae*) [19], including species of onion (*A. caricifolium*, *A. margaritae*, *A. sativum*, *A. trachyscordum*).

The identified onion species were often found in forb-grass, forb-shrub-grass, petrophytic-forb-shrub, and petrophytic-arboreal-shrub communities. In the low and middle mountains, 13 species (*A. barszczewskii*, *A. caeruleum*, *A. caesium*, *A. caricifolium*, *A. fetisowii*, *A. karataviense*, *A. leptomorphum*, *A. margaritae*, *A. renardii*, *A. sativum*, *A. talassicum*, *A. trachyscordum*, and the rare species *A. suworowii*) grew in the altitudinal range from 1050 to 1972 m asl. Six species (*A. atosanguineum*, *A. hymenorhizum*, *A. fedtschenkoanum*, *A. filifolium*, *A. polyphyllum*, *A. schoenoprasoides*) were noted in the subalpine zone at absolute altitudes of 2431–2667 m (Table 2).

The greatest phytocenotic diversity is formed in intermountain gorges and river valleys, where the main diversity of onion species is concentrated (*A. barsczewskii*, *A. caricifolium*, *A. sativum*, *A. trachyscordum*, *A. fetisowii*, *A. caesium*, etc.) (Fig. 1). Stony slopes are characterized by *A. caricifolium*, *A. karataviense*, and *A. trachyscordum*, which are found in the gorges of Tastambek, Kara-Arsha, and Makpal. A rare species of *A. suworowii* is found in the valley of the Kayindy River of the Makpal gorge under the canopy of *Acer semenovii*, *Prunus armeniaca* L., with the participation of shrubs (*Rubus caesius*, *Rosa laxa* Retz.) and forbs (*Salvia deserta* Schangin, *Sophora alopecuroides* L., *Conioselinum tataricum* Hoffm., *Origanum tyttanthum* Gontsch. etc.), and in the Sogety gorge it is noted in the river valley among tree and shrub vegetation.

Table 2

**Altitudinal confinement of species of the genus *Allium* L identified in 2024-2025
in the surveyed gorges of the Kyrgyz Alatau**

| Species | Gorges / altitude, m asl | | | | | | | | | | | | | |
|------------------------------|--------------------------|--------------|----------|-------------|----------|--------------|---------|--------------|-------|---------|-------------------|--------------|--------------|------------|
| | Auliekol | Ulken Almaly | Kaska-su | Kara-kystak | Kara-sai | Kara- Arsha | Kur-sai | Mak-pal | Merke | Mola-ly | Kyzyl-kaynar Pass | Sogety | Tastam-bek | Uzyn-bulak |
| <i>Allium atrosanguineum</i> | | | 3390 | 2520 | | | | | | | 2667 | | | |
| <i>A. barsczewskii</i> | | 1387 | | | | | | 1182 | | | | | | 1100 |
| <i>A. caeruleum</i> | | 1200 1387 | | | 1391 | | 1100 | | | | | 1270 1290 | 1113 | 1100 |
| <i>A. caesium</i> | | | | 1808 | | | | 1182 | | 1761 | | 1320 | 1113 | 1100 |
| <i>A. caricifolium</i> | | | | | | | | 1182 | | | | | | |
| <i>A. hymenorhizum</i> | 2431 | | | | | | | | | | | | | |
| <i>A. fedtschenkoanum</i> | | | | | | | | | | | 2637 | | | |
| <i>A. fetisowii</i> | | 1387 | | 1808 | | 1052 | 1100 | | | 1972 | | 1270 | 1113 | 1100 |
| <i>A. filifolium</i> | 2431 2440 | | | | | | | | | | | | | |
| <i>A. karataviense</i> | | 1200 1387 | | | 1391 | | 1100 | | 1391 | | | 1270 | 1113 | 1100 |
| <i>A. leptomorphum</i> | | | | 1660 | | | | | | | | | | |
| <i>A. margaritae</i> | | 1200 | | | | | | | | | | | | |
| <i>A. polyphyllum</i> | | | | | | | | | | | 2667 | | | |
| <i>A. renardii</i> | | | | | | | | | | 1911 | | | | |
| <i>A. sativum</i> | | | | | | | | 1070 | | | | 1170 | | |
| <i>A. schoenoprasoides</i> | 2440 | | | | | | | | | | | | | |
| <i>A. suworowii</i> | | | | | | | | 1182 1070 | | | | 1270 | | |
| <i>A. talassicum</i> | | | | 1808 | | | | | | | | | | |
| <i>A. trachyscordum</i> | | | | | | 1050 1069 | | 1123 | | | | | 1083 1131 | |
| Total species | 3 | 5 | 1 | 5 | 2 | 2 | 3 | 6 | 1 | 3 | 3 | 6 | 5 | 5 |

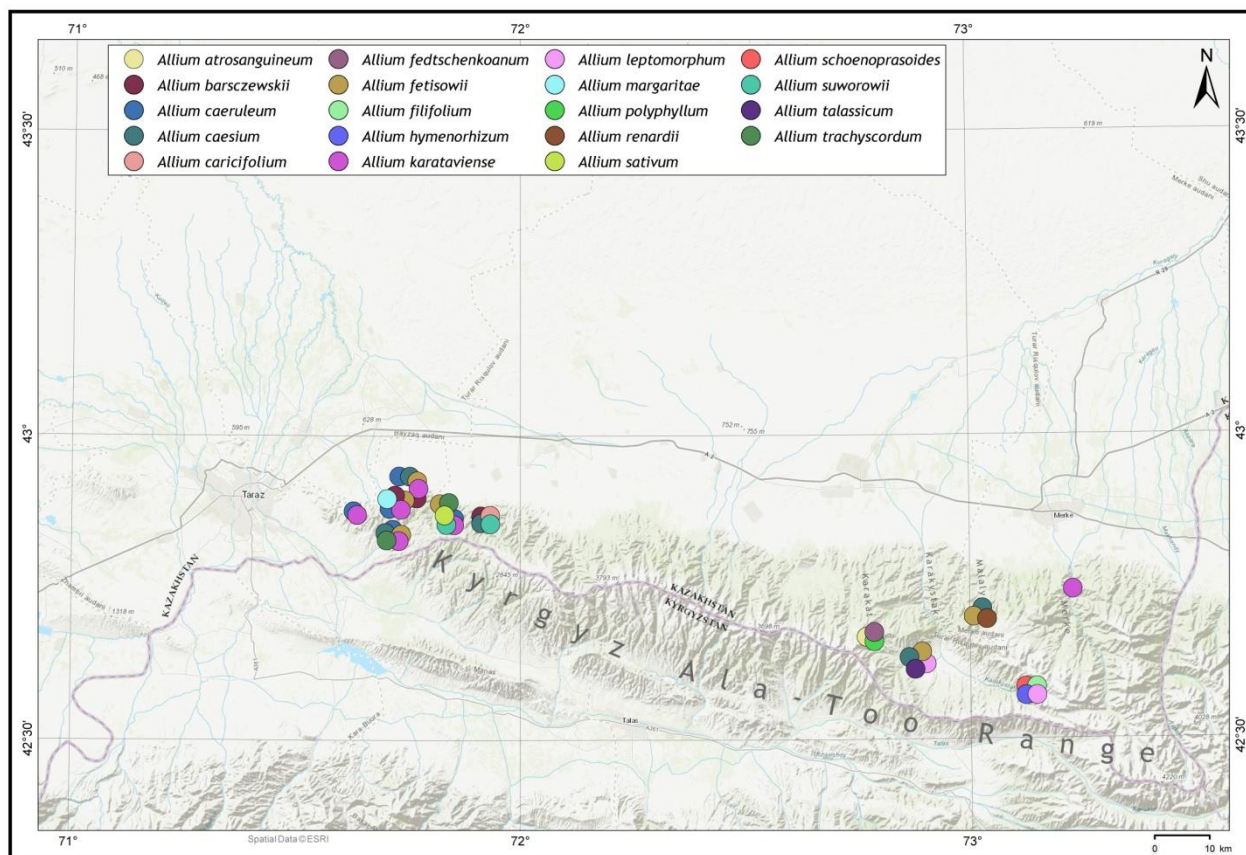


Figure 1. — Map of the localities of wild species of the genus *Allium* L. identified in 2024-2025 on the northern macroslope of the Kyrghyz Alatau range

Wild garlic (*A. sativum*) was found in the Sogety gorge in the weed-bluegrass community, where *Poa bulbosa*, *Euphorbia virgata* Waldst. & Kit., *Galium aparine*, *Mentha longifolia*, *Achillea millefolium*, *Sonchus palustris* L., *Artemisia dracunculus* L., *Sisymbrium loeselii* L. are also noted in the species composition. In the Makpal gorge, this species is found in abundance of “sp” in floodplain meadows.

In the Ulken Almaly gorge, on the stony southern slope, three species of onions grow at once (*A. margaritae*, *A. caeruleum*, *A. karataviense*) as part of an ephemeroïd-grass with the participation of spirea and bassia (*Stipa caucasica*, *Bromus japonicus*, *Eremurus* sp, *Rheum cordatum* Losinsk., *Spiraea hypericifolia*, *Bassia prostrata* (L.) Beck) community.

In the Makpal gorge on the right bank of the Kayindy River, six species of onions (*A. barszewskii*, *A. caesium*, *A. caricifolium*, *A. sativum*, *A. suworowii*, *A. trachyscordum*) were found, confined to forbs and shrubs (*Spiraea hypericifolia*, *Atraphaxis pyrifolia*, *Rosa plathyacantha*, *Hypericum perforatum*, *H. scabrum*, *Salvia deserta*, *Rheum cordatum*, *Haplophyllum latifolium* Kar. & Kir, *Betonica betoniciflora* (Rupr. ex O. Fedtsch. & B. Fedtsch.) Sennikov, *Helichrysum maracandicum* Popov ex Kirp., *Ziziphora clinopodioides*, *Centaurea virgata* subsp. *squarrosa* (Boiss.) Gugler) cenoses.

The subendemic species *A. trachyscordum* was found in the Tastambek, Makpal and Kara-Arsha gorges on stony screens in separate clumps among the thickets of shrubs (*Prunus griffithii* var. *tianshanica*, *Spiraea hypericifolia*, *Atraphaxis pyrifolia*) and forbs (*Gypsophila paniculata* L., *Salvia sclarea* L., *Hypericum scabrum*, *Rheum cordatum*, *Euphorbia virgata*, *Alcea nudiflora* (Lindl.) Boiss., *Tulipa greigii* Regel, *Capparis spinosa* var. *herbacea* (Willd.) Fici.).

According to previous studies, *A. caeruleum* was found in forb-grass floodplain meadows (*Elymus repens*, *Thinopyrum intermedium* subsp. *intermedium*, *Medicago falcata*, *Hypericum perforatum*, *Achillea asiatica* Serg., *Sanguisorba officinalis* L., *Mentha longifolia*) in the gorge of the Kogershin river at an altitude of 1182 m asl.

In the subbelt of meadow steppes, rich forb–grass–fescue communities are represented. Fescue (*Festuca valesiaca*) dominates, with less abundant other steppe grasses (*Stipa capillata*, *S. kirghisorum* P.A. Smirn.,

Helictochloa hookeri, *Phleum phleoides*), meadow-steppe species (*Salvia deserta*, *Nepeta nuda* subsp. *nuda*, *Galium verum*, *Phlomoides pratensis*, *Dactylis glomerata*, *Geranium collinum* Stephan ex Willd.).

Meadow steppes are combined with shrub thickets on stony slopes (*Spiraea hypericifolia*, *Rosa spinosissima* L., *Atraphaxis pyrifolia*, *Juniperus pseudosabina*) with species of *Eremurus* M.Bieb. (*E. regelii* Vved., *E. tianshanicus*, *E. cristatus* Vved.) and savannoids in the grass layer (*Taeniatherum caput-medusae*, *Aegilops cylindrica*, *Botriochloa ischaemum*). In the Sogety Gorge, among the thickets of shrubs (*Atraphaxis pyrifolia*, *Prunus griffithii* var. *tianshanica*, *Ephedra equisetina*), *A. caesium*, *A. caeruleum*, *A. fetisowii*, *A. sativum*, *A. suworowii*, and *A. karataviense*, which is confined to the outcrops of bedrock.

Gallery forests in the Makpal gorges (Kayindy river valley), Karakystak and Merke form *Salix cinerea* L., *S. alba* L., and *Acer semenovii*, in the shrub layer — *Rosa beggeriana*, *Lonicera microphylla*, *Euonimus semenovii* Regel & Herder, *Rubus caesus*, *Berberis heteropoda* Schrenk ex Fisch. & C.A. Mey. The grass layer is formed by tall grasses: *Catabrosa aquatica*, *Melica transsilvanica*, *Phalaris arundinacea* L. and variegated forbs (*Medicago falcata*, *Nepeta nuda* subsp. *nuda*, *Potentilla inclinata* Vill., *Elwendia setacea* (Schrenk) Pimenov & Kljuykov, *Impatiens parviflora* DC.).

According to early field studies, rich forb-grass steppe meadows and meadow steppes are common in the intermountain valley of the Karabulak (1485–1588 m asl). The dominant species are wheatgrass (*Thinopyrum intermedium* subsp. *intermedium*, *Elymus repens*) and fescue grass (*Festuca valesiaca*). Among the steppe forbs: *Salvia deserta*, *Elwendia setacea*, *Nepeta nuda* subsp. *nuda*, *Medicago falcata*. Meadow forbs are represented by: *Achillea millefolium*, *A. asiatica*, *Potentilla asiatica* (Th. Wolf) Juz., *P. inclinata*, *Pulsatilla patens* subsp. *multifida* (Pritz.) Zämelis, *Jacobaea vulgaris* Gaertn., *Jacobaea erucifolia* (L.) G. Gaertn., B. Mey. & Scherb., *Dipsacus azureus* Schrenk ex Fisch. & C.A. Mey., *Origanum vulgare* L., *Hypericum perforatum*, *Lathyrus tuberosus* L., *L. pratensis*, *Rumex confertus* Willd., *Phlomoides fetisowii* (Regel) Adylov, Kamelin & Makhm., *Betonica betoniciflora*, *Trifolium hybridum* L. Meadow communities are often dominated by grasses (*Dactylis glomerata*, *Elymus repens*, *Bromus inermis*), projective coverage of onion (*A. caesium*, *A. caeruleum*) is up to 10 %. According to field observations from 2024–2025, these species were also found in the Kursai, Karasai, Sogety, Uzynbulak and Tastambek gorges, where they grow not only in meadows, but also in shrub thickets (*Prunus griffithii* var. *tianshanica*, *Rosa platyacantha*, *Atraphaxis pyrifolia*, *A. virgata*, *Spiraea hypericifolia*) on the slopes of the southern exposure. In the grass layer, there are: *Alcea nudiflora*, *Rheum cordatum*, *Epilobium angustifolium* L., *Galium verum*.

Floodplain meadows in the valley of the Shalsu River (1377 m asl) are formed by cereals and forbs (*Elymus repens*, *Dactylis glomerata*, *Mentha longifolia*, *Achillea millefolium*, *Origanum vulgare*). Shrub thickets are formed by rosehips (*Rosa platiacantha*, *R. beggeriana*). Apricot, Djungarian hawthorn, juniper (*Juniperus semiglobosa*) are sporadically found on stony cliffs. The meadow vegetation of high river terraces is diverse and forb-grass (*Elytrigia repens*, *Achillea millefolium*, *Carex* sp., *Potentilla inclinata*, *Nepeta nuda* subsp. *nuda*, *Galium verum*, *Vickifunkia thomsonii* (C.B. Clarke) C. Ren, L. Wang, I.D. Illar. & Q.E. Yang, *Dipsacus azureus*), where *A. caesium* occurs in abundance with “sp”. *A. caeruleum* grew on a low river terrace in floodplain meadows (*Dactylis glomerata*, *Nepeta nuda* subsp. *nuda*, *Lathyrus pratensis*, *Mentha longifolia*, *Malva pusilla* Sm.).

In the valley of the Almaly river, in hydromorphic habitats, the consists of Semenov’s maple (*Acer semenovii*) and Sivers’ apple tree (*Malus sieversii* (Ledeb.) M. Roem.). The vegetation of the floodplain meadows is forb-grass with a predominance of reed (*Phragmites australis* (Cav.) Trin. ex Steud.) and an abundance of *Mentha longifolia*, *Lathyrus pratensis*, *Vicia cracca* L.). On the stony slopes, shrub thickets (*Lonicera microphylla*, *Spiraea hypericifolia*, *Ephedra equisetina*) are common, in which onion species (*A. barszczewskii*, *A. caeruleum*, *A. fetisowii*) are found.

Juniper woodland belt is represented by shrub-juniper woodlands (*Juniperus pseudosabina*, *J. semiglobosa*, *Rosa platyacantha*, *Spiraea lasiocarpa* Kar. & Kir., *Ephedra equisetina*, *Atraphaxis pyrifolia*, *Atragene sibirica* L.) on stony slopes in combination with meadows and steppes (*Festuca valesiaca*, *Helictochloa hookeri*, *Stipa kirghisorum*, *Phleum phleoides*, *Phlomoides pratensis*). In the Merke Gorge, dense shrub thickets are formed by the following species: *Rosa platyacantha*, *R. beggeriana*, *Spiraea hypericifolia*, *S. lasiocarpa*, *Sorbus tianshanica*, *Lonicera microphylla*, *Salix triandra*. Grasses (*Melica transsilvanica*, *Catabrosa aquatica*, *Bromus inermis*, *Lolium pratense*, *Phleum phleoides*) and forbs (*Patrinia intermedia*, *Delphinium oreophyllum*, *Hypericum perforatum*, *Medicago falcata*, *Potentilla inclinata*, *Thalictrum minus* subsp. *saxatile* Gaudin, *Eremurus tianshanicus*, *A. caesium*, etc.) take part in the formation of the herbal layer. *A. caesium* is also found in meadow forbs in the valleys of the Terekty and Molaly rivers.

Juniper woodlands in the Kogershin Gorge are confined to steep slopes. In the lower part of the slopes, dense shrub thickets are formed with the dominance of *Rosa spinosissima* and the participation of *R. beggeriana*, *Cotoneaster uniflorus* Bunge, *Lonicera microphylla*, and *Spiraea hypericifolia*. In the herbal layer, there are meadow forbs (*Campanula glomerata* L., *Veronica spuria* L., *Lathyrus pratensis*, *Origanum vulgare*, *Achillea asiatica*, *Thalictrum minus* subsp. *saxatile*, etc.). Steppe meadows and meadow steppes are spread along the valleys and gentle slopes. Steppe grasses (*Festuca valesiaca*, *Stipa kirghisorum*, *S. capillata*, *Phleum phleoides*) and meadow grasses (*Alopecurus arundinaceus*, *Elymus repens*) occupy the same projective cover. Meadow forbs are up to 20 species, including *A. caeruleum* and many forage and resource-significant species (*Trifolium repens*, *Achillea millefolium*, *Ziziphora clinopodioides*, *Rumex confertus*, *Artemisia dracuncululus*, *Hypericum perforatum*). It should be noted that in this altitudinal belt, *A. leptomorphum*, and *A. talassicum* (Karakystak Gorge) are found on stony slopes. Habitats *A. fetisowii*, *A. renardii* is confined to steppe slopes and shrub thickets in the Molaly and Karakystak gorges.

The belt of subalpine meadows and prostrate juniper thickets is characterized by grass-rich, forb-grass and steppe meadows with the participation of prostrate (*J. pseudosabina*) and tree junipers (*J. semiglobosa*), and spiny pads (*Acantholimon fetisovii*, *A. purpureum*, *A. alberti*). On dry slopes, steppe communities grow. Steppe meadows are formed by grasses and forbs. In 2024–2025, *A. atosanguineum*, *A. hymenorhizum*, *A. filifolium*, *A. polyphyllum*, *A. schoenoprasoides*, *A. fedtschenkoanum* were recorded in this belt. They are confined to the upper reaches of the Karakystak River (Auliekol Gorge) and the Kyzylkaynar Pass.

In the alpine belt cryophytic low-grass meadows are widespread, as well as kobresia communities (*Carex alatauensis*, *C. capillifolia*). The tops of the ranges are occupied by open aggregations of cryophilic petrophytes from genera: *Thylacospermum* Fenzl, *Rhodiola* L., *Saxifraga* Tourn. ex L., *Lonicera* L., *Ephedra* Tourn. ex L., grow on stony slopes, rocks, moraines, screes. The cracks of the rock occupy *Potentilla crantzii*, *Allardia tomentosa* Decne., *Saussurea gnaphalodes* [1]. In this belt there are: *A. atosanguineum*, *A. hymenorhizum* (Kaskasu Gorge).

According to the herbarium (AA), *A. polyphyllum* grows near snowfields.

Conclusion

For the first time, an analysis of the phytocoenotic and altitudinal distribution of habitats for 19 species of the genus *Allium* L. was conducted in 14 gorges on the northern macroslope of the Kyrgyz Alatau mountain range.

It was established that the distribution of wild onions in the mountains begins at the savannoid and meadow steppe sub-belts, continues at the belts of juniper woodlands subalpine meadows and prostrate juniper thickets, and ends with the alpine belt of cryophytic meadows and communities of kobresia.

Most of the species are found in the steppe belt, where 10 of the 14 identified species grow: *A. barsczewskii*, *A. caeruleum*, *A. caesium*, *A. caricifolium*, *A. fetisowii*, *A. karataviense*, *A. margaritae*, *A. suworowii*, *A. sativum*, *A. trachyscordum*.

About half of the species (6) prefer the subalpine meadows: *A. atosanguineum*, *A. hymenorhizum*, *A. fedtschenkoanum*, *A. filifolium*, *A. polyphyllum*, *A. schoenoprasoides*.

The identified onion species were often found in forb-grass, forb-shrub-grass, petrophytic-forb-shrub, and petrophytic-arboreal-shrub communities. In the low and middle mountains, 13 species (*A. barsczewskii*, *A. caeruleum*, *A. caesium*, *A. caricifolium*, *A. fetisowii*, *A. karataviense*, *A. leptomorphum*, *A. margaritae*, *A. renardii*, *A. sativum*, *A. talassicum*, *A. trachyscordum*, and the rare species *A. suworowii*) grew in the altitude range from 1050 to 1972 m asl. Six species (*A. atosanguineum*, *A. hymenorhizum*, *A. fedtschenkoanum*, *A. filifolium*, *A. polyphyllum*, *A. schoenoprasoides*) were noted in the subalpine zone at altitudes of 2431–2667 m asl.

A wide altitudinal range is possessed by *A. fetisowii* and *A. caesium* (1100–2000 m asl), occurring from lowland steppes to juniper woodlands.

The greatest diversity is distinguished in the gorges of Sogety (6 species), Makpal (6), Ulken Almaly (5). A rare species *A. suworowii* is found in the Sogety and Makpal gorges in the thickets of shrubs and floodplain meadows of the low mountains. Subendemics (*A. margaritae*, *A. trachyscordum*) grow in the gorges of Ulken Almaly, Makpal, Kara-Arsha in forb-shrub communities in the subbelt of savannoid steppes.

Based on field research, a map of the localities of 19 identified wild species of the genus *Allium* L. on the northern macroslope of the Kyrgyz Alatau range was created.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Gemejiyeva N.G.** — supervision, investigation, review & editing, visualization, funding acquisition; **Dimeyeva L.A.** — conceptualization, methodology, writing — original draft, writing — review & editing; **Abdildanov D.Sh.** — investigation, data curation, formal analysis; **Friesen N.V.** — investigation, writing — review & editing.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Волкова Е.А. Растительный покров гор / Е.А. Волкова; под редакцией Е.И. Рачковской, Е.А. Волковой, В.Н. Храмова // Ботаническая география Казахстана и Средней Азии (в пределах пустынной области). — СПб.: Бостон-Спектр, 2003. — С. 167–191.
- 2 Димеева Л.А. Высотно-пооясная дифференциация растительного покрова Киргизского хребта в пределах Казахстана / Л.А. Димеева, К. Усен // Проблемы ботаники Южной Сибири и Монголии. Сб. науч. ст. по мат-лам Четырнадцатой междунар. науч.-практ. конф. — Барнаул, 2015. — С. 185–189.
- 3 Gemejiyeva N.G. Species composition and altitudinal distribution patterns of wild *Allium* L. relatives in the Kyrgyz Alatau mountain range / N.G. Gemejiyeva, G.T. Sitpayeva, L.A. Dimeyeva // XX International Botanical Congress IBC 2024, Spain. Book of Abstracts. Posters. Publisher: Fase 20 Ediciones. — P. 472.
- 4 Gemejiyeva N.G. Species of the genus *Allium* L. of the western part of the Kyrgyz Alatau range: the current status and prospects of studying / N.G. Gemejiyeva, D.Sh. Abdildanov, G.M. Kudabayeva, P.V. Vesselova, N.V. Nelina, N.V. Friesen // Fundamental and Experimental Biology. — 2025. — Vol. 30. — Issue 2(118). DOI: <https://doi.org/10.31489/2025feb2/13-25>
- 5 Vesselova P.V. Integral Assessment of Species of the Genus *Allium* L. (Amaryllidaceae) in the Western Part of the Kyrgyz Alatau / P.V. Vesselova, G.M. Kudabayeva, D.Sh. Abdildanov, B.B. Osmonali, S. Ussen, M.V. Skaptsov, N. Friesen // Plants. — 2025. — 14(18). — С. 2890. <https://doi.org/10.3390/plants14182890>.
- 6 Kubentayev S.A. Revised checklist of endemic vascular plants of Kazakhstan / S.A. Kubentayev, D.T. Alibekov, Y.V. Perezhogin, G.A. Lazkov, A.N. Kupriyanov, A.L. Ebel, K. Izbastina, O. Borodulina, B.B. Kubentayeva // PhytoKeys. — 2024. — 238. — С. 241–279. <https://doi.org/10.3897/phytokeys.238.114475>
- 7 Турдуматова Н.К. Род лук (*Allium* L.) в Кыргызстане (вопросы систематики, география и перспективы использования): автореф. дис. ... канд. биол. наук. — Бишкек, 2022. — 22 с.
- 8 Красная книга Казахстана / гл. ред. И.О. Байтулин; отв. ред. Г.Т. Ситпаева. — Изд. 2-е, исправл. и дополн. — Т. 2. — Ч. 1. Растения. — Астана: ТОО «АртPrintXXI», 2014. — 452 с.
- 9 Пермитина В.Н. Высотная приуроченность видов рода *Allium* L. (Liliaceae) гор Жетысуского Алатау [Электронный ресурс] / В.Н. Пермитина, Л.А. Димеева, А.И. Иманолинова // Проблемы ботаники Южной Сибири и Монголии, 2024. — Т. 23, № 2. — С. 308–312. — Режим доступа: <https://journal.asu.ru/bpssm/article/view/bpssm.2024110>.
- 10 Котухов Ю.А. Конспект луков Восточного Казахстана / Ю.А. Котухов, А.Н. Данилова, А.А. Сумбембаев, О.А. Ануфриева / отв. ред. А.Н. Куприянов. — Риддер: изд-во «Принт Центр», 2025. — 141 с.
- 11 Абдилданов Д.Ш. Разнообразие видов рода *Allium* флоры Арало-Балхашского региона / Д.Ш. Абдилданов, П.В. Веселова, Г.М. Кудабеева // Проблемы ботаники Южной Сибири и Монголии, 2023. — Т. 22, № 1. — С. 6–11. DOI: 10.14258/bpssm.2023001. URL: <https://journal.asu.ru/bpssm/article/view/bpssm.2023001>.
- 12 Рачковская Е.И. Принципы и основные единицы районирования / Е.И. Рачковская, И.Н. Сафронова, Е.А. Волкова. Под ред. Е.И. Рачковской, Е.А. Волковой, В.Н. Храмова // Ботаническая география Казахстана и Средней Азии (в пределах пустынной области). — СПб.: Бостон-Спектр, 2003. — С. 172–195.

13 Флора Казахстана: [в 9-и т.] / Ред. Н.В. Павлов. — Алма-Ата: Изд-во АН КазССР, 1956. — Т. 1. — 354 с.; 1958. — Т. 2. — 292 с.; 1960. — Т. 3. — 460 с.; 1961. — Т. 4. — 548 с.; 1961. — Т. 5. — 515 с.; 1963. — Т. 6. — 465 с.; 1964. — Т. 7. — 497 с.; 1965. — Т. 8. — 447 с.; 1966. — Т. 9. — 640 с.

14 Иллюстрированный определитель растений Казахстана [в 2-х т.] / Ред. В.П. Голоскоков. — Алма-Ата: Наука «Казахской ССР», 1969. — Т. 1. — 644 с.; 1972. — Т. 2. — 572 с.

15 Плантариум: открытый онлайн атлас-определитель растений и лишайников России и сопредельных стран. — 2007–2026. — [Электронный ресурс]. — Режим доступа: <http://www.plantarium.ru/>

16 POWO. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. — 2026. — [Electronic resource]. — Access mode: <https://powo.science.kew.org>.

17 Быков Б.А. Геоботаника / Б.А. Быков. — Алма-Ата: Наука, 1978. — 288 с.

18 Нелина Н.В. К видовому составу флоры ущелий Мерке и Каракыстак западной части Киргизского Алатау / Н.В. Нелина, Г.М. Кудобаева, С.К. Мухтубаева, Б.К. Билибаева // Проблемы ботаники Южной Сибири и Монголии: мат. XV Междунар. научно-практ. конф. — Барнаул, 2016. — С. 392–398.

19 Исламкулова А.Ф. Редколесья фисташников в Киргизском Алатау / А.Ф. Исламкулова, Н.Е. Зверев, К.Р. Калыбаев // Перспективы и пути развития промышленного ореховодства на юге Казахстана: сб. мат. Междунар. научно-практ. конф. — Шымкент, 2017. — С. 30–38.

Н.Г. Гемеджиева, Л.А. Димеева, Д.Ш. Абдилданов, Н.В. Фризен

Кыргыз Алатау жотасының солтүстік макробеткейінде *Allium L.* туыс түрлерінің қатысуымен қауымдастықтардың биіктігі мен фитоценотикалық әртүрлілігі

Кыргыз Алатауы Солтүстік Тянь-Шанның ең батыс жотасы. Теңіз деңгейінен биіктігі 3700 м дейін жотаның солтүстік макробеткейінің батыс бөлігі Қазақстан шегінде орналасқан. Бұл таулы ел Батыс Тянь-Шань өсімдіктерімен байланысы бар «қырғыз белдеу түрімен» ерекшеленеді. Гербарий және экспедициялық үлгілер анықтаған *Allium L.* тұқымдас түрлерінің нақтыланған тізіміне 25 таксон кіреді, олардың ішінде *A. suworowii* сирек кездесетін түрі және 2 субэндемик (*A. margaritae*, *A. trachyscordum*) бар. 2024–2025 жылдар ішінде Кыргыз Алатауы жотасының солтүстік макробеткейінің 14 шаткалында анықталған *Allium L.* тұқымдасының 19 түрі өсетін жерлердің фитоценотикалық және биіктік сәйкестігін талдау, олардың тауларда таралуы саванноидті және шалғынды далалар белдеуінен басталатынын, аршалы белдеумен жалғасатынын көрсетті, сирек ормандар, субальпілік шалғындар мен жатаған бұталар, алпі белдеуімен аяқталады. Ең көп фитоценотикалық әртүрлілік пияз түрлерінің негізгі әртүрлілігі шоғырланған тау аралық шатқалдар мен өзен алқаптарында қалыптасады. Жотаның батыс төмен таулы және орта таулы бөлігіндегі: Сөгеті, Мақпал, Үлкен Алмалы, Тастамбек, Ұзынбұлақ шатқалдары, сондай-ақ шығысында орналасқан Қарақыстақ шатқалында пияздың 5-тен 6-ға дейін түрі кездеседі. Далалық зерттеулердің нәтижелері бойынша зерттелетін жотаның солтүстік макробеткейінде анықталған *Allium L.* тұқымдасының 19 жабайы түрінің орналасу картасы жасалды.

Кілт сөздер: *Allium L.* тұқымдасы, биіктік тектестігі, фитоценотикалық әртүрлілік, Кыргыз Алатауы жотасы.

Н.Г. Гемеджиева, Л.А. Димеева, Д.Ш. Абдилданов, Н.В. Фризен

Высотная приуроченность и фитоценотическое разнообразие сообществ с участием видов рода *Allium L.* на северном макросклоне хребта Киргизский Алатау

Киргизский Алатау является самым западным хребтом Северного Тянь-Шаня. Западная часть северного макросклона хребта с абсолютными высотами до 3700 м над ур. м. расположена в пределах Казахстана. Для этой горной страны выделяется «киргизский тип поясности», в котором проявляется связь с растительностью Западного Тянь-Шаня. После определения гербарных и экспедиционных образцов уточненный список видов рода *Allium L.* включает 25 таксонов, в числе которых редкий вид *A. suworowii* и 2 субэндемика (*A. margaritae*, *A. trachyscordum*). Анализ фитоценотической и высотной приуроченности местообитаний 19 видов рода *Allium L.*, выявленных в течение 2024–2025 гг. в 14 ущельях северного макросклона хребта Киргизский Алатау, показал, что их распространение в горах начинается с подпоясов саванноидных и луговых степей, продолжается поясом арчовых редколесий, субальпийских лугов и стлаников, завершаясь альпийским поясом. Наибольшее фитоценотическое разнообразие формируется в межгорных ущельях и долинах рек, где сосредоточено основное разно-

образии видов лука. Видовым разнообразием луков характеризуются ущелья западной низкогорной и среднегорной части хребта: Согеты, Макпал, Улькен Алмалы, Тастамбек, Узынбулак, а также расположенное восточнее ущелье Каракыстак, в которых встречаются от 5 до 6 видов лука. По результатам полевых исследований создана карта местонахождений 19 выявленных дикорастущих видов рода *Allium* L. на северном макросклоне изучаемого хребта.

Ключевые слова: род *Allium* L., высотная приуроченность, фитоценотическое разнообразие, хребет Киргизский Алатау.

References

- 1 Volkova, E.A. (2003). Rastitelnyi pokrov gor [Vegetation cover of mountains]. *Botanicheskaya geografiya Kazakhstana i Srednei Azii (v predelakh pustynnoi oblasti) — Botanical geography of Kazakhstan and Central Asia (within the desert region)* (pp. 167–191). E.I. Rachkovskaya, E.A. Volkova, V.N. Khramtsov (Ed.). Saint Petersburg: Boston-Spektr [in Russian].
- 2 Dimeyeva, L.A., & Ussen, K. (2015). Vysotno-poisnaia differentsiatsiia rastitelnogo pokrova Kirgizskogo khrebta v predelakh Kazakhstana [Altitudinal zonation of vegetation cover of the Kyrgyz Range within Kazakhstan]. *Problemy botaniki Yuzhnoi Sibiri i Mongolii. Sbornik nauchnykh statei po materialam Chetyrnadtsatoi mezhdunarodnoi nauchno-prakticheskoi konferentsii — Problems of Botany of Southern Siberia and Mongolia. Collection of scientific articles based on the materials of the Fourteenth International Scientific and Practical Conference* (pp. 185–189). Barnaul [in Russian].
- 3 Gemejyeva, N.G., Sitpayeva, G.T., & Dimeyeva, L.A. (2024). Species composition and altitudinal distribution patterns of wild *Allium* L. relatives in the Kyrgyz Alatau mountain range. In *XX International Botanical Congress. Book of Abstracts. Posters* (p. 472). Spain: Fase 20 Ediciones.
- 4 Gemejyeva, N.G., Abdildanov, D.Sh., Kudabayeva, G.M., Vesselova, P.V., Nelina, N.V., & Friesen, N.V. (2025). Species of the genus *Allium* L. of the western part of the Kyrgyz Alatau range: Current status and prospects of studying. *Fundamental and Experimental Biology*, 30, 2(118), 13–25. <https://doi.org/10.31489/2025feb2/13-25>
- 5 Vesselova, P.V., Kudabayeva, G.M., Abdildanov, D.Sh., Osmonali, B.B., Ussen, S., Skaptsov, M.V., & Friesen, N. (2025). Integral assessment of species of the genus *Allium* L. (Amaryllidaceae) in the western part of the Kyrgyz Alatau. *Plants*, 14(18), 2890. <https://doi.org/10.3390/plants14182890>
- 6 Kubentayev, S.A., Alibekov, D.T., Perezhogin, Y.V., Lazkov, G.A., Kupriyanov, A.N., Ebel, A.L., Izbastina, K., Borodulina, O., & Kubentayeva, B.B. (2024). Revised checklist of endemic vascular plants of Kazakhstan. *PhytoKeys*, 238, 241–279. <https://doi.org/10.3897/phytokeys.238.114475>.
- 7 Turdumatova, N.K. (2022). Rod luk (*Allium* L.) v Kyrgyzstane (voprosy sistematiki, geografiia i perspektivy ispolzovaniia) [Genus *Allium* L. in Kyrgyzstan (questions of systematics, geography, and prospects of use)]. *Extended abstract of candidate's thesis*. Bishkek [in Russian].
- 8 (2014). *Krasnaya kniga Kazakhstana* [Red Book of Kazakhstan]. Vol. 2. Part 1. Rasteniia — Plants (2d ed.). Astana: TOO «ArtPrintXX1» [in Russian].
- 9 Permitina, V.N., Dimeyeva, L.A., & Imanolinova, A.I. (2024). Vysotnaia priurochennost vidov roda *Allium* L. (Liliaceae) gor Zhetysuskogo Alatau [Altitudinal distribution of species of the genus *Allium* L. (Liliaceae) in the Zhetysu Alatau Mountains]. *Problemy botaniki Yuzhnoi Sibiri i Mongolii — Problems of Botany of Southern Siberia and Mongolia*, 23(2), 308–312. Retrieved from <https://journal.asu.ru/bpssm/article/view/pbssm.2024110> [in Russian].
- 10 Kotukhov, Y.A., Danilova, A.N., Sumbembayev, A.A., & Anufriyeva, O.A. (2025). *Konspekt lukov Vostochnogo Kazakhstana* [Synopsis of onions of Eastern Kazakhstan]. Ridder: Print Center [in Russian].
- 11 Abdildanov, D.Sh., Vesselova, P.V., & Kudabayeva, G.M. (2023). Raznoobrazie vidov roda *Allium* flory Aralo-Balkhashskogo regiona [Species diversity of the genus *Allium* in the flora of the Aral Balkhash region]. *Problemy botaniki Yuzhnoi Sibiri i Mongolii — Problems of Botany of Southern Siberia and Mongolia*, 22(1), 6–11. <https://doi.org/10.14258/pbssm.2023001> [in Russian].
- 12 Rachkovskaya, E.I. (2003). Printsipy i osnovnye edynitsy raionirovaniia [Principles and main units of regionalization]. *Botanicheskaya geografiya Kazakhstana i Srednei Azii (v predelakh pustynnoi oblasti) — Botanical geography of Kazakhstan and Central Asia (within the desert region)* (pp. 172–195). Saint Petersburg [in Russian].
- 13 Pavlov, N.V. (Ed.). (1956–1966). *Flora Kazakhstana* [Flora of Kazakhstan] (Vols. 1–9). Alma-Ata: Izdatelstvo Akademii Nauk Kazakhskoi SSR [in Russian].
- 14 Goloskokov, V.P. (Ed.). (1969–1972). *Illustrirovannyi opredelitel rastenii Kazakhstana* [Illustrated guide to plants of Kazakhstan]. (Vols. 1–2). Alma-Ata: Nauka [in Russian].
- 15 (2007–2026). Plantarium: otkrytyi onlain atlas-opredelitel rastenii i lishainikov Rossii i sopredelnykh stran [Plantarium: Open online atlas and identification guide of plants and lichens of Russia and neighboring countries]. www.plantarium.ru. Retrieved from <http://www.plantarium.ru>.
- 16 (2026). *Plants of the World Online*. Royal Botanic Gardens, Kew. Retrieved from <https://powo.science.kew.org>.
- 17 Bykov, B.A. (1978). *Geobotanika* [Geobotany]. Alma-Ata: Nauka [in Russian].
- 18 Nelina, N.V., Kudabayeva, G.M., Mukhtubayeva, S.K., & Bilibayeva, B.K. (2016). K vidovomu sostavu flory ushchelii Merke i Karakystak zapadnoi chasti Kirgizskogo Alatau [The species composition of the flora of the Merke and Karakystak gorges

of the western part of the Kyrgyz Alatau]. *Problemy botaniki Yuzhnoi Sibiri i Mongolii. Sbornik nauchnykh statei po materialam XV mezhdunarodnoi nauchno-prakticheskoi konferentsii — Problems of Botany of Southern Siberia and Mongolia: collection of scientific articles based on the materials of the XV International Scientific and Practical Conference* (pp. 392–398). Barnaul [in Russian].

19 Islamkulova, A.F., Zverev, N.E., & Kalybayev, K.R. (2017). Redkolesia fistashnikov v Kirgizskom Alatau [Pistachio open woodlands in the Kyrgyz Alatau]. *Perspektivy i puti razvitiia promyshlennogo orekhovodstva na yuge Kazakhstana: sbornik materialov mezhdunarodnoi nauchno-prakticheskoi konferentsii — Prospects and ways of development of industrial nut farming in the south of Kazakhstan: collection of materials of the International Scientific and practical Conference* (pp. 30–38). Shymkent [in Russian].

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In silico* analysis of miR156-mediated post-transcriptional regulation of SPL genes involved in cell wall formation and cellulose biosynthesis in *Oryza sativa

Plant cell wall formation and cellulose biosynthesis are central processes determining plant growth, mechanical strength, and biomass quality. Rice (*Oryza sativa*), the second most important crop worldwide after maize, represents a well-established model system due to its fully sequenced and well-annotated genome. In this study, an *in silico* approach was applied to investigate microRNA (miRNA) mediated post-transcriptional regulation of genes involved in cell wall formation and cellulose biosynthesis in *Oryza sativa* (*O. sativa*). Using publicly available databases, including miRBase, TarDB, and NCBI, we systematically predicted miRNA — target gene interactions and reconstructed regulatory networks associated with structural, enzymatic, and signaling components of the plant cell wall. A total of 20 high-confidence miRNA — target gene pairs were identified, involving transcription factors (SPL, NAC, GRAS, AP2, TCP and HD-ZIP III), cell wall-related enzymes (laccases, redox- and copper-dependent proteins), and hormone-responsive regulators. The miR156 — SPL regulatory module emerged as a central and evolutionarily conserved node controlling secondary cell wall formation and cellulose microfibril organization. Additional regulatory layers included miR164 — NAC, miR397 laccase, and miR408/miR528-mediated redox pathways, as well as auxin-related miRNA networks. The results demonstrate that cellulose biosynthesis and cell wall formation in rice are governed by complex, multilevel miRNA-mediated regulatory systems. These findings provide a theoretical framework for future experimental validation and for biotechnological strategies aimed at improving agricultural biomass utilization and cellulose-based sustainable materials.

Keywords: *Oryza sativa*, miRNA, cell wall formation, cellulose biosynthesis, *in silico* analysis.

Introduction

The plant cell wall is a fundamental structural system that ensures the growth, development, and resistance of agricultural plants to environmental factors [1, 2]. Its main component, cellulose, not only provides mechanical strength to plant tissues but also plays a decisive role in maintaining cell shape, tissue differentiation, and morphogenesis [3, 4]. Therefore, investigating the molecular regulatory mechanisms that control cellulose biosynthesis and cell wall formation is a highly relevant topic in modern plant biology, agricultural biotechnology, and sustainable development [5]. In recent years, agricultural biomass has been widely considered a renewable and environmentally friendly source of raw materials. Plant-derived cellulose obtained from straw, rice husks, corn stalks, and other plant residues is regarded as a promising resource for the production of biodegradable and biocompatible materials [6, 7]. The high mechanical strength of cellulose, its processability, and its natural biodegradability make it a key component in the development of biodegradable packaging materials, eco-friendly composites, and sustainable polymer-based products [8]. In this context, a deep understanding of the genetic and post-transcriptional regulatory mechanisms that determine cellulose formation in plants provides a scientific basis for the efficient utilization of agricultural biomass and the development of environmentally friendly packaging technologies [9, 10]. The expression of genes involved in plant cell wall formation and cellulose biosynthesis is controlled by multilevel regulatory systems, among which post-transcriptional regulation plays a particularly important role [11, 12]. At this level, miRNAs act as key regulatory molecules. In plants, miRNA biogenesis begins with the transcription of MIR

genes in the nucleus, resulting in the formation of primary pri-miRNAs; these transcripts are sequentially processed by the DICER-LIKE1 (DCL1) enzyme and its cofactors to generate a mature miRNA duplex. The mature miRNA subsequently associates with Argonaute (AGO) proteins to form a functional complex that recognizes complementary mRNA sequences in the nucleus or cytoplasm. By binding to their target mRNAs, miRNAs promote transcript degradation or inhibit translation. In plants, such interactions are typically characterized by a high degree of complementarity and often lead to direct mRNA cleavage mediated by AGO-containing complexes. Consequently, miRNAs enable precise and efficient regulation of structural programs such as cell wall formation, cellulose synthesis, and cell wall remodeling (Fig. 1) [13–15]. *O. sativa* is not only one of the major crops ensuring global food security but also a model organism for plant genomics and molecular biology [16]. *In silico* analysis provides an efficient approach for predicting miRNA target gene interactions and reconstructing regulatory networks using genome-wide sequence information and curated bioinformatics databases [17, 18]. The complete sequencing of the rice genome, together with the availability of open bioinformatics resources such as miRBase, TarDB, and NCBI, enables comprehensive *in silico* analyses of miRNA–target gene interactions [19, 20]. These approaches facilitate the identification of key regulatory nodes, the characterization of gene network organization, and the formulation of functional hypotheses prior to experimental validation. The aim of this study is to analyze, using *in silico* approaches, the post-transcriptional regulation mediated by miRNAs of genes involved in cellulose biosynthesis and plant cell wall formation in *O. sativa*, including genes encoding SPL transcription factors. The results obtained provide deeper insight into the molecular mechanisms governing plant cell wall formation and establish a scientific foundation for future biotechnological and genetic engineering studies focused on the development of biodegradable materials and environmentally friendly packaging products derived from agricultural biomass.

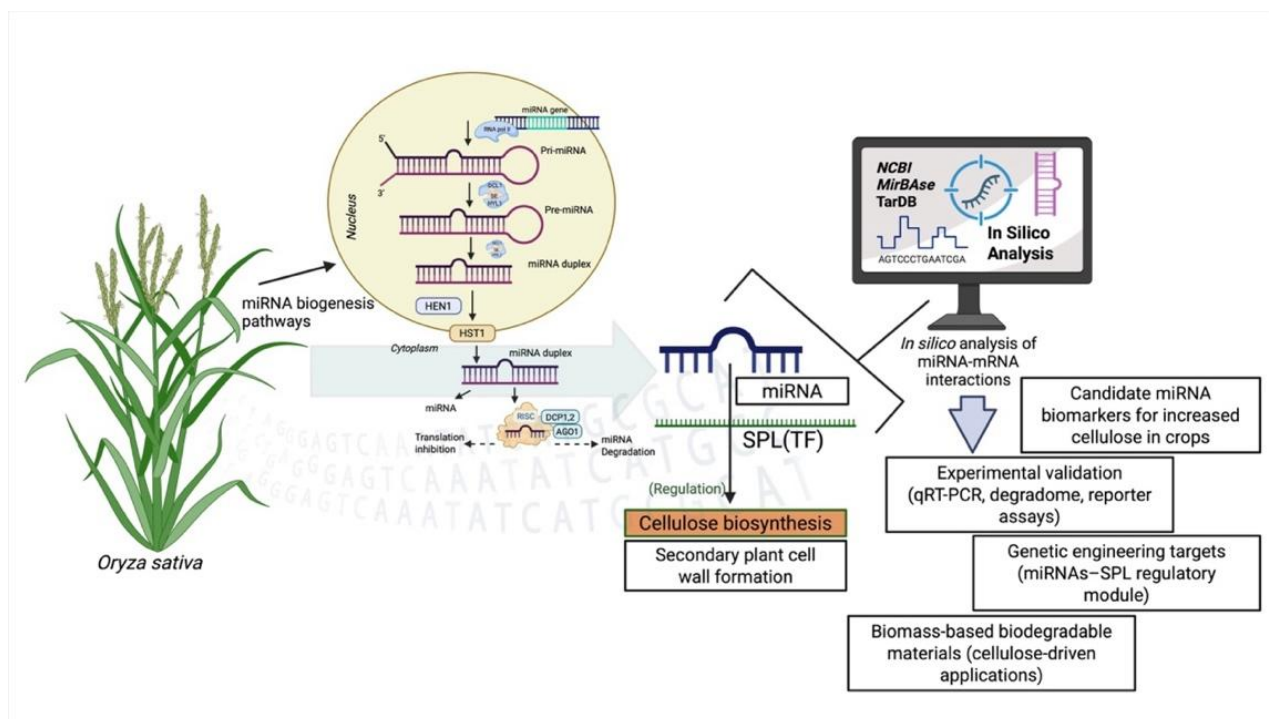


Figure 1. Schematic overview of miRNA biogenesis, miRNA–SPL interactions, and their role in the regulation of cellulose biosynthesis and plant cell wall formation in *O. sativa*.

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Experimental

Databases and retrieval of nucleotide sequences. In this study, all analyses were performed exclusively using *in silico* approaches based on publicly available bioinformatics databases. miRNA sequences specific to *O. sativa* were retrieved from the miRBase database (<https://www.mirbase.org>), which provides curated and experimentally validated annotations of plant miRNAs. Nucleotide sequences of candidate genes in-

volved in plant cell wall formation and cellulose biosynthesis, including transcripts encoding SPL transcription factors (LOC_Os08g39890.1 and LOC_Os09g31438.1), were obtained from the NCBI Gene and NCBI Nucleotide databases (<https://www.ncbi.nlm.nih.gov>). Functional annotations of these genes were additionally examined to confirm their involvement in cell wall development, secondary cell wall formation, and cellulose-related regulatory processes.

Prediction of miRNA target gene interactions. Prediction of miRNA — mRNA interactions was performed using the plant-adapted TarDB database (<http://www.biosequencing.cn/TarDB/>) [21]. This platform is specifically optimized for identifying plant miRNA interactions characterized by high sequence complementarity and predominantly cleavage-based regulatory mechanisms. For each candidate gene, all *O. sativa*-specific miRNAs were systematically screened. The following TarDB parameters were used to evaluate interaction confidence: TarHunter score, an indicator of interaction reliability; Total mismatch, the total number of mismatched nucleotides within the miRNA–mRNA duplex; Seed mismatch, the number of mismatches within the seed region; Predicted cleavage, the likelihood of Argonaute-mediated mRNA cleavage. This study was conducted entirely using computational methods, and the obtained results are proposed as a theoretical framework for future experimental validation.

Results and Discussion

Based on *in silico* analysis using the TarDB database, a multilevel regulatory network consisting of 20 miRNA target gene pairs was identified in *O. sativa*, which are directly or indirectly involved in plant cell wall formation and cellulose biosynthesis (Table 1). The identified network comprises miRNA families targeting transcription factors, structural and enzymatic proteins, as well as key components of phytohormone-dependent signaling pathways. These interactions indicate the presence of complex molecular mechanisms regulating cell wall formation and remodeling at the post-transcriptional level. The results demonstrate that miRNAs regulate the expression of cell wall-related genes not at a single level, but across multiple functional layers. This regulation is organized into interconnected modules involving transcriptional control, enzymatic activity, and hormonal signaling pathways, reflecting the integrative nature of cell wall biosynthesis regulation.

Table 1

Predicted miRNA target gene pairs involved in plant cell wall formation and cellulose biosynthesis in *O. Sativa* based on TarDB analysis

| No | miRNA | Target transcript | Gene function | References |
|----|---------------|-------------------|---|------------|
| 1 | miR156 family | LOC_Os08g39890.1 | SPL transcription factor (secondary cell wall regulation) | [22] |
| | | LOC_Os09g31438.1 | | |
| 2 | miR164 family | LOC_Os06g46270.1 | NAC transcription factor, regulation of cell wall formation and plant development | [23] |
| 3 | miR171 family | LOC_Os02g44360.1 | GRAS family transcription factor, regulation of plant growth and cell differentiation | [24] |
| | | LOC_Os06g01620.1 | | |
| 4 | miR172 family | LOC_Os06g43220.1 | AP2-like transcription factor | [25,26] |
| | | LOC_Os05g03040.1 | | |
| 5 | miR397 family | LOC_Os01g62490.1 | Laccase, a cell wall associated enzyme involved in lignin metabolism | [27] |
| | | LOC_Os01g63200.1 | | |
| 6 | miR394 family | LOC_Os01g69940.1 | F-box protein (auxin signaling) | [28] |
| 7 | miR395 family | LOC_Os03g53230.1 | ATP sulfurylase/sulfate metabolism regulator | [29] |
| 8 | miR414 | LOC_Os11g37990.1 | Regulatory protein (stress-responsive, rice-specific) | [30] |
| 9 | miR319 family | LOC_Os03g57190.1 | TCP transcription factor (growth and cell wall regulation) | [31, 32] |
| 10 | miR408-3p | LOC_Os01g03530.1 | Blue copper protein / oxidative stress and cell wall metabolism | [33] |
| 11 | miR169 family | LOC_Os10g26470.1 | NF-YA (Nuclear Factor Y, subunit A) drought/stress and development regulator | [34] |

| № | miRNA | Target transcript | Gene function | References |
|------------------|------------------|------------------------|--|------------|
| 12 | miR530 | LOC_Os01g56780.1 | Receptor-like regulatory protein (plant development and stress regulation) | [35] |
| 13 | miR393 family | LOC_Os01g53280.1 | TIR1/AFB auxin receptor pathway (auxin signaling) | [36] |
| 14 | miR396 family | LOC_Os01g53610.1 | GRF transcription factors (growth, leaf development; cell proliferation) | [37] |
| | | LOC_Os06g10310 | | |
| | | LOC_Os02g53690.1 | | |
| | | LOC_Os04g51190.1/.2/.3 | | |
| | | LOC_Os02g47280.1/.2 | | |
| | | LOC_Os06g02560.1/.2/.3 | | |
| | | LOC_Os03g51970.1 | | |
| | | LOC_Os03g47140.1 | | |
| | | LOC_Os12g29980.1/.2 | | |
| | | LOC_Os02g45570.1/.2 | | |
| LOC_Os04g48510.1 | | | | |
| 15 | miR167 family | LOC_Os04g57610.3 | ARF (Auxin Response Factor) auxin-mediated development | [38] |
| 16 | miR399e | LOC_Os11g03700.1 | PHO2/UBC24-related phosphate homeostasis (Pi starvation response) | [39] |
| 17 | miR166 family | LOC_Os02g45380.1 | HD-ZIP III transcription factors (vascular/cell wall patterning) | [40] |
| 18 | miR162a | LOC_Os03g01090.1 | DCL1 (miRNA biogenesis regulator) | [41] |
| 19 | miR164 family | LOC_Os02g36880.2 | NAC transcription factors (involved in plant development and stress responses; occasionally associated with cell wall-related regulatory networks) | [42] |
| 20 | miR528-5p family | LOC_Os12g36620.1 | Redox- and copper-dependent enzymes operating within cell wall-associated enzymatic networks | [43, 44] |
| | | LOC_Os03g03724.2 | | |

The miRNA families targeting transcription factors were identified as a major regulatory module associated with cell wall formation and cellulose biosynthesis. In particular, the miR156 family was predicted to interact with genes encoding SPL transcription factors, suggesting its involvement in regulating genes responsible for secondary cell wall formation and the organization of cellulose microfibrils. This miR156 — SPL module represents a central regulatory node controlling the structural program of the plant cell wall. The miR164 family targets NAC transcription factors and is associated with processes related to cell wall thickening, lignin biosynthesis, and tissue maturation. Regulation of NAC factors contributes not only to maintaining the mechanical strength of the cell wall, but also influences the plant's ability to adapt to external stress conditions during development [45]. These observations highlight the functional importance of the miR164 NAC regulatory interaction in ensuring cell wall stability. In addition, the miR171 and miR172 families were found to target GRAS and AP2-like transcription factors, respectively. These transcription factors indirectly affect cell wall formation through their roles in plant morphogenesis, cellular differentiation, and developmental programs [46]. Acting as components of higher-order transcriptional cascades, these miRNAs contribute to the temporal and spatial regulation of cell wall biosynthesis. Enzymatic components directly involved in determining the chemical composition of the plant cell wall were also found to be regulated by miRNAs. The targeting of laccase genes by the miR397 family is associated with lignin polymerization and the formation of the cellulose lignin matrix, representing one of the key enzymatic regulatory mechanisms governing cell wall rigidity and mechanical strength. Furthermore, miR408-3p and miR528-5p interact with genes encoding redox-active and copper-containing proteins, thereby regulating oxidation reduction processes linked to cell wall metabolism. These miRNAs constitute an additional regulatory layer contributing to the maintenance of energetic and metabolic balance during cell wall biosynthesis. Indirect regulation mediated through hormonal signaling pathways was also identified. The miR393, miR167, and miR394 families target key components of the auxin signaling pathway, coordinating cell expansion, cell wall remodeling, and de-

by a single nucleotide were identified for specific isoforms (e.g., osa-miR156l-5p), whereas osa-miR156k showed no confident interaction (TarHunter score = 0) (Fig. 2).

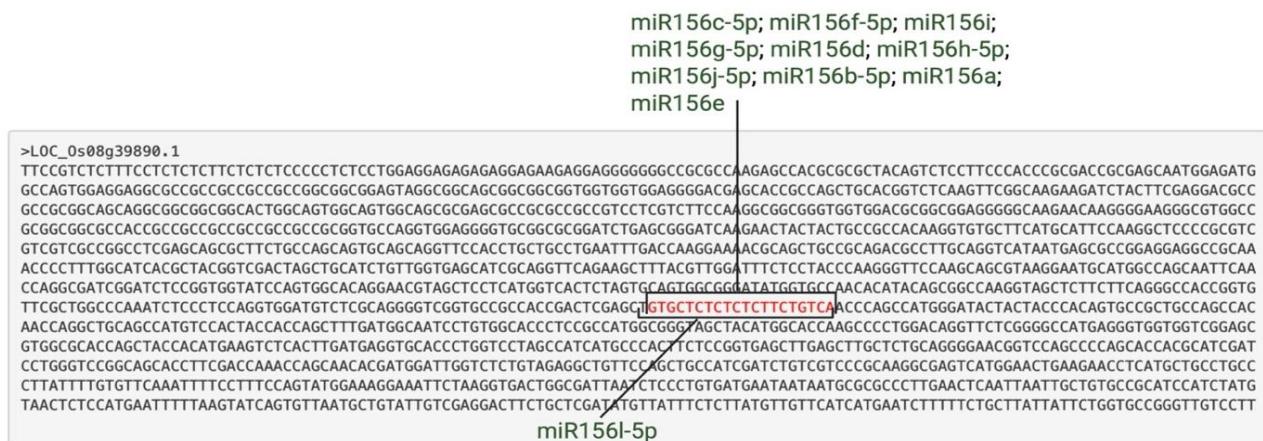


Figure 2. Localization of a shared miR156 family binding region within the *LOC_Os08g39890.1* transcript. The core target sequence 5'-GUGCUCUCUCUCUUCUGUCA-3' is highlighted in red. This site is recognized by multiple miR156 isoforms, while osa-miR156l-5p binds to a slightly shifted overlapping site

In addition to LOC_Os08g39890.1, LOC_Os09g31438.1 was also identified as a conserved target of the miR156 family based on TarDB predictions. Multiple miR156 isoforms, including osa-miR156d, osa-miR156f-5p, osa-miR156i, osa-miR156l-5p, osa-miR156h-5p, osa-miR156e, osa-miR156j-5p, osa-miR156a, osa-miR156c-5p, osa-miR156b-5p, osa-miR156g-5p and osa-miR156k were predicted to bind to a shared target region within the LOC_Os09g31438.1 transcript (Table 3).

Table 3

Schemes of miR156 family binding sites in the LOC_Os09g31438.1 SPL mRNA involved in cell wall formation in *O. sativa*

| miRNA; tarHunter score; total mispair; seed mispair | |
|--|---|
| miR156d; 1; 1; 0. 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | miR156f-5p; 1; 1; 0. 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' |
| miR156i; 1; 1; 0. 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | miR156l-5p; 2,5; 3; 0. 5' UGUGCUCUCUCUCUUCUGUCA 3' o 3' AUACGAGUGAGAGAAGACAGC 5' |
| miR156h-5p; 1; 1; 0. 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | miR156e; 1; 1; 0. 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' |
| miR156j-5p; 1; 1; 0. 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | miR156a; 1; 1; 0. 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' |
| miR156c-5p; 1; 1; 0. 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | miR156b-5p; 1; 1; 0. 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' |
| miR156g-5p; 1; 1; 0. 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | miR156k; 0; 0; 0. 5' UGUGCUCUCUCUCUUCUGUCA 3' 3' ACACGAGAGAGAGAAGACAGU 5' |
| Note. mRNA sequences are shown in green, miRNAs in blue; vertical bars indicate canonical base pairing, and "o" denotes a G: U wobble interaction. | |

A conserved target region 5'-GUGCUCUCUCUCUUCUGUCA-3' was identified within the LOC_Os09g31438.1 transcript and was predicted to be recognized by 10 high-confidence members of the miR156 family (Fig. 3). Specifically, osa-miR156a, osa-miR156b-5p, osa-miR156c-5p, osa-miR156d, osa-miR156e, osa-miR156f-5p, osa-miR156g-5p, osa-miR156h-5p, osa-miR156i, and osa-miR156j-5p exhibited strong complementarity to this target sequence. All of these interactions were characterized by zero seed mismatches and a consistent prediction of cleavage-based regulation, indicating high confidence miRNA-mRNA pairing. In addition, osa-miR156l-5p was predicted to bind to an overlapping target site shifted by a single nucleotide relative to the core region. This interaction showed the presence of a G: U wobble pair and a higher overall mismatch score (TarHunter score = 2.5), suggesting reduced binding stringency compared to the core miR156 isoforms. In contrast, osa-miR156k did not display a confident interaction with this region (TarHunter score = 0). These results demonstrate that LOC_Os09g31438.1 is subject to robust, family-level post-transcriptional regulation by miR156, mediated primarily through a conserved core binding site and complemented by isoform-specific shifted interactions.

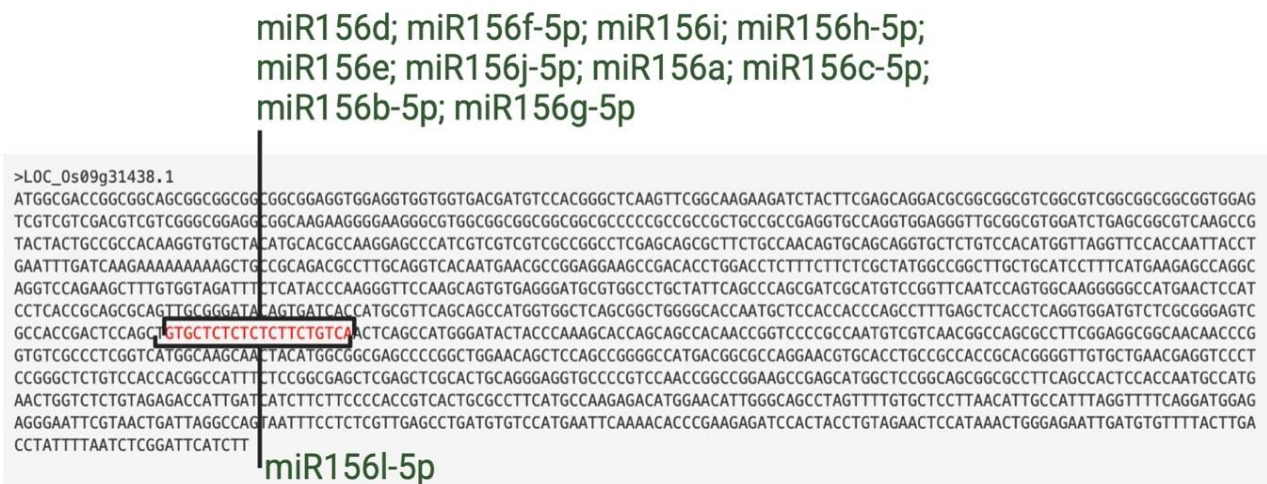


Figure 3. The miR156 family binding site in the LOC_Os09g31438.1 mRNA.

The core target sequence 5'-GUGCUCUCUCUCUUCUGUCA-3' is highlighted in red and is recognized by multiple miR156 isoforms, including miR156d, miR156f-5p, miR156i, miR156h-5p, miR156e, miR156j-5p, miR156a, miR156c-5p, miR156b-5p, and miR156g-5p.

The position of the shifted overlapping binding site for miR156l-5p is also indicated

Comparative *in silico* analysis revealed that multiple members of the miR156 family in *Zea mays* (*Z. mays*) are predicted to target SPL-like transcripts through a conserved binding site identical to that identified in *O. sativa*. In particular, zma-miR156a-5p showed consistent and high-confidence interactions with several maize SPL-related transcripts, including GRMZM2G126018_T02, GRMZM2G460544_T01, GRMZM2G307588_T01, GRMZM2G160917_T03, and GRMZM2G371033_T01, all of which exhibited low TarHunter scores (≤ 1), zero seed mismatches, and predicted cleavage activity (Table 4). The majority of these interactions were characterized by near-perfect complementarity to the conserved target motif 5'-GUGCUCUCUCUCUUCUGUCA-3', indicating strong evolutionary conservation of the miR156 — SPL regulatory module across monocot species. Additional zma-miR156a-5p target transcripts displayed slightly higher TarHunter scores and limited mismatches, suggesting weaker but still plausible regulatory interactions.

In contrast, other miR156 isoforms, such as zma-miR156j-5p and zma-miR156k-5p, showed reduced interaction confidence or absence of predicted cleavage for several candidate transcripts, indicating functional divergence within the miR156 family in maize. Overall, these results demonstrate that zma-miR156a-5p represents the dominant and most conserved regulatory miRNA targeting SPL-like genes in *Z. mays*, paralleling the regulatory patterns observed in *O. sativa*.

Predicted miR156 family binding sites in SPL-like transcripts involved in cell wall formation in *Z. mays*

| Species | miRNA | Target transcript | Pairing | Tar Hunter Score | Total mispair | Seed mispair |
|----------------|------------|--------------------|---|------------------|---------------|--------------|
| <i>Z. mays</i> | miR156a-5p | GRMZM2G126018_T02 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM2G460544_T01 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM2G307588_T01 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM2G160917_T03 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM2G371033_T01 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM2G465165_T01 | 5' GUGGUCGUCUCUCUUCUGUCA 3' o 3' CACGAGUGAGAGAAGACAGU 5' | 3.5 | 3 | 0 |
| | | AC233751.1_FG T002 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM5G806833_T01 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM2G101511_T02 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM2G052921_T01 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM2G065451_T01 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM2G414805_T07 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM2G022489_T01 | 5' GUGCUCACCCUCUAUCUGUCA 3' 3' CACGAGUGAGAGA-AGACAGU 5' | 4 | 2 | 1 |
| | | GRMZM2G022489_T01 | 5' GUGCUCACUUCUCUCUCUGUCA 3' 3' CACGAGUG-AGAGA-AGACAGU 5' | 3 | 2 | 1 |
| | | GRMZM2G551565_T01 | 5' GUGCUCACUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 0 | 0 | 0 |
| | | GRMZM2G067624_T02 | 5' AUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 2 | 2 | 0 |
| | | GRMZM2G113779_T01 | 5' AUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 2 | 2 | 0 |
| | | GRMZM2G106798_T02 | 5' GUGCUCUCUCUCUUCUGUCA 3' 3' CACGAGUGAGAGAAGACAGU 5' | 1 | 1 | 0 |
| | | GRMZM2G146446_T02 | 5' GCCGUCGUUCUCUUCUGUCA 3' o 3' CACGAGUGAGAGAAGACAGU 5' | 4 | 5 | 0 |

Note. mRNA sequences are shown in green, miRNAs in blue; vertical bars indicate canonical base pairing, and “o” denotes a G: U wobble interaction.

These data demonstrate that the miR156 — SPL regulatory module represents an evolutionarily conserved, universal, and functionally significant molecular regulatory mechanism that governs gene networks involved in plant cell wall formation and cellulose biosynthesis. The identification of a conserved miR156 binding region shared by multiple SPL transcripts, together with the presence of numerous high-confidence miR156 isoforms targeting the same sites, indicates a robust and tightly controlled post-transcriptional regu-

latory system. The predominance of perfect or near-perfect complementarity within the seed region and the consistent prediction of cleavage-based regulation further support the functional relevance of these interactions. Importantly, the conservation of the miR156–SPL interaction across monocot species, including *O. sativa* and *Z. mays*, suggests that this regulatory module has been maintained during evolution due to its critical role in controlling structural and developmental programs of the plant cell wall. Such conservation implies selective pressure to preserve precise regulation of SPL transcription factors, which are known to orchestrate secondary cell wall formation, cellulose microfibril organization, and tissue maturation. These findings indicate that the miR156 — SPL axis functions as a central regulatory hub integrating developmental cues with structural gene expression, thereby ensuring coordinated control of cellulose biosynthesis and cell wall architecture.

Rice (*O. sativa*) is a crop of strategic importance in global agriculture and is considered one of the main food plants, ranking second after maize in terms of production volume [47]. In addition, the *O. sativa* genome has been fully sequenced, is well functionally annotated, and is widely used as a model species in molecular and genetic studies [16, 48]. These characteristics make rice a suitable model system for investigating the molecular regulation of cell wall formation and cellulose biosynthesis [49, 50]. Recent studies have shown that plant cell wall formation and cellulose synthesis are regulated through multilevel and dynamic regulatory networks [51]. These networks integrate transcription factors, enzymatic complexes, and phytohormone-dependent signaling pathways. Regulation at the post-transcriptional level, including the control of gene expression by miRNAs, has attracted increasing attention in recent years [13, 14, 52].

The *in silico* analysis conducted in this study demonstrated that miRNA-mediated regulation of genes involved in cell wall formation and cellulose biosynthesis in *O. sativa* represents a complex and integrated system. The results indicate that miRNA families targeting transcription factors act as dominant regulatory modules in this process. In particular, the miR156 — SPL regulatory module occupies a central position in controlling gene programs associated with secondary cell wall formation and the organization of cellulose microfibrils. Recent studies have shown that SPL transcription factors play a decisive role in regulating cell wall thickening and structural integrity [53, 54]. In addition, NAC transcription factors regulated by miR164 link cell wall formation and lignin accumulation with plant developmental stages and stress conditions. Recently, Xiong et al. (2025) demonstrated that NAC factors are key regulators of cell wall remodeling and stress tolerance [23]. This is fully consistent with our results and confirms the structural and physiological importance of the miR164 — NAC axis. At the enzymatic level, laccase genes regulated by miR397 play an important role in the formation of the cellulose lignin matrix. Laccases catalyze lignin polymerization, thereby enhancing the mechanical strength of the cell wall. Studies by Janusz et al. (2020) [55] and Chen et al. (2023) [44] have shown that copper-dependent redox enzymes coordinate cell wall formation through oxidation–reduction reactions in the apoplast. In this context, the redox/copper-dependent enzymes regulated by miR408-3p and miR528-5p identified in our study can be considered key components of enzyme networks associated with the cell wall. MiRNA networks associated with hormonal signaling also deserve special attention. Regulation of key components of the auxin signaling pathway by miR393, miR167, and miR394 is directly linked to cell elongation, cell wall remodeling, and morphogenetic processes. Recently, Prigge et al. (2020) [56] and Jing & Strader (2023) [57] highlighted the role of auxin signaling in regulating cell wall plasticity and emphasized the integrative function of miRNAs in this process. At the systemic level, the miR396 — GRF regulatory axis indirectly influences proper cell wall formation by determining cell proliferation and the rate of tissue growth. Recent genomic studies have shown that GRF factors contribute to structural development by regulating cell number and tissue architecture. [58, 59] In conclusion, this *in silico* study demonstrates that cell wall formation and cellulose biosynthesis in *O. sativa* are controlled by evolutionarily conserved, multilevel, and functionally significant miRNA-mediated regulatory networks. The obtained data provide a solid theoretical foundation for molecular-level control of cellulose properties derived from agricultural biomass and for the future development of applied biotechnological and genetic engineering based solutions.

Conclusion

This study provides a comprehensive *in silico* characterization of miRNA-mediated regulatory networks controlling cell wall formation and cellulose biosynthesis in *O. sativa*. The results demonstrate that these processes are regulated through interconnected and evolutionarily conserved miRNA — target gene modules that integrate transcriptional control, enzymatic activity, and hormone-dependent signaling pathways into a unified regulatory system. In particular, the miR156 — SPL axis represents a core regulatory module

governing secondary cell wall development and cellulose microfibril organization, highlighting its central role in determining structural properties of plant biomass. In parallel, miR164 — NAC and miR397 laccase interactions link cell wall reinforcement with developmental regulation and stress-responsive programs, underscoring the multifunctional nature of cell wall-associated regulatory networks. Furthermore, the involvement of redox- and copper-dependent enzymes regulated by miR408-3p and miR528-5p emphasizes the importance of apoplastic redox balance in coordinating enzymatic processes during cell wall assembly and remodeling. Together, these findings indicate that plant cell wall biosynthesis is governed by a multilayered post-transcriptional regulatory framework, rather than by isolated genetic pathways acting independently. The regulatory map generated in this study provides a solid theoretical foundation for future experimental validation and functional studies. Importantly, it also offers valuable perspectives for plant biotechnology, genetic engineering, and the rational improvement of cellulose-rich agricultural biomass aimed at the development of sustainable, biodegradable, and bio-based materials.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Belkozhayev A.M.** — conceptualization, methodology, investigation, bioinformatics analysis, data curation, formal analysis, writing — original draft, supervision; **Kossalbayev B.D. and Gizatullina N** — data curation, bioinformatic analysis, visualization, writing — review & editing; **Toleutay G.** — supervision, writing — review and editing.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Ezquer, I., Salameh, I., Colombo, L., & Kalaitzis, P. (2020). Plant Cell Walls Tackling Climate Change: Insights into Plant Cell Wall Remodeling, Its Regulation, and Biotechnological Strategies to Improve Crop Adaptations and Photosynthesis in Response to Global Warming. *Plants (Basel)*, *9*(2), 212. <https://doi.org/10.3390/plants9020212>
- 2 Soni, N., & Bacete, L. (2023). The Interplay between Cell Wall Integrity and Cell Cycle Progression in Plants. *Plant Molecular Biology*, *113*(6), 367–382. <https://doi.org/10.1007/s11103-023-01394-w>
- 3 Rongpipi, S., Ye, D., Gomez, E.D., & Gomez, E.W. (2019). Progress and Opportunities in the Characterization of Cellulose — An Important Regulator of Cell Wall Growth and Mechanics. *Frontiers in Plant Science*, *9*, 1894. <https://doi.org/10.3389/fpls.2018.01894>
- 4 Polko, J.K., & Kieber, J.J. (2019). The Regulation of Cellulose Biosynthesis in Plants. *The Plant Cell*, *31*(2), 282–296. <https://doi.org/10.1105/tpc.18.00760>
- 5 Sun, S., Liang, H., Lei, Z., Xu, J., Wang, S., Zhao, Z., & Yin, T. (2025). Cellulose Biosynthesis in Nature and In Vitro: Mechanisms and Challenges. *Enzyme and Microbial Technology*, *195*, 110804. <https://doi.org/10.1016/j.enzmictec.2025.110804>
- 6 Qureshi, S.S., Nizamuddin, S., Xu, J., Vancov, T., & Chen, C. (2024). Cellulose Nanocrystals from Agriculture and Forestry Biomass: Synthesis Methods, Characterization and Industrial Applications. *Environmental Science and Pollution Research*, *31*(49), 58745–58778. <https://doi.org/10.1007/s11356-024-35127-3>
- 7 Almeida, B.P., Pavão, L.F.S., de Farias, M.S., Nicolodi, N.M., Petry, M.T., Leal, M.M., Coradi, P.C., de Souza, V.L., Queirós, M.d.S., Furtado, G.d.F., et al. (2025). Agricultural Biomass as a Resource for Biomaterials, Biofertilizers, and Bioproducts: A Systematic Review. *Agrochemicals*, *4*, 23. <https://doi.org/10.3390/agrochemicals4040023>
- 8 Yaradoddi, J.S., Banapurmath, N.R., Ganachari, S.V., Soudagar, M.E.M., Mubarak, N.M., Hallad, S., Hugar, S., & Fayaz, H. (2020). Biodegradable Carboxymethyl Cellulose Based Material for Sustainable Packaging Application. *Scientific Reports*, *10*(1), 21960. <https://doi.org/10.1038/s41598-020-78912-z>
- 9 Sulis, D.B., Lavoine, N., Sederoff, H., Jiang, X., Marques, B.M., Lan, K., Cofre-Vega, C., Barrangou, R., & Wang, J.P. (2025). Advances in Lignocellulosic Feedstocks for Bioenergy and Bioproducts. *Nature Communications*, *16*(1), 1244. <https://doi.org/10.1038/s41467-025-56472-y>

- 10 Nething, D.B., Sukul, A., Mishler-Elmore, J.W., & Held, M.A. (2021). Posttranscriptional Regulation of Cellulose Synthase Genes by Small RNAs Derived from Cellulose Synthase Antisense Transcripts. *Plant Direct*, 5(9), e347. <https://doi.org/10.1002/pld3.347>
- 11 Ruprecht, C., & Persson, S. (2012). Co-Expression of Cell-Wall Related Genes: New Tools and Insights. *Frontiers in Plant Science*, 3, 83. <https://doi.org/10.3389/fpls.2012.00083>
- 12 Ivakov, A., Flis, A., Apelt, F., Fünfgeld, M., Scherer, U., Stitt, M., Kragler, F., Vissenberg, K., Persson, S., & Suslov, D. (2017). Cellulose Synthesis and Cell Expansion Are Regulated by Different Mechanisms in Growing *Arabidopsis Hypocotyls*. *The Plant Cell*, 29(6), 1305–1315. <https://doi.org/10.1105/tpc.16.00782>
- 13 Zhakypbek, Y., Rakhmetullina, A., Kamarkhan, Z., Tursbekov, S., Shi, Q., Xing, F., Pyrkova, A., Ivashchenko, A., Kossalbayev, B.D., & Belkozhayev, A.M. (2025). In Silico Analysis of miRNA–mRNA Binding Sites in *Arabidopsis thaliana* as a Model for Drought-Tolerant Plants. *Plants (Basel)*, 14(12), 1800. <https://doi.org/10.3390/plants14121800>
- 14 Zhakypbek, Y., Belkozhayev, A.M., Kerimkulova, A., Kossalbayev, B.D., Murat, T., Tursbekov, S., Turysbekova, G., Tursunova, A., Tastambek, K.T., & Allakhverdiev, S.I. (2025). MicroRNAs in Plant Genetic Regulation of Drought Tolerance and Their Function in Enhancing Stress Adaptation. *Plants (Basel)*, 14(3), 410. <https://doi.org/10.3390/plants14030410>
- 15 Chen, X. (2005). MicroRNA Biogenesis and Function in Plants. *FEBS Letters*, 579(26), 5923–5931. <https://doi.org/10.1016/j.febslet.2005.07.071>
- 16 Hamilton, J.P., Li, C., & Buell, C.R. (2025). The Rice Genome Annotation Project: An Updated Database for Mining the Rice Genome. *Nucleic Acids Research*, 53(D1), D1614–D1622. <https://doi.org/10.1093/nar/gkae1061>
- 17 Dweep, H., Sticht, C., & Gretz, N. (2013). In-Silico Algorithms for the Screening of Possible microRNA Binding Sites and Their Interactions. *Current Genomics*, 14(2), 127–136. <https://doi.org/10.2174/1389202911314020005>
- 18 Mikheeva, E.V., Aulova, K.S., Nevinsky, G.A., & Timofeeva, A.M. (2025). In Silico Analysis of miRNA Regulatory Networks to Identify Potential Biomarkers for the Clinical Course of Viral Infections. *International Journal of Molecular Sciences*, 26(20), 10100. <https://doi.org/10.3390/ijms262010100>
- 19 Moore, A.C., Winkjer, J.S., & Tseng, T.T. (2016). Bioinformatics Resources for MicroRNA Discovery. *Biomarker Insights*, 10(Suppl 4), 53–58. <https://doi.org/10.4137/BMI.S29513>
- 20 Griffiths-Jones, S. (2006). miRBase: The microRNA Sequence Database. *Methods in Molecular Biology*, 342, 129–138. <https://doi.org/10.1385/1-59745-123-1:129>
- 21 Liu, J., Liu, X., Zhang, S., Liang, S., Luan, W., & Ma, X. (2021). TarDB: An Online Database for Plant miRNA Targets and miRNA-Triggered Phased siRNAs. *BMC Genomics*, 22(1), 348. <https://doi.org/10.1186/s12864-021-07680-5>
- 22 Li, M., Yao, T., Galli, M., Lin, W., Zhou, Y., Chen, J.G., Gallavotti, A., & Huang, S.C. (2024). Diversification and Conservation of DNA Binding Specificities of SPL Family of Transcription Factors. *bioRxiv*. <https://doi.org/10.1101/2024.09.13.612952>
- 23 Xiong, H., He, H., Chang, Y., Miao, B., Liu, Z., Wang, Q., Dong, F., & Xiong, L. (2025). Multiple Roles of NAC Transcription Factors in Plant Development and Stress Responses. *Journal of Integrative Plant Biology*, 67(3), 510–538. <https://doi.org/10.1111/jipb.13854>
- 24 Jaiswal, V., Kakkar, M., Kumari, P., Zinta, G., Gahlaut, V., & Kumar, S. (2022). Multifaceted Roles of GRAS Transcription Factors in Growth and Stress Responses in Plants. *iScience*, 25(9), 105026. <https://doi.org/10.1016/j.isci.2022.105026>
- 25 Ma, N., Sun, P., Li, Z.Y., Zhang, F.J., Wang, X.F., You, C.X., Zhang, C.L., & Zhang, Z. (2024). Plant Disease Resistance Outputs Regulated by AP2/ERF Transcription Factor Family. *Stress Biology*, 4(1), 2. <https://doi.org/10.1007/s44154-023-00140-y>
- 26 Feng, K., Hou, X.L., Xing, G.M., Liu, J.X., Duan, A.Q., Xu, Z.S., Li, M.Y., Zhuang, J., & Xiong, A.S. (2020). Advances in AP2/ERF Super-Family Transcription Factors in Plants. *Critical Reviews in Biotechnology*, 40(6), 750–776. <https://doi.org/10.1080/07388551.2020.1768509>
- 27 Somssich, M. (2020). Lignification and Oxidative Enzymes: Localization, Localization, Localization! *Plant Physiology*, 184(2), 554–555. <https://doi.org/10.1104/pp.20.01021>
- 28 Wright, R.C., Zahler, M.L., Gerben, S.R., & Nemhauser, J.L. (2017). Insights into the Evolution and Function of Auxin Signaling F-Box Proteins in *Arabidopsis thaliana* Through Synthetic Analysis of Natural Variants. *Genetics*, 207(2), 583–591. <https://doi.org/10.1534/genetics.117.300092>
- 29 Kim, W.S., Sun-Hyung, J., Oehrle, N.W., Jez, J.M., & Krishnan, H.B. (2020). Overexpression of ATP Sulfurylase Improves the Sulfur Amino Acid Content, Enhances the Accumulation of Bowman–Birk Protease Inhibitor and Suppresses the Accumulation of the β -Subunit of β -Conglycinin in Soybean Seeds. *Scientific Reports*, 10(1), 14989. <https://doi.org/10.1038/s41598-020-72134-z>
- 30 Zhao, H., Liu, X., Wang, J., Qian, Q., & Zhang, G. (2022). The Coordinated Regulation Mechanism of Rice Plant Architecture and Its Tolerance to Stress. *Frontiers in Plant Science*, 13, 1087378. <https://doi.org/10.3389/fpls.2022.1087378>
- 31 Shen, F., Zhang, H., Wan, M., Yang, Y., Kuang, Z., Xiao, L., Zuo, D., Li, Z., Qin, G., & Li, L. (2025). The CIN-TCP Transcription Factors Regulate Endocycle Progression and Pavement Cell Size by Promoting Cell Wall Pectin Degradation. *Nature Communications*, 16(1), 4108. <https://doi.org/10.1038/s41467-025-59336-7>
- 32 Rath, M., Challa, K.R., Sarvepalli, K., & Nath, U. (2022). CINCINNATA-Like TCP Transcription Factors in Cell Growth — An Expanding Portfolio. *Frontiers in Plant Science*, 13, 825341. <https://doi.org/10.3389/fpls.2022.825341>
- 33 Zhou, Y., & Zhang, L. (2023). The Interplay between Copper Metabolism and Microbes: In Perspective of Host Copper-Dependent ATPases ATP7A/B. *Frontiers in Cellular and Infection Microbiology*, 13, 1267931. <https://doi.org/10.3389/fcimb.2023.1267931>

- 34 Wu, H., Hou, X., & Zhang, C. (2025). Nuclear Factor-Y Transcription Factors in Crops: Biological Roles, Regulation, and Breeding Applications. *Plant Communications*, 6(11), 101530. <https://doi.org/10.1016/j.xplc.2025.101530>
- 35 Gandhi, A., & Oelmüller, R. (2023). Emerging Roles of Receptor-Like Protein Kinases in Plant Response to Abiotic Stresses. *International Journal of Molecular Sciences*, 24(19), 14762. <https://doi.org/10.3390/ijms241914762>
- 36 Prigge, M.J., Platre, M., Kadakia, N., Zhang, Y., Greenham, K., Szutu, W., Pandey, B.K., Bhosale, R.A., Bennett, M.J., Busch, W., & Estelle, M. (2020). Genetic Analysis of the *Arabidopsis* TIR1/AFB Auxin Receptors Reveals Both Overlapping and Specialized Functions. *eLife*, 9, e54740. <https://doi.org/10.7554/eLife.54740>
- 37 Huang, W., He, Y., Yang, L., Lu, C., Zhu, Y., Sun, C., Ma, D., & Yin, J. (2021). Genome-Wide Analysis of Growth-Regulating Factors (GRFs) in *Triticum aestivum*. *PeerJ*, 9, e10701. <https://doi.org/10.7717/peerj.10701>
- 38 Roosjen, M., Paque, S., & Weijers, D. (2018). Auxin Response Factors: Output Control in Auxin Biology. *Journal of Experimental Botany*, 69(2), 179–188. <https://doi.org/10.1093/jxb/erx237>
- 39 Yang, S.Y., Lin, W.Y., Hsiao, Y.M., & Chiou, T.J. (2024). Milestones in Understanding Transport, Sensing, and Signaling of the Plant Nutrient Phosphorus. *The Plant Cell*, 36(5), 1504–1523. <https://doi.org/10.1093/plcell/koad326>
- 40 Gao, J., Chen, J., Feng, L., Wang, Q., Li, S., Tan, X., Yang, F., & Yang, W. (2022). HD-Zip III Gene Family: Identification and Expression Profiles during Leaf Vein Development in Soybean. *Plants (Basel)*, 11(13), 1728. <https://doi.org/10.3390/plants11131728>
- 41 Sun, Z., Li, M., Zhou, Y., Guo, T., Liu, Y., Zhang, H., & Fang, Y. (2018). Coordinated Regulation of *Arabidopsis* microRNA Biogenesis and Red Light Signaling through Dicer-Like 1 and Phytochrome-Interacting Factor 4. *PLoS Genetics*, 14(3), e1007247. <https://doi.org/10.1371/journal.pgen.1007247>
- 42 Dong, B., Liu, Y., Huang, G., Song, A., Chen, S., Jiang, J., Chen, F., & Fang, W. (2024). Plant NAC Transcription Factors in the Battle against Pathogens. *BMC Plant Biology*, 24(1), 958. <https://doi.org/10.1186/s12870-024-05636-x>
- 43 Ravet, K., & Pilon, M. (2013). Copper and Iron Homeostasis in Plants: The Challenges of Oxidative Stress. *Antioxidants & Redox Signaling*, 19(9), 919–932. <https://doi.org/10.1089/ars.2012.5084>
- 44 Chen, C., Zhang, Y., Cai, J., Qiu, Y., Li, L., Gao, C., Gao, Y., Ke, M., Wu, S., Wei, C., Chen, J., Xu, T., Friml, J., Wang, J., Li, R., Chao, D., Zhang, B., Chen, X., & Gao, Z. (2023). Multi-Copper Oxidases SKU5 and SKS1 Coordinate Cell Wall Formation Using Apoplastic Redox-Based Reactions in Roots. *Plant Physiology*, 192(3), 2243–2260. <https://doi.org/10.1093/plphys/kiad207>
- 45 Singh, S., Koyama, H., Bhati, K.K., & Alok, A. (2021). The Biotechnological Importance of the Plant-Specific NAC Transcription Factor Family in Crop Improvement. *Journal of Plant Research*, 134(3), 475–495. <https://doi.org/10.1007/s10265-021-01270-y>
- 46 Ho-Plágaro, T., & García-Garrido, J.M. (2022). Multifarious and Interactive Roles of GRAS Transcription Factors during Arbuscular Mycorrhiza Development. *Frontiers in Plant Science*, 13, 836213. <https://doi.org/10.3389/fpls.2022.836213>
- 47 Singh, D.K., Mehra, S., Chatterjee, S., & Purty, R.S. (2020). In Silico Identification and Validation of miRNA and Their DIR-Specific Targets in *Oryza sativa* Indica under Abiotic Stress. *Noncoding RNA Research*, 5(4), 167–177. <https://doi.org/10.1016/j.ncrna.2020.09.002>
- 48 Notsu, Y., Masood, S., Nishikawa, T., Kubo, N., Akiduki, G., Nakazono, M., Hirai, A., & Kadowaki, K. (2002). The Complete Sequence of the Rice (*Oryza sativa* L.) Mitochondrial Genome: Frequent DNA Sequence Acquisition and Loss during the Evolution of Flowering Plants. *Molecular Genetics and Genomics*, 268(4), 434–445. <https://doi.org/10.1007/s00438-002-0767-1>
- 49 Liu, X., Yin, Z., Wang, Y., Cao, S., Yao, W., Liu, J., Lu, X., Wang, F., Zhang, G., Xiao, Y., Tang, W., & Deng, H. (2022). Rice Cellulose Synthase-Like Protein OsCSLD4 Coordinates the Trade-Off between Plant Growth and Defense. *Frontiers in Plant Science*, 13, 980424. <https://doi.org/10.3389/fpls.2022.980424>
- 50 Li, M., Xiong, G., Li, R., Cui, J., Tang, D., Zhang, B., Pauly, M., Cheng, Z., & Zhou, Y. (2009). Rice Cellulose Synthase-Like D4 Is Essential for Normal Cell-Wall Biosynthesis and Plant Growth. *The Plant Journal*, 60(6), 1055–1069. <https://doi.org/10.1111/j.1365-3113.2009.04022.x>
- 51 Rao, X., Bartley, L.E., Drakakaki, G., & Anderson, C.T. (2020). Editorial: Regulation of and by the Plant Cell Wall. *Frontiers in Plant Science*, 11, 513. <https://doi.org/10.3389/fpls.2020.00513>
- 52 Bravo-Vázquez, L.A., Castro-Pacheco, A.M., Pérez-Vargas, R., Velázquez-Jiménez, J.F., & Paul, S. (2025). The Emerging Applications of Artificial MicroRNA-Mediated Gene Silencing in Plant Biotechnology. *Noncoding RNA*, 11(2), 19. <https://doi.org/10.3390/ncrna11020019>
- 53 Ritonga, F.N., Xu, Y., Cui, B., Liu, X., Gao, J., & Li, J. (2025). Unraveling the Multifaceted Roles of SPL Transcription Factors in Leaf Development. *Frontiers in Plant Science*, 16, 1696036. <https://doi.org/10.3389/fpls.2025.1696036>
- 54 Baez, L.A., Tichá, T., & Hamann, T. (2022). Cell Wall Integrity Regulation across Plant Species. *Plant Molecular Biology*, 109(4–5), 483–504. <https://doi.org/10.1007/s11103-022-01284-7>
- 55 Janusz, G., Pawlik, A., Świdarska-Burek, U., Polak, J., Sulej, J., Jarosz-Wilkolazka, A., & Paszczyński, A. (2020). Laccase Properties, Physiological Functions, and Evolution. *International Journal of Molecular Sciences*, 21, 966. <https://doi.org/10.3390/ijms21030966>
- 56 Prigge, M.J., Platre, M., Kadakia, N., Zhang, Y., Greenham, K., Szutu, W., Pandey, B.K., Bhosale, R.A., Bennett, M.J., Busch, W., & Estelle, M. (2020). Genetic Analysis of the *Arabidopsis* TIR1/AFB Auxin Receptors Reveals Both Overlapping and Specialized Functions. *eLife*, 9, e54740. <https://doi.org/10.7554/eLife.54740>
- 57 Jing, H., & Strader, L.C. (2023). AUXIN RESPONSE FACTOR Protein Accumulation and Function. *BioEssays*, 45(11), e2300018. <https://doi.org/10.1002/bies.202300018>

58 Ma, Y., Wang, R., Sang, Y., Wang, T., & Su, Y. (2025). Genome-Wide Characterization and Expression Analysis of the Growth-Regulating Factor Family in *Mikania micrantha*. *BMC Plant Biology*, 25(1), 1132. <https://doi.org/10.1186/s12870-025-07219-w>

59 Wang, P., Xiao, Y., Yan, M., Yan, Y., Lei, X., Di, P., & Wang, Y. (2023). Whole-Genome Identification and Expression Profiling of Growth-Regulating Factor (GRF) and GRF-Interacting Factor (GIF) Gene Families in *Panax ginseng*. *BMC Genomics*, 24(1), 334. <https://doi.org/10.1186/s12864-023-09435-w>

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***In silico* әдістерімен *Oryza sativa* өсімдігінде жасуша қабырғасының түзілуі мен целлюлоза биосинтезіне қатысатын SPL гендерінің miR156 арқылы посттранскрипциялық реттелуін талдау**

Өсімдік жасуша қабырғасының түзілуі мен целлюлоза биосинтезі өсімдіктің өсуін, механикалық беріктігін және биомассаның сапасын анықтайтын негізгі үдерістер. Күріш (*Oryza sativa*) жүгеріден кейінгі әлемдегі екінші маңызды дақыл толық секвенирленген және жақсы аннотацияланған геномы бар үлгілік жүйе ретінде кеңінен қолданылады. Бұл зерттеуде *Oryza sativa* (*O. sativa*) өсімдігінде жасуша қабырғасының түзілуі мен целлюлоза биосинтезіне қатысатын гендердің микроРНК (miRNA) арқылы посттранскрипциялық реттелуін зерттеу үшін *in silico* әдісі қолданылды. miRBase, TarDB және NCBI сияқты ашық дерекқорларды пайдалана отырып, miRNA таргет ген өзара әрекеттесулері жүйелі түрде болжанып, өсімдік жасуша қабырғасының құрылымдық, ферментативтік және сигналдық компоненттерімен байланысты реттеуші желілер қайта құрылды. Нәтижесінде транскрипциялық факторларды (SPL, NAC, GRAS, AP2, TCP және HD-ZIP III), жасуша қабырғасына қатысты ферменттерді (лакказалар, редокс- және мысқа тәуелді ақуыздар) және гормонға жауап беретін реттегіштерді қамтитын, жоғары сенімді 20 miRNA таргет ген жұбы анықталды. miR156 SPL реттеуші модулі екінші реттік жасуша қабырғасының түзілуі мен целлюлоза микрофибриллаларының ұйымдасуын бақылайтын орталық әрі эволюциялық тұрғыда консервацияланған түйін ретінде айқындалды. Қосымша реттеуші деңгейлерге miR164 NAC, miR397 лакказа, miR408/miR528 арқылы жүретін редокс жолдары, сондай-ақ ауксинге байланысты miRNA желілері кірді. Алынған нәтижелер күріште целлюлоза биосинтезі мен жасуша қабырғасының түзілуі күрделі, көпдеңгейлі miRNA-тәуелді реттеуші жүйелермен басқарылатынын көрсетеді. Бұл тұжырымдар болашақта эксперименттік валидация жүргізуге және ауыл шаруашылық биомассасын тиімді пайдалану мен целлюлоза негізіндегі орнықты материалдарды жетілдіруге бағытталған биотехнологиялық стратегияларды әзірлеуге теориялық негіз қалайды.

Кілт сөздер: *Oryza sativa*, miRNA, жасуша қабырғасының түзілуі, целлюлоза биосинтезі, *in silico* талдау.

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In silico* анализ посттранскрипционной регуляции генов SPL, участвующих в формировании клеточной стенки и биосинтезе целлюлозы, опосредованной miR156, у *Oryza sativa

Формирование клеточной стенки растений и биосинтез целлюлозы являются ключевыми процессами, определяющими рост растений, их механическую прочность и качество биомассы. Рис (*Oryza sativa*), вторая по значимости сельскохозяйственная культура в мире после кукурузы, широко используется как модельная система благодаря полностью секвенированному и хорошо аннотированному геному. В данном исследовании применён *in silico* метод для изучения посттранскрипционной регуляции генов, участвующих в формировании клеточной стенки и биосинтезе целлюлозы у *Oryza sativa* (*O. sativa*), опосредованной микроРНК (miRNA). С использованием открытых баз данных miRBase, TarDB и NCBI были систематически предсказаны взаимодействия miRNA с таргетными генами и реконструированы регуляторные сети, связанные со структурными, ферментативными и сигнальными компонентами клеточной стенки растений. В результате идентифицировано 20 высокодостоверных пар miRNA–таргетных генов, включающих транскрипционные факторы (SPL, NAC, GRAS, AP2, TCP и HD-ZIP III), ферменты, связанные с клеточной стенкой (лакказы, редокс- и медь-зависимые белки), а также гормон-чувствительные регуляторы. Регуляторный модуль miR156-SPL был выявлен как центральный и эволюционно консервативный узел, контролирующий формирование вторичной клеточной стенки и организацию микрофибрилл целлюлозы. Дополнительные уровни регуляции включали взаимодействия miR164-NAC, miR397-лакказа, редокс-пути, опосредованные miR408/miR528, а также miRNA-сети, связанные с ауксиновым сигналингом. Полученные результаты демонстрируют, что

биосинтез целлюлозы и формирование клеточной стенки у риса контролируются сложными многоуровневыми miRNA-опосредованными регуляторными системами. Эти выводы создают теоретическую основу для последующей экспериментальной валидации и разработки биотехнологических стратегий, направленных на эффективное использование сельскохозяйственной биомассы и совершенствование устойчивых материалов на основе целлюлозы.

Ключевые слова: *Oryza sativa*, miRNA, формирование клеточной стенки, биосинтез целлюлозы, *in silico* анализ.

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Endemic species *Allium kujukense* Vved. in Kazakhstan: distribution, history, and prospects for study

The article presents the results of a comprehensive analysis of the distribution of *Allium kujukense* Vved., a rare paleoendemic species of the mountains of southern Kazakhstan, based on the study of herbarium materials and modern electronic databases. A total of 49 documented records were analyzed, including 43 herbarium specimens from collections in Kazakhstan (AA) and Russia (MW, LE), as well as the collections of the Institute of Plant Biology and Biotechnology (IPBB), and 6 occurrence records obtained from the electronic resources Plantarium and GBIF/iNaturalist. Comparison of data from different periods made it possible to clarify the spatial structure of the species' range and to confirm its confinement to the Syrdarya Karatau mountain system (including the Boraldytau Range) and several adjacent small mountain massifs of the Western Tien Shan, forming a mosaic and geographically restricted distribution area. The presented materials substantiate the importance of conducting targeted studies on the distribution and assessment of the feasibility of measures to protect this species.

Keywords: *Allium kujukense*, Kazakhstan, Syrdarya Karatau, herbarium data, electronic databases, distribution.

Introduction

The genus *Allium*, belonging to the family Amaryllidaceae J. St. -Hil. (formerly Alliaceae J. Agardh), is characterized by extreme variability and represents one of the most taxonomically complex groups, currently comprising more than 900 accepted species and over 1,100 synonymous names at the species and infraspecific levels [1, 2]. These taxa are distributed among 15 subgenera, approximately 85 sections, and more than 30 groups below the sectional level [3–6]. For systematic purposes, a wide range of morphological characters has traditionally been employed [6–9], supplemented by data from anatomical studies [10], karyology [11–16], chemical and phenological investigations [17, 18], as well as molecular markers [19–25], which has significantly expanded the methodological basis for taxonomic decision-making.

One of the representatives of this genus that is of particular interest is the endemic species *Allium kujukense* Vved. *Allium kujukense* is a perennial herbaceous plant, a rare species endemic to the southern regions of Kazakhstan [2, 26–29], occurring on clayey and gravelly slopes of the lower mountain belt (Fig. 1).



Figure 1. *Allium kujukense* in nature (Karatau ridge, Berkara gorge) [30]

The species was described on the basis of herbarium specimens collected by V.P. Drobov, M.G. Popov, and A.I. Vvedensky in the Syrdarya Karatau (Kujuk Mountains) in 1922. Its phylogenetic relationships remained unclear for a long time: in the original description, the species was compared with the Central Asian *Allium oreophilum* C.A. Mey., from which it differs markedly by the presence of fistulose leaves [31]. R.V. Kamelin (1973) [32] assigned this clearly isolated species to the monotypic section *Vvedenskya* Kamelin within the subgenus *Melanocrommyum* (Webb et Berthel.) Rouy; later, this section was elevated to the rank of subgenus *Vvedenskya* (Kamelin) R.M. Fritsch [4, 33]. According to R.V. Kamelin (1990) [34], this species is a paleoendemic of presumed Miocene-Pliocene age and represents a narrowly localized endemic of the Syrdarya Karatau [35–37]. In the northwestern part of the Boralday Range, only a single locality of this species is currently known, situated in the valley of the Boralday River [38]. The peculiarities of the morphology, phenology, and distribution of this poorly studied species make it a significant object for botanical-geographical and floristic research.

Morphologically, *A. kujukense* is characterized by an ovoid bulb up to 1 cm in diameter with gray, papery tunics, a single hollow cylindrical leaf, and a short stem reaching up to 20 cm in height, partially enclosed by the leaf sheath. The flowers, with a purple perianth and a characteristic dark midvein, are arranged in a loose hemispherical umbel. Flowering occurs in spring (April-May) [39]. The distribution of the species is restricted to local areas of the Syrdarya Karatau and the Western Tian Shan, including the Mashat and Duany-Tau regions. In recent years, it has also been recorded from the Kazygurt Range, which is located at a considerable distance from the main part of the species' range [40].

The relevance of studying this species is determined by its endemism, morphological and taxonomic uniqueness, narrow ecological specialization, low population numbers, and the isolation of its populations, as well as its potential vulnerability to anthropogenic impacts and insufficient level of study. These factors underscore the need for further research and for the development of conservation measures aimed at protecting natural populations. The present study focuses on investigating the biological characteristics of *A. kujukense*, including its morphology, ecological preferences, and geographic distribution. The results obtained may be used to assess the current status of natural populations, thereby contributing to an evaluation of the species' conservation status in accordance with the IUCN Red List categories (International Union for Conservation of Nature), and may also serve as a basis for further population-genetic and phylogenetic studies.

Experimental

To clarify the range and prepare a summary of the species *A. kujukense* in Kazakhstan, an analysis of herbarium materials collected between 1922 and 1993 was conducted. The study included specimens from the Herbarium of the Institute of Botany and Phytointroduction (AA, Almaty, Kazakhstan), comprising 12 herbarium sheets; the Digital Herbarium of Lomonosov Moscow State University (MW, "Noah's Ark" Depository of Living Systems, Moscow, Russia), comprising 19 herbarium sheets; and the collections of the Herbarium of the Komarov Botanical Institute of the Russian Academy of Sciences (LE, Saint Petersburg,

Russia), comprising 11 herbarium sheets (Table 1). In addition, herbarium material from the Institute of Plant Biology and Biotechnology (IPBB, Almaty, Kazakhstan) was included in the analysis, represented by a single herbarium specimen collected in 2015. Furthermore, 6 occurrence records obtained between 2009 and 2019 from the electronic databases Plantarium and GBIF/iNaturalist were also included in the analysis (Table 1).

Table 1

Herbarium data of the *Allium kujukense* species

| Species | Number of documented records | Herbarium fund/electronic databases |
|-------------------------|------------------------------|-------------------------------------|
| <i>Allium kujukense</i> | 12 | AA |
| | 19 | MW |
| | 11 | LE |
| | 1 | IPBB |
| | 4 | Plantarium |
| | 2 | GBIF/iNaturalist |
| Total: | 49 | |

Results and Discussion

The analysis of herbarium materials of *A. kujukense*, comprising 49 specimens from three major herbarium collections—the Institute of Botany and Phytointroduction (AA, Almaty; 12 specimens), the Digital Herbarium of Lomonosov Moscow State University (MW; 19 specimens), and the Herbarium of the Komarov Botanical Institute of the Russian Academy of Sciences (LE, Saint Petersburg; 11 specimens)—as well as material from the Institute of Plant Biology and Biotechnology (IPBB; 1 specimen) and data from electronic databases (6 occurrence records from Plantarium and GBIF/iNaturalist), made it possible to significantly refine current knowledge of the species' distribution range and ecological preferences. The examined herbarium collections cover the period from 1922 to 1993, while records from electronic databases extend the temporal framework of field observations to 2009–2019, providing an almost century-long time span for studying the species in nature.

The combined data confirm that *A. kujukense* is an endemic species of the mountainous regions of southern Kazakhstan, occurring predominantly within the Karatau Range system and adjacent mountain massifs in its central part. The majority of records originate from the Syrdarya Karatau, including the Ikansu and Bayaldyr gorges, the area of the Achisai settlement, the surroundings of the Koynar-Kul tract, the Boralday Range (Bukeytau), and the foothills in the vicinity of the Karnak village, as well as from individual massifs and gorges of the Lesser Karatau, such as the Kujuk Mountains, the Berkera and Sayasu gorges, and Ulkun-Burul Mountains. Additional data from the LE collection expand the known distribution by providing repeated records from the Ulkun-Burul Mountains (west of Taraz), the Almalysay Gorge (Biylikol Basin), and central Karatau, including the Mynzhylky massif (Rais Gorge) and the Kan-Sai Gorge. Taken together, these data indicate that the species' range encompasses not only the main Karatau Range but also parallel, closely adjacent mountain massifs (the Boraldaytau Range, the Mashat-Daubaba Mountains, and the Kazygurt Range) that maintain similar orographic and ecological-coenotic conditions. At the same time, the distribution range remains geographically narrow and mosaic, a pattern typical of endemic petrophilous taxa of the Western Tien Shan.

The ecological preferences of *A. kujukense*, based on all analyzed materials, appear to be highly consistent. The species has been recorded predominantly on gravelly and rocky slopes of varying steepness and exposure, often on rocky or strongly stony substrates with a thin fine-earth layer, as well as on clayey slopes of the foothills. Its habitats are characteristic of petrophytic and shrub-steppe ecosystems, including petrophytic shrub communities (e.g., the Rais Gorge, Mynzhylky Massif) and shrub thickets involving the relict species *Spiraeanthus schrenkianus* Maxim. (Bayaldyr Gorge). Records from clayey slopes in the foothills of the Karatau Range (beyond the village of Karnak, the lateral site of Kentik-Sai) indicate that the species is capable of inhabiting not only distinctly stony sites but also substrates with a higher proportion of fine earth, provided that good drainage and open, insolated exposure are maintained. Nevertheless, in all cases the habitats are characterized by a combination of arid conditions, nutrient-poor soils, and pronounced stoniness of the substrate, which confirms a high degree of xerophytism and petrophily of the species.

The phenological features of *A. kujukense*, inferred from collection dates in herbarium specimens, become more clearly defined after the inclusion of materials from the LE collection. The earliest specimens were collected in early May (10 May 1977, Bayaldyr Gorge; 19 May 1930 and 27 May 1930, foothills of the Karatau Range in the Turkestan District), corresponding to the onset of flowering. Peak flowering is recorded in late May and the first half of June (collections dated 7 June 1956, 13 June 1931, as well as numerous specimens from AA and MW), whereas specimens collected in July and August (3 July 1931, 3 July 1973, 5 July 1974, 7 August 1973) indicate a transition to the fruiting stage and the completion of the vegetative cycle, particularly at higher elevations and on stony substrates. Thus, based on herbarium data, the period of active flowering of the species under natural conditions generally extends from early-mid-May to mid-June, while fruiting occurs in July and may continue until early August.

The chronological analysis (Table 2) indicates that the earliest records of the species date back to the 1920s–1930s (collections by E.A. Mokeeva, S. Yu. Lipschits, and N.V. Pavlov), demonstrating its long-standing presence in botanical literature and herbarium collections. The peak of field activity related to the collection of *A. kujukense* occurred during the 1950s–1970s, when significant contributions to the study of the species were made by A.I. Vvedensky, S.S. Kovalevskaya, V.P. Goloskokov, R.V. Kamelin, and their colleagues. Later collections from the 1970s–1980s and the 1990s (Table 2), represented mainly by materials from the Almaty (AA) and Moscow (MW) herbaria, indicate the persistence of the species in its traditional localities and the absence of clear evidence for a contraction of its range. At the same time, interpretation of this pattern is complicated by temporal heterogeneity in the intensity of botanical exploration across the region. According to GBIF/iNaturalist data, Ebel A. L. et al. (2018) [41] recorded a small population of the species on a south-facing rocky slope in the Boralday River valley at an elevation of approximately 800 m a.s.l. In 2019, new occurrences of *A. kujukense* were documented by V.G. Epiktetov within Zhambyl Region (Sayasu Gorge) [42, 43].

Table 2

Chronological analysis of *A. kujukense* collections

| Period | Data source | Main herbarium authors / observers | Data characteristics |
|-------------|------------------------------------|---|---|
| 1922 | Herbarium collections | Drobov V.P., Popov M.G., Vvedensky A.I. | Material for the description of a new species for science; the first documented data; |
| 1920s–1930s | Herbarium collections (AA, MW) | Mokeeva E.A., Lipshits S.Yu., Pavlov N.V. | Formation of a basic understanding of the area |
| 1950s–1970s | Herbarium collections (AA, MW, LE) | Vvedensky A.I., Kovalevskaya S.S., Goloskokov V.P., Kamelin R.V., et al. | Peak of field survey; maximum number of collections, clarification of distribution, morphology and ecology |
| 1970s–1980s | Herbarium collections (AA, MW) | Kamelin R.V.; Mikhailova T.A., Meshcheryakova A.P., Safronova I.N., Solovyov V.I.; Myrzakulov P.M.; Baytenov M.S. | Confirmation of species persistence in known locations |
| 1990s | Herbarium collections (AA) | Japarova N.K.; Ivashchenko A.A., SamoiloVA V.A.; | The latest herbarium data from the end of the 20th century |
| 2009 | Electronic databases (Plantarium) | Belousov E.M. [44] | Finds in the Karatau Mountains: eastern macroslope, Berkara tract |
| 2012 | Electronic databases (Plantarium) | Kolbintsev V.G. [45] | Finds in the Berkara tract |
| 2015 | IPBB collection | collected by: G.B. Sakauova identified by: A.A. Ivaschenko | Finds in Karatau, Kazanbulak tract, Kobylandy-Sai gorge |
| 2016 | Electronic databases (Plantarium) | Grebenjuk A.V. [46] | Finds in the central part of the Syrdarya Karatau ridge: southwestern macroslope, Biresik River valley (middle reaches), left side of the gorge |

Continuation of Table 2

| Period | Data source | Main herbarium authors / observers | Data characteristics |
|--------|--|------------------------------------|---|
| 2018 | Electronic databases (Plantarium) | Kolbintsev V.G. [47] | Finds in the Syrdarya Karatau, Ulkunburultau Mountains, about 900 m above sea level, rocky slope with southern exposure |
| 2018 | Electronic databases (GBIF / iNaturalist) | Ebel A.L. et. al. [41] | Discovery of a small population in the Boraldai River valley (≈ 800 m above sea level) |
| 2019 | Electronic databases (GBIF/iNaturalist and Plantarium) | Epiktetov V.G. [42, 43] | Modern finds within the Karatau ridge: Sayasu gorge, dry rocky slope |

A more detailed list of herbarium records of *A. kujukense*, including collection dates, is provided in Table 3.

Table 3

List of herbarium records of *Allium kujukense* arranged by collection date

| Collection date | Region | Label data | Collectors / Identifiers | Herbarium fund |
|-----------------|--------------------------------|--|--------------------------|----------------|
| 03.07.1923 | Syrdarya Karatau (Karatau) | Kan-Sai Gorge | E.A. Mokeeva | LE |
| 04.07.1923 | Syrdarya Karatau (Karatau) | Syrdarya Province, Karatau Mountains, scree slopes of the Kur-Kuz spur, along the Min-Dzhilke route | E.A. Mokeeva | MW |
| 27.05.1930 | Syrdarya Karatau | Turkestan District, foothills of Karatau, clayey steppe beyond the village of Karnak | S. Yu. Lipschits | MW |
| 19.05.1930 | Syrdarya Karatau (Karatau) | Bayaldyr Gorge, clayey slope, lateral spurs of Kentyk-Sai | S. Yu. Lipschits | MW |
| 19.05.1930 | Syrdarya Karatau (Karatau) | Turkestan District, foothills of Karatau, clayey slope beyond the village of Karnak | S. Yu. Lipschits | LE |
| 27.05.1930 | Syrdarya Karatau (Karatau) | Turkestan District, foothills of Karatau, clayey steppe beyond the village of Karnak | S. Yu. Lipschits | MW |
| 27.05.1930 | Syrdarya Karatau (Karatau) | Turkestan District, Karatau Mountains, Bayaldyr Gorge, clayey slope near a lateral spur of Kentyk-Sai | S. Yu. Lipschits | LE |
| 13.06.1931 | Syrdarya Karatau (Karatau) | Karatau Mountains, gravelly slope near the Koynar-Kum Mountains | N.V. Pavlov | MW |
| 13.06.1931 | Syrdarya Karatau (Karatau) | Karatau Mountains, gravelly slope near the Kainar-Kul locality | N.V. Pavlov | MW |
| 03.07.1931 | Syrdarya Karatau (Boraldaytau) | Karatau Mountains, gravelly screes below the summit of Bukuy-Tau | N.V. Pavlov | MW |
| 28.06.1931 | Syrdarya Karatau (Boraldaytau) | Karatau Mountains, rocky slope near the summit of Bugazy-Tau, 1500 m a.s.l. | N.V. Pavlov | MW |
| 13.06.1931 | Syrdarya Karatau (Karatau) | Karatau Mountains, gravelly slope near the Koynar-Kul locality | N.V. Pavlov | LE |
| 03.07.1931 | Syrdarya Karatau (Boraldaytau) | Gravelly slope above the summit of Bukey-Tau | N.V. Pavlov | LE |
| 21.06.1931 | Syrdarya Karatau (Karatau) | Former Syrdarya District, Dzhualy District, spurs of Karatau, Chimbulak locality, north-facing slope toward the Tespe-Bulak stream | V.S. Kornilova | AA |

| Collection date | Region | Label data | Collectors / Identifiers | Herbarium fund |
|-----------------|------------------------------------|---|--|----------------|
| 01.07.1934 | Syrdarya Karatau (Boraldaytau) | Karatau Range, near the village of Mikhailovka, gravelly slope | L. Chilikina | MW |
| 13.07.1934 | Talas Alatau | Syrdarya District, rocky slope of the Mashat Mountains opposite Tyulkubas Station | N.V. Pavlov | MW |
| 12.06.1934 | Syrdarya Karatau (Karatau) | Kainar-Bastau area, lower terrace plateau of Kyzyl-Nayza | G. Mikeshein | MW |
| 14.06.1936 | Syrdarya Karatau (Karatau) | Eastern Karatau (Syrdarya), Elekty-Sai locality, gravelly slope | L. Chilikina | MW |
| 31.05.1936 | Syrdarya Karatau (Karatau) | Little Karatau Valley, gravelly slope near the Shamdy River valley | L. Chilikina | MW |
| 12.06.1936 | Syrdarya Karatau (Karatau) | Western Tien Shan, eastern part of the Karatau Range, gravelly summit in the upper reaches of the Arbatas River | L. Chilikina | MW |
| 24.05.1939 | Syrdarya Karatau (Little Karatau) | Karatau Mountains, gravelly slopes at the Kujuk Pass (3 sheets) | N.V. Pavlov | MW |
| 27.05.1940 | Syrdarya Karatau (Central Karatau) | Zhambyl Region, Karatau Mountains, rocky slopes of hills at the foot of Mynzhylky Peak | N.M. Kuznetsov | AA |
| 27.06.1940 | Syrdarya Karatau (Central Karatau) | Zhambyl Region, Karatau Mountains, rocky slopes of hills at the foot of Mynzhylky Peak | N.M. Kuznetsov, N.V. Pavlov | MW |
| 27.05.1948 | Syrdarya Karatau (Central Karatau) | Zhambyl Region, rocky slope on Mount Ulkun-Burul | N.V. Pavlov | MW |
| 27.05.1948 | Syrdarya Karatau (Little Karatau) | Rocky slope on the piedmont apron of Mount Ulken-Burul | N.V. Pavlov | AA |
| 28.05.1952 | Syrdarya Karatau (Karatau) | Karatau Mountains, mountain ridge between the Birlik and Dzhengilchik rivers, upper slopes of the mountain, southeastern exposure | N. Parfentyeva | MW |
| 07.06.1956 | Syrdarya Karatau (Boraldaytau) | Fine-earth patches on a rocky slope between the village of Kitaevka and the Boralday River | A.I. Vvedensky, S.S. Kovalevskaya | LE |
| 06.06.1956 | Syrdarya Karatau (Little Karatau) | Kujuk Mountains, gravelly slopes | M.S. Baitenov | AA |
| 20.05.1963 | Syrdarya Karatau (Little Karatau) | Central part of the northern slope of the Ulkun-Burul Mountains (west of Zhambyl), southern rocky slopes | V.P. Goloskokov | AA |
| 20.05.1963 | Syrdarya Karatau (Little Karatau) | Central part of the northern slope of the Ulkun-Burul Mountains, west of Zhambyl; southern rocky slopes | V.P. Goloskokov | LE |
| 03.07.1973 | Syrdarya Karatau (Little Karatau) | Eastern part of Almalysai Gorge (Biylikol Basin), gravelly slope | R.V. Kamelin | LE |
| 07.08.1973 | Syrdarya Karatau (Central Karatau) | Central massif of the Syrdarya Karatau, ridge above the settlement of Achisai | R.V. Kamelin | LE |
| 05.07.1974 | Syrdarya Karatau (Central Karatau) | Mynzhylky Massif, Rais Gorge, petrophytic shrub-steppe | R.V. Kamelin | LE |
| 10.05.1977 | Syrdarya Karatau (Central Karatau) | Bayaldyr Gorge, 5 km above Bayaldyr Lake, in <i>Spiraeanthus</i> thickets | R.V. Kamelin, T.A. Mikhailova, A.P. Mishrenkova, I.N. Safronova, V.I. Solovyov | LE |
| 11.06.1981 | Syrdarya Karatau (Central Karatau) | Karatau Range, Kelinchek Massif, meadow-steppe slopes | M.S. Baitenov | AA |
| 22.05.1985 | Syrdarya Karatau (Central Karatau) | Central Karatau, northern macroslope, Kelenizek Gorge, rocky sites | P.M. Myrzakulov | AA |

Continuation of Table 3

| Collection date | Region | Label data | Collectors / Identifiers | Herbarium fund |
|-----------------|------------------------------------|--|--|--------------------|
| 15.05.1985 | Syrdarya Karatau (Central Karatau) | Central Karatau, Ikansu Gorge | P.M. Myrzakulov | AA |
| 17.05.1985 | Syrdarya Karatau (Central Karatau) | Central Karatau, southern macroslope, 10–12 km NW of the Achisai mine, vicinity of Itsanylgil, clay–gravelly slope | P.M. Myrzakulov | AA |
| 08.05.1989 | Syrdarya Karatau (Karatau) | Karatau Range, Berisek Gorge, south-facing slope | A.A. Ivashchenko, V.A. Samoilova | AA |
| 25.05.1993 | Syrdarya Karatau (Karatau) | Syrdarya Karatau Range, Ikansu River Gorge, rocky east-facing slope | N.K. Zhaparova | AA |
| май, 2009 | Syrdarya Karatau | Karatau, eastern macroslope, Berkera locality | E.M. Belousov | Plantarium |
| 26.05.2012 | Syrdarya Karatau | Berkera locality | V.G. Kolbintsev | Plantarium |
| 17.06.2015 | Syrdarya Karatau (Central Karatau) | Kazanbulak, Kabylandy-Sai Gorge | Collected by G.B. Sakauova; identified by A.A. Ivashchenko | IPBB collection |
| 28.05.2016 | Syrdarya Karatau | Central part of the Syrdarya Karatau Range: southwestern macroslope, Biresik River valley | A.V. Grebenyuk | Plantarium |
| 31.05.2018 | Syrdarya Karatau | Syrdarya Karatau, Ulkunburultau Mountains, ca. 900 m a.s.l., rocky slope | V.G. Kolbintsev | Plantarium |
| 23.05.2018 | Syrdarya Karatau (Boraldytau) | Turkestan Region, Baidibek District, Boraldy River valley (≈800 m a.s.l.) | A.L. Ebel | GBIF / iNaturalist |
| 03.06.2019 | Syrdarya Karatau | Zhambyl Region, Zhualy District, Sayasu Gorge, dry rocky slope | V. Epiktetov | GBIF / iNaturalist |

Notes. AA — Herbarium of the Institute of Botany and Phytointroduction (Almaty, Kazakhstan); MW — Digital Herbarium of Lomonosov Moscow State University (Noah's Ark Depository of Living Systems, Moscow, Russia); LE — Herbarium of the Komarov Botanical Institute, Russian Academy of Sciences (Saint Petersburg, Russia); IPBB — collection of the Institute of Plant Biology and Biotechnology.

Based on the analysis of herbarium materials and published literature data, a distribution map of *A. kujukense* within the currently known range in Kazakhstan was compiled (Fig. 2).

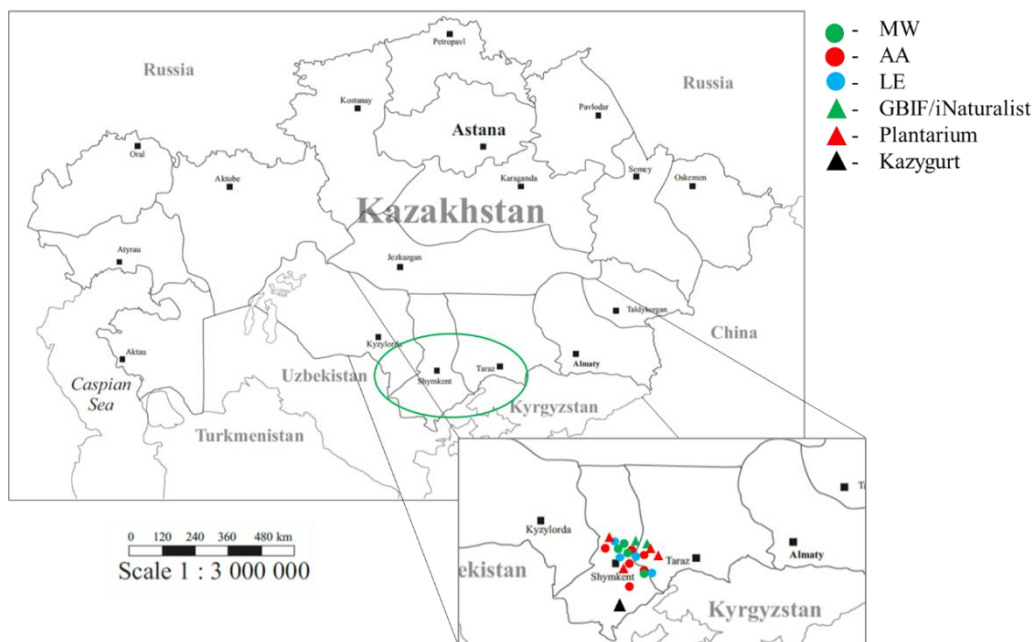


Figure 2. Map of the distribution of *Allium kujukense* in Kazakhstan

Summarizing the results, it can be concluded that *A. kujukense* remains an endemic species of the mountains of southern Kazakhstan, characterized by a narrow yet structurally complex range encompassing the Syrdarya Karatau Range and several morphologically and ecologically similar small mountain massifs. Its stable association with arid petrophytic and shrub-steppe habitats, rocky and clayey slopes, together with a relatively short vegetative period, makes the species potentially vulnerable to anthropogenic pressures related to the transformation of mountain landscapes, including grazing, cultivation of foothills, mining activities, and increasing recreational impacts. The overall body of herbarium evidence highlights the necessity of updating field surveys in key localities, refining estimates of population size, and, if warranted, considering the inclusion of the species in regional and national lists of protected plants. This is particularly relevant given that the species is not mentioned in the Red Data Books of two regions — Zhambyl (2007) [48] and Turkestan (formerly South Kazakhstan, 2002) [49] — whereas the much more widely distributed *Allium karataviense* Regel is included.

Conclusion

Thus, based on the analysis of herbarium materials from the AA, MW, and LE collections, the IPBB collection, as well as data from the electronic databases Plantarium and GBIF/iNaturalist, the distribution range, ecological preferences, and history of study of *A. kujukense* within Kazakhstan have been clarified. The species is a narrowly localized endemic of the mountainous regions of southern Kazakhstan, occurring predominantly within the Syrdarya Karatau Range system (including the Boraldytau Range) and several adjacent small mountain massifs of the Western Tian Shan, forming a mosaic and geographically restricted range. *A. kujukense* is characterized by a stable ecological association with arid conditions, rocky and clayey slopes, and petrophytic shrub communities, as well as by a relatively short vegetative period. The chronological analysis of data spanning the period from 1922 to 2019 did not reveal clear evidence of range contraction based on herbarium records; however, heterogeneity in the intensity of regional botanical exploration and the presence of only a limited number of recent records indicate the need for further targeted field surveys. Given the potential vulnerability of the species to anthropogenic impacts, monitoring of *A. kujukense* populations in its main distribution areas will be continued in order to refine estimates of population size, assess population condition and dynamics, and evaluate the necessity of additional conservation measures.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Ivashchenko A.A.** — conceptualization, data curation, investigation, methodology, writing draft- editing; **Yermagambetova M.M.** — investigation, visualization, data curation, formal analysis, supervision, writing draft-editing.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Govaerts R. World checklist of Amaryllidaceae (2005–2020) [Electronic resource] / R. Govaerts, S. Kington, N. Friesen, R. Fritsch, D.A. Snijman, R. Marcucci, P.A. Silverstone-Sopkin, S. Brullo. — 2020. — Access mode: <http://apps.kew.org/wcsp> (Date of request: 15.12.2025).
- 2 Plants of the World Online / Royal Botanic Gardens, Kew. — [Electronic resource]. — 2025. — Access mode: <https://powo.science.kew.org/> (Date of request: 15.12.2025).
- 3 Friesen N. Phylogeny and new intrageneric classification of *Allium* (Alliaceae) based on nuclear ribosomal DNA ITS sequences / N. Friesen, R.M. Fritsch, F.R. Blattner // *Aliso*. — 2006. — Vol. 22. — P. 372–395.

- 4 Fritsch R. M. New classification of *Allium* L. subg. *Melanocrommyum* (Webb & Berthel.) Rouy (Alliaceae) based on molecular and morphological characters / R.M. Fritsch, F.R. Blattner, M. Gurushidze // *Phyton. Annales Rei Botanicae*. — 2010. — Vol. 49. — P. 145–320.
- 5 The *Allium* genomes / M. Shigyo, A. Khar, M. Abdelrahman (Eds.). — Cham: Springer International Publishing, 2018. — 230 p. DOI: 10.1007/978-3-319-95825-5.
- 6 Jang J. E. Flower morphology of *Allium* (Amaryllidaceae) and its systematic significance / J.E. Jang, S. Baasanmunkh, N. Nyamgerel, S.Y. Oh, J.H. Song, Z. Yusupov, H.J. Choi // *Plant Diversity*. — 2023. — Vol. 46, No. 1. — P. 3.
- 7 Черемушкина В. А. Биология луков Евразии / В. А. Черемушкина. — Новосибирск: Наука, 2004. — 280 с.
- 8 Namin H. H. Pollen morphology of selected species of *Allium* (Alliaceae) distributed in Iran / H.H. Namin, S.S. Mehrvarz, S. Zarre et al. // *Nordic Journal of Botany*. — 2009. — Vol. 27. — P. 54–60.
- 9 Choi H. J. Systematics of disjunct northeastern Asian and northern North American *Allium* (Amaryllidaceae) / H.J. Choi, L.M. Giussani, C.G. Jang et al. // *Botany*. — 2012. — Vol. 90. — P. 491–508.
- 10 Khorasani M. Bulb tunic anatomy and its taxonomic implication in *Allium* L. (Amaryllidaceae: Allioideae) / M. Khorasani, S. Saeidi Mehrvarz, S. Zarre // *Plant Biosystems*. — 2018. — Vol. 152. — P. 1311–1328.
- 11 Tang H. Origin of the Qinghai–Tibetan Plateau endemic *Milula* (Liliaceae): further insights from karyological comparisons with *Allium* / H. Tang, L. Ma, S. An, J. Li // *Caryologia*. — 2005. — Vol. 58. — P. 320–331.
- 12 Nagaki K. Chromosome dynamics visualized with an anti-centromeric histone H3 antibody in *Allium* / K. Nagaki, M. Yamamoto, N. Yamaji, Y. Mukai, M. Murata // *PLoS One*. — 2012. — Vol. 7. — No. 12. — e51315.
- 13 Yamamoto M. Molecular cytogenetic and epigenetic components of crossing barriers and peculiar reproduction ability in *Allium* hybrids / M. Yamamoto // *The Nucleus*. — 2015. — Vol. 58, No. 3. — P. 165–172.
- 14 Yamamoto M. Repetitive sequences / M. Yamamoto // *The Allium genomes* / eds. M. Shigyo, A. Khar, M. Abdelrahman. — Cham: Springer International Publishing, 2018. — P. 99–112.
- 15 Abdildanov D. S. Endemic of Kazakhstan *Allium lehmannianum* Merckl. ex Bunge and its position within the genus *Allium* / D.S. Abdildanov, P.V. Vesselova, G.M. Kudabayeva, B.B. Osmonali, M.V. Skaptsov, N. Friesen // *Plants*. — 2025. — Vol. 14, No. 7. — 1113.
- 16 Friesen N. Taxonomy and dated molecular phylogeny of *Allium oreophilum* sensu lato uncover a surprising number of cryptic taxa / N. Friesen, G. Lazkov, I.G. Levichev, M. Leweke, D. Abdildanov, N. Turdumatova et al. // *Taxon*. — 2025. — Vol. 74, No. 5. — P. 1035–1053.
- 17 Kadyrbayeva G. The phenolic compounds profile and cosmeceutical significance of two Kazakh species of onions: *Allium galanthum* and *A. turkestanicum* / G. Kadyrbayeva, J. Zagórska, A. Grzegorzczak, K. Gawel-Bęben, M. Str-Gomółka, A. Ludwiczuk et al. // *Molecules*. — 2021. — Vol. 26. — 5491. DOI: 10.3390/molecules26185491.
- 18 Кукушкина Т.А. Содержание биологически активных веществ в зеленой массе многолетних луков (*Allium* L.) / Т.А. Кукушкина, Т.И. Фомина // *Аграрный вестник Урала*. — 2021. — № 4 (207). — С. 85–92. DOI: 10.32417/1997-4868-2021-207-04-85-92.
- 19 Nguyen N. H. A molecular phylogeny of the wild onions (*Allium*; Alliaceae) with a focus on the western North American center of diversity / N.H. Nguyen, H.E. Driscoll, C.D. Specht // *Molecular Phylogenetics and Evolution*. — 2008. — Vol. 47. — P. 1157–1172.
- 20 Mahajan V. Genetic fingerprinting of onion cultivars using SSR markers / V. Mahajan, J. Jakse, M.J. Havey, K.E. Lawande // *Indian Journal of Horticulture*. — 2009. — Vol. 66, No. 1. — P. 62–68.
- 21 Seregin A. Molecular and morphological revision of the *Allium saxatile* group (Amaryllidaceae): geographical isolation as the driving force of underestimated speciation / A. Seregin, G. Anackov, N. Friesen // *Botanical Journal of the Linnean Society*. — 2015. — Vol. 178, No. 1. — P. 67–101. DOI: 10.1111/boj.12269.
- 22 Yang L. Development of polymorphic genic SSR markers by transcriptome sequencing in the Welsh onion (*Allium fistulosum* L.) / L. Yang, C. Wen, H. Zhao, Q. Liu, J. Yang, L. Liu, Y. Wang // *Applied Sciences*. — 2015. — Vol. 5, No. 4. — P. 1050–1063.
- 23 Abugalieva S. Taxonomic assessment of *Allium* species from Kazakhstan based on ITS and matK markers / S. Abugalieva, L. Volkova, Y. Genievskaya, A. Ivaschenko, Y. Kotukhov, G. Sakauova, Y. Turuspekov // *BMC Plant Biology*. — 2017. — Vol. 17. — Suppl. 2. — 258.
- 24 Hu J. Development of SSR molecular markers for *Allium mongolicum* / J. Hu, X. Hu, Q. Zhang, J. Zhang, B. Fan, Q. Yu // *Genes & Genomics*. — 2017. — Vol. 39, No. 12. — P. 1387–1394.
- 25 Li X. SSR markers development and their application in genetic diversity evaluation of garlic (*Allium sativum*) germplasm / X. Li, L. Qiao, B. Chen, Y. Zheng, C. Zhi, S. Zhang et al. // *Plant Diversity*. — 2022. — Vol. 44, No. 5. — P. 481–491.
- 26 Введенский А.И. Лук — *Allium* L. / А.И. Введенский // *Флора СССР*. — Т. 4: Liliaceae Hall. — Orchidaceae Lindl. — Л.: Изд-во АН СССР, 1935. — С. 112–280.
- 27 Абдулина С.А. Список сосудистых растений Казахстана / С.А. Абдулина. — Алматы, 1999. — 187 с.
- 28 Рачковская Е.И. О Каратавской ботанико-географической провинции / Е.И. Рачковская, Р.Е. Садвакасов // *Ботанические исследования в Казахстане*. — Алматы, 2003. — С. 108–112.

- 29 Сакауова Г. Б. Материалы к флоре редких и эндемичных растений Боралдайских гор / Г.Б. Сакауова, Б.М. Мошкалов // Научные труды Южно-Казахстанского государственного университета им. М. Ауэзова. — 2015. — С. 140.
- 30 Kolbintsev V. Image of *Allium kujukense* Vved. [Electronic resource] / V. Kolbintsev // Plantarium. Plants and lichens of Russia and neighboring countries. — 2014. — Access mode: <https://www.plantarium.ru/lang/en/page/image/id/268515.html> (Date of request: 22.01.2026).
- 31 Введенский А.И. *Allium L.* — Лук / А.И. Введенский // Определитель растений Средней Азии. Критический конспект флоры. — Т. 2. — Ташкент: ФАН Узбекской ССР, 1971. — С. 39–89.
- 32 Камелин Р.В. Флорогенетический анализ естественной флоры горной Средней Азии / Р.В. Камелин. — Л.: Наука, 1973. — 356 с.
- 33 Красовская Л.С. Род *Allium L.* и вклад Р.В. Камелина в его познание / Л.С. Красовская // Ботанико-географические исследования. Камелинские чтения: сб. науч. тр. / под ред. С.А. Овеснова, О.Г. Барановой. — Пермь: Изд-во Пермского нац. исслед. политехн. ун-та, 2019. — С. 100–103.
- 34 Камелин Р.В. Флора Сырдарьинского Каратау / Р.В. Камелин. — Л.: Наука, 1990. — 145 с.
- 35 Tojibaev Sh. K. An annotated checklist of endemic vascular plants of the Tian-Shan Mountains in Central Asian countries / Sh. K. Tojibaev, C. Jang, G.A. Lazkov, K.S. Chang, G.T. Sitpayeva, N. Safarov et al. // Phytotaxa. — 2020. — Vol. 464, No. 2. — P. 117–158.
- 36 Sennikov A. N. Checklist of vascular plants of the Tian-Shan Mountain System / A.N. Sennikov, K.S. — Pocheon: Korea National Arboretum, 2021.
- 37 Kubentayev S. A. Revised checklist of endemic vascular plants of Kazakhstan / S.A. Kubentayev, D.T. Alibekov, Y.V. Perezhogin, G.A. Lazkov, A.N. Kupriyanov, A.L. Ebel et al. // PhytoKeys. — 2024. — Vol. 238. — P. 241.
- 38 Эбель А.Л. Флора северо-западной части Боралдайтау / А.Л. Эбель, А.Н. Куприянов, И.А. Хрусталева, Н.Н. Лащинский, Б.М. Мошкалов. — Шымкент: South Print Corporation, 2024. — 256 с.
- 39 Флора Казахстана. — Алма-Ата, 1958. — Т. 2. — 180 с.
- 40 Иващенко А.А. Новые и редкие виды флоры хребта Казыгурт (Западный Тянь-Шань) / А.А. Иващенко // Изучение, сохранение и рациональное использование растительного мира Евразии: материалы Междунар. науч. конф. — Алматы, 2017. — С. 218–223.
- 41 iNaturalist contributors. iNaturalist Research-grade Observations. Occurrence dataset. iNaturalist.org. — [Electronic resource]. — 2026. — Access mode: <https://www.gbif.org/occurrence/2557780219> (accessed via GBIF.org on 22 January 2026) <https://doi.org/10.15468/ab3s5x>
- 42 iNaturalist contributors. iNaturalist Research-grade Observations. Occurrence dataset. iNaturalist.org. — [Electronic resource]. — 2026.— Access mode: <https://www.gbif.org/occurrence/2550129001> (accessed via GBIF.org on 22 January 2026) <https://doi.org/10.15468/ab3s5x>
- 43 Epiktetov V. Image of *Allium kujukense* Vved [Electronic resource] / V. Epiktetov // Plantarium. Plants and lichens of Russia and neighboring countries: open online galleries and plant identification guide. — 2019. — Access mode: <https://www.plantarium.ru/lang/en/page/image/id/635306.html> (accessed on 22 Jan 2026).
- 44 Belousov E. Image of *Allium kujukense* Vved [Electronic resource] / E. Belousov // Plantarium. Plants and lichens of Russia and neighboring countries: open online galleries and plant identification guide. — 2009. — Access mode: <https://www.plantarium.ru/lang/en/page/image/id/41970.html> (accessed on 22 Jan 2026).
- 45 Kolbintsev V. Image of *Allium kujukense* Vved [Electronic resource] / V. Kolbintsev // Plantarium. Plants and lichens of Russia and neighboring countries: open online galleries and plant identification guide. — 2012. — Access mode: <https://www.plantarium.ru/lang/en/page/image/id/268515.html> (accessed on 22 Jan 2026).
- 46 Grebenjuk A. Image of *Allium kujukense* Vved [Electronic resource] / A. Grebenjuk // Plantarium. Plants and lichens of Russia and neighboring countries: open online galleries and plant identification guide. — 2016. — Access mode: <https://www.plantarium.ru/lang/en/page/image/id/458229.html> (accessed on 22 Jan 2026).
- 47 Kolbintsev V. Image of *Allium kujukense* Vved [Electronic resource] / V. Kolbintsev // Plantarium. Plants and lichens of Russia and neighboring countries: open online galleries and plant identification guide. — 2018. — Access mode: <https://www.plantarium.ru/lang/en/page/image/id/569906.html> (accessed on 22 Jan 2026).
- 48 Аралбай Н.К. Государственный кадастр растений Жамбылской области / Н.К. Аралбай, С.К. Мухтубаева, А.А. Шорманова. — Алматы, 2007. — 517 с.
- 49 Аралбаев Н.К. Государственный кадастр растений Южно-Казахстанской области. Красная книга: дикорастущие редкие и исчезающие виды растений / Н.К. Аралбаев, Н.К. Жапарова, Г.М. Кудабеева, М.П. Данилов, П.В. Веселова, Р.О. Закирова. — Алматы: НИЦ «Ғылым», 2002. — 148 с.

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**Қазақстандағы *Allium kujukense* Vved. эндем түрі:
таралуы, тарихы және зерттеу перспективалары**

Мақалада гербарий материалдары мен заманауи электрондық деректер базасын зерделеу негізінде Оңтүстік Қазақстан тауларының сирек кездесетін палеоэндемигі күйік пиязының (*Allium kujukense* Vved.) таралуын кешенді талдау нәтижелері келтірілген. Жұмыста Қазақстан (AA) және Ресей (MW, LE) 43 гербарий парағын және ӨББИ жинағын, сондай-ақ Plantarium және GBIF/iNaturalist электрондық ресурстарынан 6 бақылауды қамтитын 49 құжатталған жазба талданды. Өртүрлі кезендердің деректерін салыстыру түрдің таралу аймағының кеңістіктік құрылымын нақтылауға және оның Сырдария Қаратауы жоталар жүйесіне (Боралдайтауды қоса алғанда) және Батыс Тянь-Шаньның мозаикалық және географиялық тұрғыдан шектеулі таралу аймағын құрайтын бірқатар жақын маңдағы шағын тау жоталарымен шектелгенін растауға мүмкіндік берді. Ұсынылған материалдар осы түрдің таралуы бойынша арнайы зерттеулер және оны қорғау шараларын жүргізудің маңыздылығын негіздейді.

Кілт сөздер: *Allium kujukense*, Қазақстан, Сырдария Қаратауы, гербарий деректері, электрондық деректер, таралуы.

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**Эндемичный вид *Allium kujukense* Vved. в Казахстане:
распространение, история и перспективы изучения**

В статье представлены результаты комплексного анализа распространения лука куюкского (*Allium kujukense* Vved.), редкого палеоэндемика гор Южного Казахстана, на основе изучения гербарных материалов и современных электронных баз данных. В работе проанализированы 49 документированных записей, включающих 43 гербарных листа из фондов Казахстана (AA) и России (MW, LE) и коллекции ИББР, а также 6 наблюдений из электронных ресурсов Plantarium и GBIF/iNaturalist. Сопоставление данных различных периодов позволило уточнить пространственную структуру ареала вида и подтвердить его приуроченность к системе хребта Сырдарьинский Каратау (включая Боралдайтау) и ряду близлежащих небольших горных массивов Западного Тянь-Шаня, формирующих мозаичный и географически ограниченный ареал. Представленные материалы обосновывают важность проведения специальных исследований по распространению и оценке целесообразности мер по охране данного вида.

Ключевые слова: *Allium kujukense*, Казахстан, Сырдарьинский Каратау, гербарные данные, электронные базы данных, распространение.

References

- 1 Govaerts, R., Kington, S., Friesen, N., Fritsch, R., Snijman, D. A., Marcucci, R., Silverstone-Sopkin, P. A., & Brullo, S. (2020). World checklist of Amaryllidaceae (2005–2020). *apps.kew.org*. Retrieved from <http://apps.kew.org/wcsp>
- 2 (2025). Plants of the World Online. Royal Botanic Gardens, Kew. *powo.science.kew.org* Retrieved from <https://powo.science.kew.org/>
- 3 Friesen, N., Fritsch, R. M., & Blattner, F. R. (2006). Phylogeny and new intrageneric classification of *Allium* (Alliaceae) based on nuclear ribosomal DNA ITS sequences. *Aliso*, 22, 372–395.
- 4 Fritsch, R. M., Blattner, F. R., & Gurushidze, M. (2010). New classification of *Allium* L. subg. *Melanocrommyum* (Webb & Berthel.) Rouy (Alliaceae) based on molecular and morphological characters. *Phyton. Annales Rei Botanicae*, 49, 145–320.
- 5 Shigyo, M., Khar, A., & Abdelrahman, M. (Eds.). (2018). The *Allium* genomes. *Springer*, 230 p. <https://doi.org/10.1007/978-3-319-95825-5>
- 6 Jang, J. E., Baasanmunkh, S., Nyamgerel, N., Oh, S. Y., Song, J. H., Yusupov, Z., & Choi, H. J. (2023). Flower morphology of *Allium* (Amaryllidaceae) and its systematic significance. *Plant Diversity*, 46(1), 3.
- 7 Cheremushkina, V. A. (2004). *Biologiya lukov Evrazii* [Biology of onions of Eurasia]. Nauka [in Russian].
- 8 Namin, H. H., Mehrvarz, S. S., Zarre, S., et al. (2009). Pollen morphology of selected species of *Allium* (Alliaceae) distributed in Iran. *Nordic Journal of Botany*, 27, 54–60.
- 9 Choi, H. J., Giussani, L. M., Jang, C. G., et al. (2012). Systematics of disjunct northeastern Asian and northern North American *Allium* (Amaryllidaceae). *Botany*, 90, 491–508.

- 10 Khorasani, M., Saeidi Mehrvarz, S., & Zarre, S. (2018). Bulb tunic anatomy and its taxonomic implication in *Allium L.* (Amaryllidaceae: Allioidae). *Plant Biosystems*, *152*, 1311–1328.
- 11 Tang, H., Ma, L., An, S., & Li, J. (2005). Origin of the Qinghai–Tibetan Plateau endemic *Milula* (Liliaceae): Further insights from karyological comparisons with *Allium*. *Caryologia*, *58*, 320–331.
- 12 Nagaki, K., Yamamoto, M., Yamaji, N., Mukai, Y., & Murata, M. (2012). Chromosome dynamics visualized with an anti-centromeric histone H3 antibody in *Allium*. *PLoS ONE*, *7*(12), e51315. <https://doi.org/10.1371/journal.pone.0051315>
- 13 Yamamoto, M. (2015). Molecular cytogenetic and epigenetic components of crossing barriers and peculiar reproduction ability in *Allium* hybrids. *The Nucleus*, *58*(3), 165–172.
- 14 Yamamoto, M. (2018). Repetitive sequences. In M. Shigyo, A. Khar, & M. Abdelrahman (Eds.). *The Allium genomes* (pp. 99–112). Springer.
- 15 Abdildanov, D. S., Vesselova, P. V., Kudabayeva, G. M., Osmonali, B. B., Skaptsov, M. V., & Friesen, N. (2025). Endemic of Kazakhstan *Allium lehmannianum* Merckl. ex Bunge and its position within the genus *Allium*. *Plants*, *14*(7), 1113. <https://doi.org/10.3390/plants14071113>
- 16 Friesen, N., Lazkov, G., Levichev, I. G., Leweke, M., Abdildanov, D., Turdumatova, N., et al. (2025). Taxonomy and dated molecular phylogeny of *Allium oreophilum* sensu lato uncover a surprising number of cryptic taxa. *Taxon*, *74*(5), 1035–1053.
- 17 Kadyrbayeva, G., Zagórska, J., Grzegorzczak, A., Gawel-Bęben, K., Strzępek-Gomółka, M., Ludwiczuk, A., et al. (2021). The phenolic compounds profile and cosmeceutical significance of two Kazakh species of onions: *Allium galanthum* and *A. turkestanicum*. *Molecules*, *26*, 5491. <https://doi.org/10.3390/molecules26185491>
- 18 Kukushkina, T. A., & Fomina, T. I. (2021). Soderzhanie biologicheskii aktivnykh veshchestv v zelenoi masse mnogoletnikh lukov (*Allium L.*) [Content of biologically active substances in the green mass of perennial onions]. *Agrarnyi vestnik Urala — Agrarian Bulletin of the Urals*, *4*(207), 85–92. <https://doi.org/10.32417/1997-4868-2021-207-04-85-92> [in Russian].
- 19 Nguyen, N. H., Driscoll, H. E., & Specht, C. D. (2008). A molecular phylogeny of the wild onions (*Allium*; Alliaceae) with a focus on the western North American center of diversity. *Molecular Phylogenetics and Evolution*, *47*, 1157–1172.
- 20 Mahajan, V., Jakse, J., Havey, M. J., & Lawande, K. E. (2009). Genetic fingerprinting of onion cultivars using SSR markers. *Indian Journal of Horticulture*, *66*(1), 62–68.
- 21 Seregin, A., Anackov, G., & Friesen, N. (2015). Molecular and morphological revision of the *Allium saxatile* group (Amaryllidaceae): Geographical isolation as the driving force of underestimated speciation. *Botanical Journal of the Linnean Society*, *178*(1), 67–101. <https://doi.org/10.1111/boj.12269>
- 22 Yang, L., Wen, C., Zhao, H., Liu, Q., Yang, J., Liu, L., & Wang, Y. (2015). Development of polymorphic genic SSR markers by transcriptome sequencing in the Welsh onion (*Allium fistulosum L.*). *Applied Sciences*, *5*(4), 1050–1063.
- 23 Abugalieva, S., Volkova, L., Genievskaya, Y., Ivaschenko, A., Kotukhov, Y., Sakauova, G., & Turuspekov, Y. (2017). Taxonomic assessment of *Allium* species from Kazakhstan based on ITS and matK markers. *BMC Plant Biology*, *17*(Suppl. 2), 258.
- 24 Hu, J., Hu, X., Zhang, Q., Zhang, J., Fan, B., & Yu, Q. (2017). Development of SSR molecular markers for *Allium mongolicum*. *Genes & Genomics*, *39*(12), 1387–1394.
- 25 Li, X., Qiao, L., Chen, B., Zheng, Y., Zhi, C., Zhang, S., et al. (2022). SSR markers development and their application in genetic diversity evaluation of garlic (*Allium sativum*) germplasm. *Plant Diversity*, *44*(5), 481–491.
- 26 Vvedensky, A. I. (1935). Luk — *Allium L.* [Onion — *Allium L.*]. *Flora SSSR — Flora of the USSR*, *4*, 112–280. Leningrad: Izdatelstvo Akademii Nauk SSSR [in Russian].
- 27 Abdulina, S. A. (1999). *Spisok sosudistykh rastenii Kazakhstana* [Checklist of vascular plants of Kazakhstan]. Almaty [in Russian].
- 28 Rachkovskaya, E. I., & Sadvakasov, R. E. (2003). O Karatavskoi botaniko-geograficheskoi provintsii [On the Karatau botanical-geographical province]. *Botanicheskie issledovaniia v Kazakhstane — Botanical studies in Kazakhstan* (pp. 108–112). Almaty [in Russian].
- 29 Sakauova, G. B., & Moshkalov, B. M. (2015). Materialy k flore redkikh i endemichnykh rastenii Boraldaiskikh gor [Materials on the flora of rare and endemic plants of the Boraldai Mountains]. *Nauchnye trudy Yuzhno-Kazakhstanskogo gosudarstvennogo universiteta imeni M. Auezova — Scientific Works of M. Auezov South Kazakhstan University* (p. 140) [in Russian].
- 30 Kolbintsev, V. (2014). Image of *Allium kujukense* Vved. *Plantarium. Plants and lichens of Russia and neighboring countries*. Retrieved from <https://www.plantarium.ru/lang/en/page/image/id/268515.html>
- 31 Vvedensky, A. I. (1971). *Allium L.* — Luk [*Allium L.* — Onion]. *Opredelitel rastenii Srednei Azii. Kriticheskii konspekt flory — Identification guide of plants of Central Asia. Critical synopsis of flora*, *2*, 39–89). FAN Uzbekskoi SSR [in Russian].
- 32 Kamelin, R. V. (1973). *Florogeneticheskii analiz estestvennoi flory gornoi Srednei Azii* [Florogenetic analysis of the natural flora of Mountain Central Asia]. Nauka [in Russian].
- 33 Krasovskaya, L. S. (2019). Rod *Allium L.* i vklad R.V. Kamelina v ego poznanie [The genus *Allium L.* and the contribution of R.V. Kamelin to its study]. *Botaniko-geograficheskie issledovaniia. Kamelinskie chteniia: sbornik nauchnykh trudov — Botanical and geographical studies. Kamelin readings: a collection of scientific papers* (pp. 100–103). Perm: Izdatelstvo Permskogo natsionalnogo issledovatel'skogo politekhnicheskogo universiteta [in Russian].
- 34 Kamelin, R. V. (1990). *Flora Syrdarinskogo Karatau* [Flora of the Syrdarya Karatau]. Nauka [in Russian].
- 35 Tojibaev, S. K., Jang, C., Lazkov, G. A., Chang, K. S., Sitpayeva, G. T., Safarov, N., et al. (2020). An annotated checklist of endemic vascular plants of the Tian-Shan Mountains in Central Asian countries. *Phytotaxa*, *464*(2), 117–158.

- 36 Sennikov, A. N., & Tojibaev, K. S. (2021). *Checklist of vascular plants of the Tian-Shan Mountain System*. Korea National Arboretum.
- 37 Kubentayev, S. A., Alibekov, D. T., Perezhogin, Y. V., Lazkov, G. A., Kupriyanov, A. N., Ebel, A. L., et al. (2024). Revised checklist of endemic vascular plants of Kazakhstan. *PhytoKeys*, 238, 241.
- 38 Ebel, A. L., Kupriyanov, A. N., Khurstaleva, I. A., Lashchinsky, N. N., & Moshkalov, B. M. (2024). *Flora severo-zapadnoi chasti Boraldaitau* [Flora of the northwestern part of Boraldaitau]. Shymkent: South Print Corporation [in Russian].
- 39 (1958). *Flora Kazakhstana* [Flora of Kazakhstan]. (Vol. 2). Alma-Ata [in Russian].
- 40 Ivashchenko, A. A. (2017). Novye i redkie vidy flory khrebta Kazygurt (Zapadnyi Tyan-Shan) [New and rare plant species of the Kazygurt Range (Western Tien Shan)]. *Izuchenie, sokhranenie i ratsionalnoe ispolzovanie rastiitelnogo mira Evrazii: materialy Mezhdunarodnoi nauchnoi konferentsii — Study, conservation and sustainable use of the plant world of Eurasia: Proceedings of the International Scientific Conference* (pp. 218–223). Almaty [in Russian].
- 41 (2026). iNaturalist contributors. iNaturalist Research-grade Observations. Occurrence dataset. iNaturalist.org. www.gbif.org. Retrieved from <https://www.gbif.org/occurrence/2557780219> (accessed via GBIF.org on 22 January 2026). <https://doi.org/10.15468/ab3s5x>
- 42 (2026). iNaturalist contributors. iNaturalist Research-grade Observations. Occurrence dataset. iNaturalist.org. www.gbif.org. Retrieved from <https://www.gbif.org/occurrence/2550129001> (accessed via GBIF.org on 22 January 2026) <https://doi.org/10.15468/ab3s5x>
- 43 Epiketov, V. (2019). Image of *Allium kujukense* Vved. *Plantarium. Plants and lichens of Russia and neighboring countries: open online galleries and plant identification guide*. Retrieved from <https://www.plantarium.ru/lang/en/page/image/id/635306.html> (accessed on 22 Jan 2026).
- 44 Belousov, E. (2009). Image of *Allium kujukense* Vved. *Plantarium. Plants and lichens of Russia and neighboring countries: open online galleries and plant identification guide*. Retrieved from <https://www.plantarium.ru/lang/en/page/image/id/41970.html> (accessed on 22 Jan 2026).
- 45 Kolbintsev, V. (2012). Image of *Allium kujukense* Vved. *Plantarium. Plants and lichens of Russia and neighboring countries: open online galleries and plant identification guide*. Retrieved from <https://www.plantarium.ru/lang/en/page/image/id/268515.html> (accessed on 22 Jan 2026).
- 46 Grebenjuk, A. (2016). Image of *Allium kujukense* Vved. *Plantarium. Plants and lichens of Russia and neighboring countries: open online galleries and plant identification guide*. Retrieved from <https://www.plantarium.ru/lang/en/page/image/id/458229.html> (accessed on 22 Jan 2026).
- 47 Kolbintsev, V. (2018). Image of *Allium kujukense* Vved. *Plantarium. Plants and lichens of Russia and neighboring countries: open online galleries and plant identification guide*. Retrieved from <https://www.plantarium.ru/lang/en/page/image/id/569906.html> (accessed on 22 Jan 2026).
- 48 Aralbay, N. K., Mukhtubayeva, S. K., & Shormanova, A. A. (2007). *Gosudarstvennyi kadastr rastenii Zhambylskoi oblasti* [State cadastre of plants of Zhambyl Region]. Almaty [in Russian].
- 49 Aralbayev, N. K., Zhaparova, N. K., Kudabayeva, G. M., Danilov, M. P., Vesselova, P. V., & Zakirova, R. O. (2002). *Gosudarstvennyi kadastr rastenii Yuzhno-Kazakhstanskoi oblasti. Krasnaia kniga: Dikorastushchie redkie i ischezaiushchie vidy rastenii* [State cadastre of plants of South Kazakhstan Region. Red Data Book: Wild rare and endangered plant species]. Almaty NITS “Gylm” [in Russian].

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Safety assessment of different extracts of *Linaria vulgaris* Mill. in models of cytotoxicity and acute toxicity

The paper presents the results of a study on the acute toxicity and cytotoxic activity of extracts from the aboveground part of *Linaria vulgaris* Mill., collected during the flowering phase in the steppe areas of the Bukhar-Zhyrau district of the Karaganda region (Republic of Kazakhstan). The extracts were obtained by maceration, percolation, and ultrasonic extraction using various organic solvents (ethanol, ethyl acetate, and chloroform). Acute toxicity was studied in outbred white mice weighing 18–25 g after a single intragastric administration at doses of 500, 1500, and 2500 mg/kg. Cytotoxic activity was assessed using the *Artemia salina* larvae lethality assay. The data obtained showed that the 70 % ethanol extract of *Linaria vulgaris* Mill. belongs to the category of practically non-toxic substances and is classified as low-toxic (toxicity class III). The study of cytotoxic activity demonstrated that the *Linaria vulgaris* Mill. extracts, regardless of the method of preparation or the extractants used, do not exhibit toxic effects against *Artemia salina* larvae. Thus, the studied extracts of the aboveground part of *Linaria vulgaris* Mill. are characterized by low toxicity and lack of cytotoxic activity, which indicates their potential safety and prospects for further biological and pharmacological studies.

Keywords: *Linaria vulgaris* Mill., medicinal plant, extract, acute toxicity, cytotoxicity.

Introduction

Linaria vulgaris Mill. (*Scrophulariaceae* family) is a perennial herbaceous plant. The genus *Linaria* Mill. includes about 200 species, mainly distributed in the Northern Hemisphere, in East Asia, and the Mediterranean Basin [1]. In the flora of the Republic of Kazakhstan, 21 species are found, of which 8 are endemic [2].

It is known that in traditional medicine, *Linaria grandiflora* Desf., *Linaria genistifolia* subsp. *confertiflora* (Boiss.) Davis, and *Linaria aucheri* Boiss. have traditionally been used for treating wounds and vascular disorders, as well as for their laxative, tonic, antidiabetic, and diuretic properties [3]. In *in vitro* experiments, aqueous-methanol, ethyl acetate, and butanol extracts of *Linaria* Mill. species exhibited inhibitory activity against cholinesterase [4]. The use of certain species of the *Linaria* Mill. genus in folk medicine has attracted significant interest in chemical and biological research.

According to the literature [5, 6], studies addressing the phytochemical composition and biological activity of *Linaria vulgaris* Mill. are limited. Phytochemical investigations have identified benzyl alcohol glycosides, syringin, liriiodendrin, and other phytoconstituents in *Linaria vulgaris* Mill. plants, supporting the presence of multiple compound classes such as glycosides and alkaloid-related substances. Available research also indicates that extracts of *Linaria vulgaris* Mill. contain phenolic acids and flavonoids with antimicrobial activity in vitro assays against *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*. Furthermore, chromatographic analyses have shown that *Linaria vulgaris* Mill. extracts contain other phenolic compounds that may contribute to additional biological effects [7].

For the first time, we performed microscopic and histochemical analyses of *Linaria vulgaris* Mill., collected from the Bukhar-Zhyrau district in the Karaganda region of Kazakhstan. The histochemical examination demonstrated that flavonoids, phenolic compounds, traces of essential oils, alkaloids, and sesquiterpene lactones are distributed within the tissues of the leaves and stems [8-9].

Previous studies have reported that cytotoxic activity in various plant extracts has been attributed to biologically active compounds such as alkaloids, flavonoids, and phenolics [10].

Studies on the acute toxicity of extracts help assess the risk and potential side effects associated with the use of plant extracts, which is crucial for ensuring their safe application in medicinal practice and pharmaceutical formulations [11].

No information is available in the accessible literature regarding the study of the acute toxicity of *Linaria vulgaris* Mill. extract, which served as the basis for determining its safety for further use as a medicinal product.

Thus, the aim of this study is to evaluate the acute toxicity and assess the cytotoxic potential of *Linaria vulgaris* Mill. extracts on the larvae of *Artemia salina* larvae.

Experimental

Acute toxicity was evaluated in white outbred mice weighing 18–25 g at the vivarium of the Institute of Life Sciences, Karaganda Medical University.

The animals were divided into four groups of six individuals each.

The studied samples were administered once via a gastric tube at doses of 500, 1500, and 2500 mg/kg.

A precise weight of 50 g of dried and crushed raw material (2 mm particle size) was placed in a round-bottom flask, followed by the addition of 500 mL of 70 % ethanol. The flask was connected to a reflux condenser and heated in a water bath for 3 hours. The obtained extract was filtered and evaporated under reduced pressure using a rotary evaporator. The extraction process was repeated three times, and the resulting fractions were combined and dried.

The administered dose was calculated individually based on body weight.

The acute toxicity study was conducted over a 14-day observation period, with continuous monitoring during the first 24 hours. Systematic evaluations were performed to assess the general condition of the animals, behavioral patterns, motor activity, the presence and type of convulsions, coat condition, mucous membrane coloration, food and water consumption, and changes in body weight [12].

No mortality was observed at any of the tested doses, including the highest dose of 2500 mg/kg. Therefore, the median lethal dose (LD₅₀) of the extract was considered to be greater than 2500 mg/kg after oral administration in mice.

Biochemical blood parameters of mice were analyzed on day 14 of the experiment. Blood samples were collected from the tail vein following the 14-day observation period. The analyses were performed at the veterinary clinic “Dobry Doctor” (Karaganda) using an automated biochemical analyzer [insert model and manufacturer] with standard commercial reagent kits [insert manufacturer]. The following parameters were measured: total protein, urea, glucose, total bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and creatinine.

Studies on the cytotoxicity of the samples were conducted at the Scientific Research Institute of New Chemical Technologies, L.N. Gumilyov Eurasian National University.

To assess cytotoxic activity, a series of extracts obtained by maceration (LV-96) and ultrasonic extraction (LV-U70) using various organic solvents, including ethanol, ethyl acetate (LV-EtAc), and chloroform (LV-Chl), were used.

Marine crustaceans *Artemia salina* larvae were used to determine cytotoxic activity. This method measures acute toxicity by comparing the mortality of *Artemia salina* larvae in the test samples with that in a control containing only water. A substance is considered acutely toxic if it causes 50 % or greater mortality of the larvae compared to the control.

Dilutions were prepared by dissolving 1 mg of the substance in 1 ml of solvent. Each sample was tested in triplicate. Experiments were conducted at 20 ± 2 °C under natural light conditions. The control artificial seawater was prepared in the laboratory and had a pH of 8.0–8.5. Newly hatched *Artemia salina* larvae, up to 1 day old, were used for the bioassays, with 20–40 larvae placed in each test tube [13].

All experimental procedures were approved by the Institutional Animal Care and Use Committee (IUCAC). There is a conclusion from the ethical committee of the NJSC “Karaganda Medical University” No. 45, Protocol No. 9 dated 19/06/24.

Results and Discussion

The overall condition of the animals was assessed daily based on appearance, behavior, physiological parameters, and food and water intake. Animals were classified as “normal” if they exhibited typical activity, intact fur and skin, regular food and water consumption, and no observable behavioral or physiological ab-

normalities. “Good condition” was assigned to animals showing all of the above characteristics along with strong responsiveness to stimuli and overall alertness.

Group 1 (Dose: 500 mg/kg): After administration, the mice remained active throughout the day. No observable changes in behavior or functional status were detected. Fur and skin remained intact, and the mice maintained regular food and water intake. No mortality was recorded. On the second day and throughout the entire observation period, no pathological changes in behavior or physiological parameters were observed. Food and water consumption remained normal, and no delays in growth or development were noted. All mice survived the 14-day observation period.

Group 2 (Dose: 1500 mg/kg): Following administration, the mice remained active throughout the day, showing no observable changes in behavior or physiological condition. Their fur and skin appeared intact, and they consumed food and water without any issues. No mortality was recorded. On the second day and throughout the 14-day observation period, no behavioral abnormalities or physiological disturbances were observed. Food and water intake remained consistent, and normal growth and development were maintained. No deaths occurred during the study.

Group 3 (Dose: 2500 mg/kg): Throughout the 14-day observation period following administration, no alterations in behavior or physiological parameters were noted. The mice maintained regular food and water intake and exhibited typical responses to light and sound stimuli. Fur and skin remained in good condition, and urination and defecation were normal. No delays in growth or weight gain were observed. No mortality occurred (Table 1).

After intragastric administration of the extract, all animals maintained normal overall condition, according to the defined criteria.

Over the following 14 days, no notable changes in appearance, behavior, or activity were observed in the mice.

Table 1 summarizes the results of the study assessing the effects of a single intragastric dose of the extract on mouse viability.

Table 1

Assessment of the toxic effects of the dry ethanol extract of *Linaria vulgaris* Mill. in mice following a single oral administration

| Dose (mg/kg) | n (male) | n (female) | Deaths (male) | Deaths (female) | Mortality (%) |
|--------------|----------|------------|---------------|-----------------|---------------|
| 500 | 3 | 3 | 0 | 0 | 0 |
| 1500 | 3 | 3 | 0 | 0 | 0 |
| 2500 | 3 | 3 | 0 | 0 | 0 |
| Control | 3 | 3 | 0 | 0 | 0 |

Preclinical studies of sample LV-70 (*Linaria vulgaris* extract) demonstrated that it does not exhibit acute nonspecific toxicity. The maximum achievable dose for single intragastric administration in mice is 2500 mg/kg, which is considered safe.

Analysis of experimental mice over 7 and 14 days after acute administration of the ethanol extract of *Linaria vulgaris* Mill. at doses of 500, 1500, and 2500 mg/kg showed no adverse effects on appearance, general condition, body weight, or behavior. The results of the biochemical analyses are summarized in Table 2. No significant deviations from control values were observed for any parameter, confirming the low acute toxicity of the ethanol extract under the tested conditions.

Table 2

Biochemical parameters of mice after acute administration of *Linaria vulgaris* Mill. extract

| Parameter | Sex | Control (n=3) | 500 mg/kg (n=3) | 1500 mg/kg (n=3) | 2500 mg/kg (n=3) |
|--------------------|-----|---------------|-----------------|------------------|------------------|
| Total protein, g/L | ♂ | 63.6 ± 2.1 | 56.14 ± 0.3 | 45.6 ± 3.0 | 47.6 ± 0.7 |
| | ♀ | 61.5 ± 1.8 | 59.3 ± 0.8 | 56.72 ± 0.8 | 49.2 ± 0.5 |
| Urea, mmol/L | ♂ | 12.2 ± 0.9 | 13.7 ± 1.0 | 14.5 ± 0.7 | 15.6 ± 0.6 |
| | ♀ | 11.7 ± 0.2 | 16.3 ± 2.7 | 16.7 ± 0.6 | 14.5 ± 0.8 |

Continuation of Table 2

| Parameter | Sex | Control (n=3) | 500 mg/kg (n=3) | 1500 mg/kg (n=3) | 2500 mg/kg (n=3) |
|-------------------------|-----|---------------|-----------------|------------------|------------------|
| Glucose, mmol/L | ♂ | 9.5 ± 0.24 | 10.6 ± 0.18 | 9.54 ± 0.5 | 10.2 ± 0.2 |
| | ♀ | 9.54 ± 0.41 | 8.43 ± 2.7 | 9.87 ± 0.63 | 9.34 ± 0.28 |
| Total bilirubin, mmol/L | ♂ | 5.46 ± 0.012 | 4.6 ± 0.61 | 5.94 ± 0.08 | 6.01 ± 0.02 |
| | ♀ | 5.68 ± 0.14 | 5.17 ± 0.25 | 6.13 ± 0.02 | 5.96 ± 0.02 |
| AST, mmol/L·s | ♂ | 43.74 ± 0.08 | 40.3 ± 0.06 | 42.1 ± 0.3 | 44.21 ± 0.3 |
| | ♀ | 42.5 ± 0.61 | 40.9 ± 1.7 | 43.2 ± 0.5 | 46.1 ± 0.7 |
| ALT, mmol/L·s | ♂ | 47.35 ± 0.02 | 42.0 ± 0.03 | 45.1 ± 0.05 | 49.2 ± 0.1 |
| | ♀ | 42.54 ± 0.06 | 43.8 ± 0.02 | 44.4 ± 0.03 | 47.3 ± 0.5 |
| Creatinine, mmol/L | ♂ | 170.24 ± 0.1 | 169.0 ± 0.8 | 167.2 ± 0.5 | 162.3 ± 0.2 |
| | ♀ | 167.43 ± 0.05 | 164.0 ± 0.3 | 168.3 ± 0.1 | 165.6 ± 0.5 |

Cytotoxic activity was studied using the survival method of the marine crustacean *Artemia salina* larvae. A flask was filled with artificial seawater, and *Artemia salina* eggs were added. They were kept for 3 days with gentle aeration until the crustaceans hatched.

Paclitaxel-Teva was used as a reference drug. The samples were tested at concentrations of 10, 5, and 1 mg/ml. The results of the cytotoxic activity study are presented in Table 3.

Table 3

Results of the cytotoxicity study

| Sample | Concentration (mg/ml) | Number of larvae (Control: survived/dead) | Number of larvae (Sample: survived/dead) | Mortality (%) | Neurotoxicity (%) |
|-----------------|-----------------------|---|--|---------------|-------------------|
| Paclitaxel-Teva | 10 | 22 / 1 | 0 / 22 | 96 | 0 |
| | 5 | 22 / 1 | 1 / 25 | 92 | 0 |
| | 1 | 22 / 1 | 9 / 18 | 63 | 0 |
| LV-EtAc | 10 | 22 / 1 | 26 / 1 | 0 | 0 |
| | 5 | 22 / 1 | 23 / 0 | 0 | 0 |
| | 1 | 22 / 1 | 21 / 1 | 0 | 0 |
| LV-Chl | 10 | 22 / 1 | 25 / 1 | 0 | 0 |
| | 5 | 22 / 1 | 22 / 0 | 0 | 0 |
| | 1 | 22 / 1 | 23 / 0 | 0 | 0 |
| LV-U70 | 10 | 22 / 1 | 22 / 1 | 0 | 0 |
| | 5 | 22 / 1 | 22 / 0 | 0 | 0 |
| | 1 | 22 / 1 | 24 / 1 | 0 | 0 |
| LV-96 | 10 | 22 / 1 | 26 / 1 | 0 | 0 |
| | 5 | 22 / 1 | 27 / 0 | 0 | 0 |
| | 1 | 22 / 1 | 22 / 1 | 0 | 0 |

Analysis of experimental mice over 7 and 14 days after acute administration of the ethanol extract of *Linaria vulgaris* Mill. at doses of 500, 1500, and 2500 mg/kg showed no adverse effects on appearance, general condition, body weight, or behavior.

Previous studies in our group demonstrated that the aerial parts of *Linaria vulgaris* Mill. contain up to 0.052 % flavonoids (expressed as quercetin equivalents), 20 amino acids (both essential and nonessential), and 62 components in the essential oil, of which hexahydrofarnesyl acetone accounts for 11.71 % [14-15]. The presence of these compounds likely contributes to the low acute toxicity and overall safety of the extracts.

Cytotoxicity assessment revealed that the samples LV-EtAc, LV-Chl, LV-U70, and LV-96 did not exhibit cytotoxic effects at any of the tested concentrations. In contrast, the reference drug Paclitaxel-Teva ex-

hibited cytotoxicity toward *Artemia salina* larvae across all tested concentrations, with mortality rates ranging from 63 % to 96 %.

Conclusion

Thus, for the first time, we have studied the acute toxicity and cytotoxicity of extracts of *Linaria vulgaris* Mill.

1. Following a single intragastric administration, the *Linaria vulgaris* Mill. extract caused no observable behavioral or physiological changes, and all mice survived the 14-day observation period, indicating low acute toxicity under the conditions and timeframe of this study.

2. The study of cytotoxic activity allows us to conclude that the samples LV-EtAc, LV-Chl, LV-U70, and LV-96 do not exhibit cytotoxicity at any of the tested concentrations.

These findings are limited to acute toxicity, and further studies are required to assess subchronic or chronic toxicity.

Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Nurkadirov D.K.** — plant material collection, investigation; **Itzhanova Kh.I.** — project administration; **Shaimerdenova Zh.R.** — writing original draft, writing review & editing; **Wirginia Kukula-Koch** — writing review & editing.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Cheriet T. Chemical constituents and biological activities of the genus *Linaria*(Scrophulariaceae) / T. Cheriet, I. Mancini, R. Seghiri, F. Benayache, S. Benayache // Natural Product Research. — 2015. — Vol. 29, No. 17. — P. 1589–1613. DOI: 10.1080/14786419.2014.999243.
- 2 Флора Казахстана. — Т. 8. — Алма-Ата: Наука, 1965. — 34 с.
- 3 Akkol E. K. Antinociceptive and anti-inflammatory activities of some *Linaria* species from Turkey / E. Akkol, D. Ercil // Pharmaceutical Biology. — 2009. — Vol. 47, No. 3. — P. 188–194.
- 4 Utlu M. Phytochemical content, *in vitro* antioxidant and cholinesterase inhibitory activities of endemic *Linariacorifolia* Desf / M. Utlu, D. Ercil // Journal of Evidence-Based Complementary & Alternative Medicine. — 2024. DOI: 10.1177/1934578X241272734.
- 5 Hua H.M. Study on the chemical constituents of *Linaria vulgaris* Mill. / H.M. Hua, X. Li, S.E. Xing, Y.H. Pei // Zhongguo Yaoxue Zazhi. — 2005. — Vol. 40, No. 9. — P. 653–656.
- 6 Hua H. A new pyrroloquinazoline alkaloid from *Linaria vulgaris* / H. Hua, M. Cheng, X. Li, Y. Pei // Chem Pharm Bull. — 2002. — Vol. 50, No. 10. — P. 1393–1394.
- 7 Уэйли А.К. Противомикробная активность вторичных метаболитов, выделенных из травы льянки обыкновенной (*Linaria vulgaris* Mill.) / А.К. Уэйли, А.О. Уэйли, Т.В. Бомбела, О.А. Кроткова, А.С. Чащина, В.В. Новикова, В.О. Васильев, В.Г. Лужанин // Химия растительного сырья. — 2024. — №4. — С. 287–296. DOI: 10.14258/jcrpm.20240414795.
- 8 Itzhanova Kh.I. Histochemical Analysis of Raw Materials of *Linaria vulgaris* Mill. growing in Central Kazakhstan / Kh.I. Itzhanova, D.K. Nurkadirov, M. Ishmuratova, A.B. Koshberber, S.A. Baidullayeva, E. Poleszak // Research Journal of Pharmacy and Technology. — 2024. — Vol. 17, No. 9. — P. 4477–4480. DOI: 10.52711/0974-360X.2024.00692.
- 9 Итжанова Х. Анатомическое исследование растения льянки обыкновенной (*Linaria vulgaris* Mill.), произрастающей в Центральном Казахстане / Х.И. Итжанова, Д.К. Нуркадыров, М.Ю. Ишмуратова, Г.М. Абдрахманова, Е.А. Тулебаев, А.Б. Кошербек // Фармация Казахстана. — 2024. — № 6. — С. 297–302. DOI: 10.53511/pharmkaz.2025.36.51.039.
- 10 Pappachen L. K. Phytochemical screening and *in vitro* cytotoxicity studies of *Mussaendafrondosa* Linn leaves / L.K. Pappachen, K.S. Sreelakshmi // Research Journal of Pharmacy and Technology. — 2017. — Vol. 10, No. 12. — P. 4227–4230. DOI: 10.5958/0974-360X.2017.00774.0.
- 11 Johnson D. B. Antidiabetic activity and toxicity studies of ethanolic extract of *Polyalthialongifolia* roots / D.B. Johnson, A. Raj, R. Venkatanarayan // Research Journal of Pharmacy and Technology. — 2017. — Vol. 10, No. 5. — P. 1305–1312.
- 12 Миронов А.Н. Руководство по проведению доклинических исследований лекарственных средств / А.Н. Миронов. — М.: Гриф и К, 2012. — Ч. 1. — С. 13–41.
- 13 Руководство по экспериментальному (доклиническому) изучению новых фармакологических веществ / под общ. ред. Р.У. Хабриева. — 2-е изд., перераб. и доп. — М.: ОАО «Издательство “Медицина”», 2005. — 832 с.

14 Nurkadirov D.K. Quantitative determination of flavonoids from the aerial parts of *Linaria vulgaris* Mill. / D.K. Nurkadirov, Kh.I. Itzhanova // International Scientific and Technical Conference “Actual Problems of the Chemistry of Natural Compounds”. — Tashkent, 2024. — P. 179.

15 Nurkadirov D.K. Study of amino acid composition of *Linaria vulgaris* Mill. / D.K. Nurkadirov, Kh.I. Itzhanova, A. Kosherbek // International Scientific and Practical Online Conference “Modern Achievements of Experimental, Clinical, Environmental Biochemistry and Molecular Biology”. — Ukraine, 2024. — P. 408–410.

16 Nurkadirov D.K. Analysis of the chemical composition of the essential oil of *Linaria vulgaris* Mill. / D.K. Nurkadirov, Kh.I. Itzhanova // Silk Road Chemistry: Modern Chemical Technologies and Science: Collection of abstracts of the 1st International Scientific and Practical Conference, dedicated to the 100th anniversary of Academician Ye.A. Buketov. — Karaganda. — 2025. — P. 164-165.

Д.К. Нуркадыров, Х.И. Итжанова, Ж.П. Шаймерденова, Wirginia Kukula-Koch
***Linaria vulgaris* Mill. өсімдігінің әртүрлі сығындыларының цитоуыттылық және жіті уыттылық модельдерінде қауіпсіздігін бағалау**

Жұмыста Қарағанды облысы Бұқар жырау ауданының (Қазақстан Республикасы) дала учаскелерінде гүлдену кезеңінде жиналған *Linaria vulgaris* Mill. жерүсті бөлігі сығындыларының жіті уыттылығы мен цитоуыттылық белсенділігін зерттеу нәтижелері келтірілген. Жіті уыттылықты зерттеу үшін салмағы 18-25 г ақ тұқымсыз тышқандарға 500, 1500 және 2500 мг/кг дозада бір рет асқазан ішіне енгізілетін 70 % этанол сығындысы қолданылды. Цитоуыттылық белсенділікті бағалау үшін этанол, этилацетат және хлороформды қоса алғанда, әртүрлі органикалық еріткіштерді қолдана отырып, мацерация және ультрадыбыстық экстракция әдістерімен алынған сығындылар сериясы пайдаланылды. Цитоуыттылық *Artemia salina* дернәсілдерінің сынағы арқылы бағаланды. Нәтижесінде *Linaria vulgaris* Mill. сығындысы іс жүзінде улы емес заттар санатына жататынын және уыттылығы төмен (уыттылықтың III класы) ретінде жіктелетінін көрсетті. Цитотоксикалық белсенділікті зерттеу барысында *Linaria vulgaris* Mill. сығындылары өндіру әдісіне және қолданылған экстрагенттерге қарамастан *Artemia salina* дернәсілдеріне уытты әсер етпейтіні анықталды. Осылайша *Linaria vulgaris* Mill. жерүсті бөлігінің зерттелген сығындылары төмен уыттылықпен және цитоуыттылық белсенділіктің болмауымен сипатталады, бұл олардың әлеуетті қауіпсіздігін және одан әрі биологиялық және фармакологиялық зерттеулердің болашағын көрсетеді.

Кілт сөздер: *Linaria vulgaris* Mill., дәрілік өсімдік, сығынды, жіті уыттылық, цитоуыттылық.

Д.К. Нуркадыров, Х.И. Итжанова, Ж.П. Шаймерденова, Wirginia Kukula-Koch
Оценка безопасности различных экстрактов *Linaria vulgaris* Mill. в моделях цитотоксичности и острой токсичности

В работе представлены результаты исследования острой токсичности и цитотоксической активности экстрактов надземной части *Linaria vulgaris* Mill., собранной в фазу цветения на степных участках Бухар-Жырауского района Карагандинской области (Республика Казахстан). Для исследования острой токсичности использовали 70 %-ный этанольный экстракт, который вводили белым беспородным мышам массой 18–25 г однократно внутрижелудочно в дозах 500, 1500 и 2500 мг/кг. Для оценки цитотоксической активности применяли серию экстрактов, полученных методами мацерации и ультразвуковой экстракции с использованием различных органических растворителей, включая этанол, этилацетат и хлороформ. Цитотоксическую активность оценивали с использованием теста на личинках *Artemia salina*. Полученные данные показали, что спиртовой экстракт *Linaria vulgaris* Mill. относится к категории практически нетоксичных веществ и классифицируется как малотоксичный (III класс токсичности). В ходе исследования цитотоксической активности установлено, что экстракты *Linaria vulgaris* Mill., независимо от метода получения и применённых экстрагентов, не проявляют токсического действия в отношении личинок *Artemia salina*. Таким образом, исследуемые экстракты надземной части *Linaria vulgaris* Mill. характеризуются низкой токсичностью и отсутствием цитотоксической активности, что указывает на их потенциальную безопасность и перспективность для дальнейших биологических и фармакологических исследований.

Ключевые слова: *Linaria vulgaris* Mill., лекарственное растение, экстракт, острая токсичность, цитотоксичность.

References

- 1 Cheriet, T., Mancini, I., Seghiri, R., Benayache, F., & Benayache, S. (2015). Chemical constituents and biological activities of the genus *Linaria* (Scrophulariaceae). *Natural Product Research*, 29(17), 1589–1613. <https://doi.org/10.1080/14786419.2014.999243>.
- 2 (1965). *Flora Kazakhstana* [Flora of Kazakhstan]. (Vol. 8). Alma-Ata: Nauka [in Russian].
- 3 Akkol, E. K., & Ercil, D. (2009). Antinociceptive and anti-inflammatory activities of some *Linaria* species from Turkey. *Pharmaceutical Biology*, 47(3), 188–194. <https://doi.org/10.1080/13880200802617773>.
- 4 Utlu, M., & Ercil, D. (2024). Phytochemical content, *in vitro* antioxidant, and cholinesterase inhibitory activities determination of endemic *Linariacorifolia* Desf. *Journal of Evidence-Based Complementary & Alternative Medicine*. <https://doi.org/10.1177/1934578X241272734>
- 5 Hua, H. M., Li, X., Xing, S. E., & Pei, Y. H. (2005). Study on the chemical constituents of *Linaria vulgaris* Mill. *Zhongguo Yaoxue Zazhi*, 40(9), 653–656.
- 6 Hua, H., Cheng, M., Li, X., & Pei, Y. (2002). A new pyrroloquinazoline alkaloid from *Linaria vulgaris*. *Chemical & Pharmaceutical Bulletin*, 50(10), 1393–1394.
- 7 Ueyli, A.K., Ueyli, A.O., Bombela, T.V., et al. (2024). Protivomikrobnaya aktivnost vtorichnykh metabolitov, vydelennykh iz travy Inianki obyknovnoy (*Linaria vulgaris* Mill.) [Antimicrobial activity of secondary metabolites isolated from (*Linaria vulgaris* Mill.)]. *Khimiya rastitelnogo syria — Chemistry of Plant Raw Materials*, 4, 287–296.
- 8 Itzhanova, K. I., Nurkadirov, D. K., Ishmuratova, M. Yu., Kosherbek, A. B., Baidullayeva, S. A., & Poleszak, E. (2024). Histochemical analysis of raw materials of *Linaria vulgaris* Mill. growing in Central Kazakhstan. *Research Journal of Pharmacy and Technology*, 17(9), 4477–4480. <https://doi.org/10.52711/0974-360X.2024.00692>
- 9 Itzhanova, K. I., Nurkadirov, D. K., Ishmuratova, M. Yu., Abdrakhmanova, G. M., Tulebayev, Ye. A., & Kosherbek, A. B. (2024). Anatomicheskoe issledovanie rastenii Inianki obyknovnoy (*Linaria vulgaris* Mill.), proizrastaiushchei v Tsentralnom Kazakhstane — Anatomical study of the plant (*Linaria vulgaris* Mill.) growing in Central Kazakhstan. *Farmatsiya Kazakhstana — Pharmacy of Kazakhstan*, 6, 297–302. <https://doi.org/10.53511/pharmkaz.2025.36.51.039> [in Russian].
- 10 Pappachen, L.K., & Sreelakshmi, K.S. (2017). Phytochemical screening and *in vitro* cytotoxicity studies of *Mussaendafrondosa* Linn leaves. *Research Journal of Pharmacy and Technology*, 10(12), 4227–4230. <https://doi.org/10.5958/0974-360X.2017.00774.0>.
- 11 Johnson, D. B., Raj, A., & Venkatanarayan, R. (2017). Antidiabetic activity and toxicity studies of ethanolic extract of *Polyalthialongifolia* roots. *Research Journal of Pharmacy and Technology*, 10(5), 1305–1312.
- 12 Mironov, A. N. (2012). *Rukovodstvo po provedeniiu doklinicheskikh issledovaniy lekarstvennykh sredstv — Guidelines for conducting preclinical studies of drugs* (Part 1, pp. 13–41). Moscow, Grif & K [in Russian].
- 13 Khabriev, R. U. (Ed.). (2005). *Rukovodstvo po eksperimentalnomu (doklinicheskomu) izucheniiu novykh farmakologicheskikh veshchestv — Guidelines for the experimental (preclinical) study of new pharmacological substances* (2nd ed., rev. & enl.). Moscow: OAO «Izdatelstvo “Meditsina”» [in Russian].
- 14 Nurkadirov, D. K., & Itzhanova, Kh. I. (2024). Quantitative determination of flavonoids from the aerial parts of *Linaria vulgaris* Mill. In *International Scientific and Technical Conference “Actual Problems of the Chemistry of Natural Compounds”* (p. 179). Tashkent, Uzbekistan.
- 15 Nurkadirov, D. K., Itzhanova, Kh. I., & Kosherbek, A. (2024). Study of amino acid composition of *Linaria vulgaris* Mill. In *International Scientific and Practical Online Conference “Modern Achievements of Experimental, Clinical, Environmental Biochemistry and Molecular Biology”* (pp. 408–410). Ukraine.
- 16 Nurkadirov, D. K., & Itzhanova, Kh. I. (2025). Analysis of the chemical composition of the essential oil of *Linaria vulgaris* Mill. In *Silk Road Chemistry: Modern Chemical Technologies and Science: Collection of abstracts of the 1st International Scientific and Practical Conference, dedicated to the 100th anniversary of Academician Ye.A. Buketov* (pp. 164–165). Karaganda.

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Important Plant Area “Petrophytic Steppes of Ulytau with *Tanacetum ulutavicum*” (Central Kazakhstan): site identification and conservation recommendations

Field surveys conducted in 2025 in the Ulytau low-mountain massif (Ulytau Region, Kazakhstan) support the identification of the Important Plant Area (IPA) “Petrophytic Steppes of Ulytau with *Tanacetum ulutavicum*.” The site comprises two polygons totaling 1,372 ha (557 and 815 ha), located largely within Ulytau State National Nature Park, at elevations of 508–1,140 m a.s.l., and includes a mosaic of petrophytic communities on rocky substrates. The primary conservation target is the narrow-range endemic *Tanacetum ulutavicum* Tzvelev (Red Data Book of Kazakhstan), occurring in discrete population patches of 207–1,200 m² with densities of 0.06–3 individuals per m². Communities supporting this species show high floristic richness (82 vascular plant species) and concentrate multiple taxa of conservation concern, including several rare and regionally significant species. The site meets the Kazakhstan-adapted IPA subcriteria A3 and A4 (endemic and subendemic species) and B2 and B3 (assemblages of high conservation and socio-economic value). Principal threats include grazing pressure, trampling, unregulated recreation, and localized substrate disturbance. Formal boundary delineation, long-term population monitoring, and regulation of grazing and visitor use are recommended to ensure effective conservation management.

Keywords: Ulytau, Important Plant Area (IPA), petrophytic steppes, endemics, *Tanacetum ulutavicum*, plant conservation, Ulytau State National Nature Park.

Introduction

The Important Plant Area (IPA) methodology is applied as a science-based tool for prioritizing sites of significance for the conservation of flora and vegetation. It is grounded in the Plantlife International framework, which includes criterion A—threatened and geographically restricted species; criterion B—diverse, unique and valuable plant communities; and criterion C—threatened habitats [1, 2].

In Kazakhstan, recent years have seen active testing and adaptation of the IPA criteria, coupled with alignment between the IPA approach and the Key Biodiversity Area (KBA) Standard. This integration enables the translation of botanical research outcomes into management decisions and spatial conservation planning [1–4, 12–14]. An important task is the identification of IPAs within existing protected areas to strengthen the conservation of plant diversity, as these areas typically retain the most intact natural complexes and provide conditions for targeted conservation management [15].

The Ulytau Mountains are characterized by a rocky terrain, a well-developed network of gorges, canyons, ravines, intermontane valleys, and a broad spectrum of low-mountain habitats. This environmental heterogeneity results in pronounced vegetation mosaicism, combining petrophytic steppes, shrub thickets, and extra- and intrazonal communities, including birch and aspen groves and mesophytic meadows. Within Ulytau, the most vulnerable elements are narrowly localized populations of endemic and rare taxa that are sensitive to changes in grazing pressure and recreational disturbance [5–10, 16].

Of particular conservation concern is Ulytau tansy (*Tanacetum ulutavicum* Tzvelev), a perennial herb of the family Asteraceae with declining population size. The species is listed in the Red Data Book of Kazakhstan as a rare (vulnerable) taxon of regional importance. Its distribution is restricted to rocky outcrops composed of slabs and scree, typically associated with both steep and gentle slopes of the Ulytau low-mountain massif and adjacent uplands [6, 7, 11].

The objective of this study is to provide a scientific justification for the designation of the IPA “Petrophytic Steppes of Ulytau with *Tanacetum ulutavicum*”, to refine its boundaries and key conservation

features, to describe habitats and threats according to a standardized framework, and to propose practical recommendations for conservation and long-term monitoring.

Experimental

Field surveys of flora and vegetation were conducted in 2025 (30 June — 5 July) within the Ulytau low-mountain massif (within the boundaries of the State National Park and beyond), where the IPA was allocated (Fig. 1, Table 1).

Slope aspect and morphological characteristics were recorded, and the coordinates of key locations were collected using the Garmin GPS navigator. Coordinates are presented in decimal format to facilitate use in GIS-based analyses. The list of vascular plants was compiled from route-based surveys and targeted geobotanical relevés carried out using classical field methods; it was published as a checklist in GBIF. Taxonomic validation and nomenclatural updates were performed using current reference databases (POWO, WCVF, IPNI) and regional identification manuals [17–27].

Geobotanical descriptions were conducted at 100 sq. m plots in communities with participation of *T. ulutavicum* [Bykov, B.A. (1978). Geobotanika [Geobotany]. Alma-Ata: Nauka [in Russian]. For this purpose, special geobotanical forms are used, which provide detailed descriptions of relief, soils, and vegetation. The following aspects were considered for describing the plant communities: 1) floristic composition; 2) total projective coverage; 3) phenophase; 4) abundance of species by the Drude scale; 5) species distribution patterns; 6) vitality. The impact of both natural and anthropogenic factors on vegetation was also considered.

Additional information on the floristic diversity and vegetation of the Ulytau mountain system was obtained from publications by A.N. Kupriyanov [16] and M.Yu. Ishmuratova et al. [5].

IPA justification followed the framework of the nationally adapted IPA criteria (A–C), with the application of subcriteria relevant to the environmental and biogeographic conditions of Kazakhstan. To ensure comparability and facilitate subsequent integration into management and planning documents, habitats were classified using EUNIS terminology, with broader correspondence to IUCN Habitats v3.1. Threats and impact factors were coded according to the IUCN–CMP Threats Classification Scheme v3.2. IPA boundaries are proposed as two polygons encompassing the most representative and vulnerable areas of petrophytic steppes and the core localities of populations of the focal endemic species [2–4, 13, 14, 17].

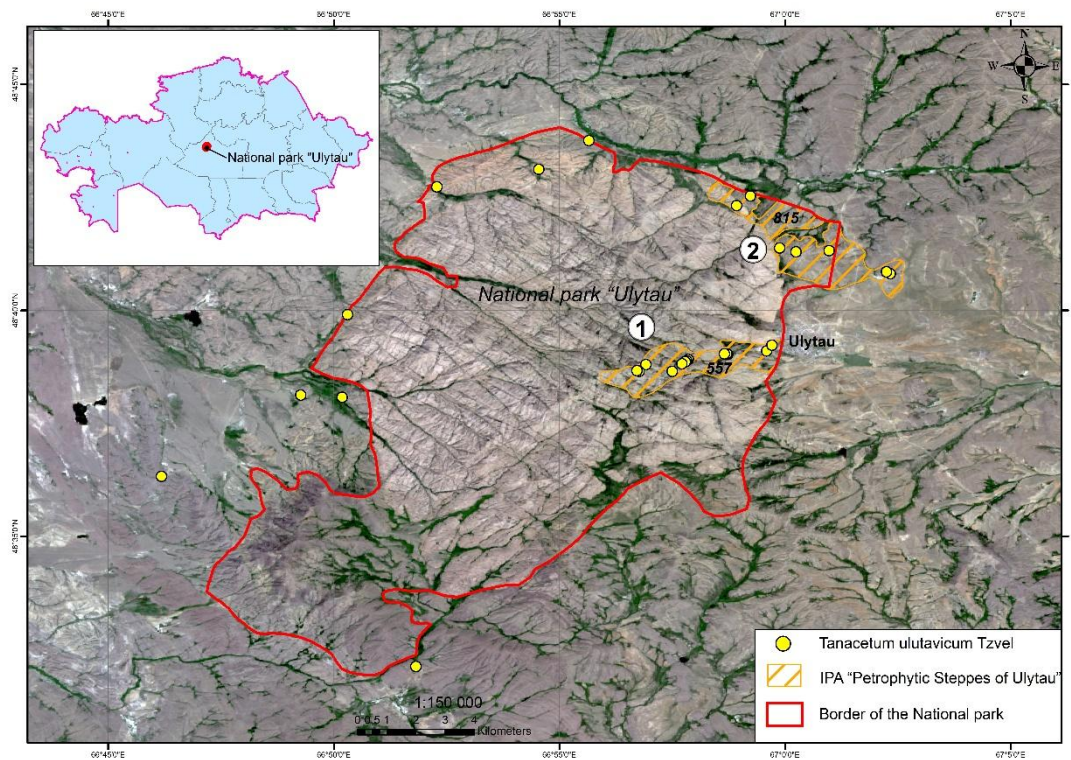


Figure 1. Location of the IPA “Petrophytic Steppes of Ulytau with *Tanacetum ulutavicum*” within the Ulytau mountain system, proposed IPA boundaries (two sites), and key population localities of *Tanacetum ulutavicum*

Table 1

Geographic and administrative characteristics of the site

| | | | |
|--|--|--|----------|
| Russian name: | Петрофитные степи Улытау с <i>Tanacetum ulutavicum</i> | | |
| English name: | Petrophytic Steppes of Ulytau with <i>Tanacetum ulutavicum</i> | | |
| Kazakh name: | <i>Tanacetum ulutavicum</i> өсетің Ұлытау петрофитті далалары | | |
| IPA code: | IPA-KZ-TU | | |
| Country: | Kazakhstan | | |
| Region: | Ulytau Region | | |
| Center latitude, site 1 (decimal degrees): | 48.6547° | Center longitude, site 1 (decimal degrees): | 66.9757° |
| Center latitude, site 2 (decimal degrees): | 48.6906° | Center longitude, site 2 (decimal degrees): | 67.0099° |
| Elevation (minimum, m a.s.l.): | 508 | Elevation (maximum, m a.s.l.): | 1140 |
| Area (ha) | 1,372 | Vector boundaries available (*.kml/kmz or *.shp) | Yes |

Results and Discussion

The main outcomes of this study include a detailed description of the Important Plant Area “Petrophytic Steppes of Ulytau with *Tanacetum ulutavicum*” (IPA-KZ-TU) and the development of recommendations for its conservation.

1. Brief site description

The IPA “Petrophytic Steppes of Ulytau with *Tanacetum ulutavicum*” was identified based on field surveys conducted in 2025 within the Ulytau low-mountain massif. The territory comprises two sites located near the village of Ulytau, predominantly within the boundaries of Ulytau State National Nature Park. The IPA includes rocky and stony–gravelly slopes, piedmont plains, and low upland areas where relatively intact petrophytic steppes and xerophytic shrub communities are preserved.

The principal conservation priority is the narrow-range endemic *Tanacetum ulutavicum*, listed in the Red Data Book of the Republic of Kazakhstan. The species occurs in fragmented populations confined to rocky substrates. Additional conservation value is provided by the presence of other Red Data Book species (*Tulipa patens* C. Agardh ex Schult. & Schult. f., *T. suaveolens* Roth), Kazakhstan subendemics (*Artemisia semiarida* (Krasch. & Lavrenko) Filatova, *Atraphaxis decipiens* Jaub. & Spach), and a substantial number of socio-economically important species, including 35 medicinal and 25 forage plants.

Communities containing *T. ulutavicum* exhibit relatively high floristic richness, with a total of 82 vascular plant species recorded.

2. Site boundaries

Site 1: northern point — 48.6548° N, 66.9592° E; southern point — 48.6736° N, 67.0149° E; western point — 48.6418° N, 66.9307° E; eastern point — 48.6486° N, 66.9980° E.

Site 2: northern point — 48.7032° N, 67.0101° E; southern point — 48.6736° N, 67.0149° E; western point — 48.7111° N, 66.9713° E; eastern point — 48.6745° N, 67.0433° E.

3. Botanical significance

The IPA represents a regionally representative, minimally disturbed complex of petrophytic steppes of Central Kazakhstan, interspersed with shrub thickets. The native vegetation of the low-mountain belt and adjacent piedmont plains is dominated by shrub thickets and petrophytic steppe communities, including bunch grass, bunch grass–forb steppes with shrubs, sagebrush–bunch grass, shrub–wormwood–bunch grass steppes, and fescue–forb meadow steppes.

Tanacetum ulutavicum Tzvelev (Asteraceae) is a narrow-range endemic of Kazakhstan, known primarily from the Ulytau massif and associated with petrophytic habitats, including rocky outcrops and fissures of granitic bedrock, where it occurs infrequently. In the Kew Plants of the World Online database, the species is recognized as an accepted taxon (protologue: [10]). Regional floristic syntheses and checklists of endemics identify it as a species listed in the Red Data Book of Kazakhstan, making it an anchor species for IPA justification under Criterion A and a focal target for long-term monitoring of populations and habitats.

Communities containing *T. ulutavicum* develop on both gentle (5–10°) and steeper slopes, as well as on level sections of the undulating piedmont plain covered by a stony mantle. The species occurs singly or in small groups (sol–sp). Local population patches range from 207 to 1,200 m², with densities of 0.06–3 individuals per m².

The coenoflora of the communities containing *T. ulutavicum* comprises 82 vascular plant species [10], with a notable concentration of resource-important and soil-stabilizing taxa typical of petrophytic steppe phytocenoses.

4. Habitats and geology

The IPA encompasses the rocky Mount Aulietau (789–1,140 m a.s.l.) and adjacent areas of the piedmont plain and low uplands. Bedrock outcrops in the form of slabs and gravelly scree cover 10–100 % of the surveyed surface. Slopes range from 30° to 50° and are characterized by frequent rock exposures and talus accumulations. Sharply dissected ridgelines are incised by deep, steep-sided ravines that contrast with the surrounding low upland and gently undulating piedmont relief.

The geological substrate of the IPA consists predominantly of granites subject to intense physical weathering under temperature fluctuations of up to 80 °C. Lithogenic soils developed on rocky slopes are shallow and gravelly, providing substrate conditions suitable for petrophytic species (e.g., *Artemisia*, *Ephedra*). The area is characterized by low-mountain chestnut soils (at higher elevations of Ulytau), as well as light chestnut, weakly developed, and skeletal stony soils [5, 10]. Humus content in the surface horizon ranges from 1.56 to 3.11 %.

According to the EUNIS habitat classification, the site includes: E1.1 — inland sandy and rocky habitats with sparse vegetation; E1.2 — perennial calcareous grasslands of the steppe zone; FD.1 — habitats dominated by xerophytic shrubs (Fig. 2) [1, 12].



Figure 2. Habitats within the IPA boundaries

For harmonization with IUCN Habitats v3.1 (for IPA documentation purposes), these habitat types can be broadly coded as *Temperate Grassland / Rocky areas* (petrophytic steppes and rocky outcrops) and *Shrubland* (xerophytic shrub communities), with subsequent refinement based on detailed field descriptions.

5. Conservation status and threats

The area lies predominantly within the boundaries of Ulytau State National Nature Park (approximately 80 %), which provides a baseline protection regime but does not eliminate localized pressures. The principal potential threats to the petrophytic steppes and local populations of *T. ulutavicum* are associated with grazing pressure, trampling, and recreational use near the settlement and along trails and access routes, as well as point disturbances of the substrate (including possible engineering works and plant collection).

An important site-specific impact is trampling and vegetation degradation along the trail leading to the summit of Mount Aulietau and at adjacent viewpoints; visitor flow management and interpretive signage are therefore recommended.

Preliminary threat coding according to the IUCN–CMP Threats Classification Scheme v3.2 includes: 2.3 Livestock farming & ranching (grazing/trampling); 6.1 Recreational activities (hiking, unregulated recreation); 4.1 Roads & railroads / 4.2 Utility & service lines (in the event of expansion of access routes or infrastructure).

6. Ecosystem services

The IPA provides several key ecosystem services:

- erosion control and slope stabilization, contributing to soil retention in rocky landscapes;
- maintenance of grazing resources and forage base, provided that sustainable stocking levels are observed;
- cultural and recreational services, reflecting the landscape value of Ulytau and its role in educational routes;
- scientific and educational functions as a reference site for monitoring rare and endemic steppe plants of Central Kazakhstan.

7. Justification of IPA status

The IPA “Petrophytic Steppes of Ulytau with *Tanacetum ulutavicum*” meets several IPA subcriteria: A3, A4, B2, and B3 (Fig. 3, Table 2).

In accordance with the nationally adapted IPA framework for Kazakhstan and its established application (subcriteria A3, A4, B2, B3), the following criteria are justified for this site.

Criterion A: A3 — sites supporting a geographically restricted national endemic (narrow-range taxon), *Tanacetum ulutavicum*;

A4 — sites supporting subendemic species, *Artemisia semiarida* Krasch. and *Atraphaxis decipiens* Jaub. & Spach.

Criterion B: B2 — plant communities of high conservation value containing national endemics, subendemics, and species listed in the Red Data Book of Kazakhstan, including *Tanacetum ulutavicum*, *Artemisia semiarida*, *Atraphaxis decipiens*, *Tulipa patens* C. Agardh ex Schult. & Schult. f., *T. suaveolens* Roth.; B3 — plant communities containing species of cultural and socio-economic importance, including medicinal plants listed in the annotated inventory of medicinal plants of Kazakhstan [28] (*Achillea millefolium* L., *Echinops ritro* L., *Helichrysum arenarium* (L.) Moench, *Hypericum scabrum* L., *Juniperus sabina* L., *Peucedanum morisonii* Besser, *Ziziphora clinopodioides* Lam., *Thymus pannonicus* All., *Dodartia orientalis* L., *Cotoneaster melanocarpus* Fisch. ex Blytt.), as well as communities supporting crop wild relatives, particularly species of *Allium* (*A. galanthum* Kar. & Kir., *A. globosum* Bunge, *A. lineare* L., *A. strictum* Schrad., *Medicago falcata* L., and the genera *Agropyron*, *Festuca*, *Lolium*, and *Poa*).

Criterion C: was not applied due to the current lack of a formally developed system for identifying unique or priority habitats in this region. Nevertheless, the petrophytic steppes of the Ulytau low mountains may reasonably be considered vulnerable habitats. Their vegetation, exposed to anthropogenic pressures (grazing, infrastructure-related disturbance, recreation), demonstrates slower recovery rates compared with lowland ecosystems. Species forming these communities typically exhibit relatively low reproductive potential, determined by local bioclimatic conditions and the characteristics of light chestnut soils in the low-mountain belt.

Overall, the IPA was delineated as the minimum area sufficient to ensure spatial connectivity while encompassing a substantial proportion of the known, compactly distributed occurrences of *Tanacetum ulutavicum* within the surveyed portion of the Ulytau low-mountain massif. The combination of a narrow-range endemic, additional nationally protected species, high floristic richness of petrophytic steppe communities, and the inherent vulnerability of rocky habitats establishes this territory as a priority for monitoring and targeted conservation management, even under the existing national park designation (Table 3).



A



B



Figure 3. Examples of key species within the IPA boundaries
(photographer and license indicated in parentheses for non-commercial use):

A — *Tanacetum ulutavicum* (V. Epiktetov, CC BY-NC 4.0); B — *Tulipa patens* (S. Lednev, CC BY-NC 4.0);
C — *Atraphaxis decipiens* (V. Epiktetov, CC BY-NC 4.0); D — *Allium galanthum* (L. Dimeyeva, CC BY-NC 4.0)

Table 2

Priority species (Criteria A and B)

| Taxon / criteria, subcriteria | | | Compliance with Criterion A: The IPA contains ... | | | For compliance with the KBA criteria, the site contains ... | | Importance / Occurrence |
|---------------------------------|----|-----|--|------------------------------------|-------------------------------------|---|-----------------------------------|------------------------------------|
| Taxon | A | B | ≥ 1 % global population (yes/no) | ≥ 5 % national population (yes/no) | 1 of 5 best national sites (yes/no) | ≥ 10 % global population (yes/no) | Entire global population (yes/no) | Socio-economic importance (yes/no) |
| <i>Tanacetum ulutavicum</i> | A3 | B 2 | Yes | Yes | Yes | Yes | No | No |
| <i>Artemisia semiarida</i> | A4 | B 2 | No | No | Yes | No | No | Yes |
| <i>Atraphaxis decipiens</i> | A4 | B 2 | No | No | Yes | No | No | No |
| <i>Tulipa patens</i> | - | B 2 | No | No | No | No | No | No |
| <i>Tulipa suaveolens</i> | - | B 2 | No | No | No | No | No | No |
| <i>Achillea millefolium</i> | - | B 3 | No | No | No | No | No | No |
| <i>Allium galanthum</i> | - | B 3 | No | No | Yes | No | No | No |
| <i>Artemisia juncea</i> | - | B 3 | No | No | No | No | No | No |
| <i>Cotoneaster melanocarpus</i> | - | B 3 | No | No | No | No | No | No |
| <i>Dodartia orientalis</i> | - | B 3 | No | No | No | No | No | No |
| <i>Echinops ritro</i> | - | B 3 | No | No | No | No | No | No |
| <i>Helichrysum arenarium</i> | - | B 3 | No | No | No | No | No | No |
| <i>Hypericum scabrum</i> | - | B 3 | No | No | No | No | No | No |
| <i>Juniperus sabina</i> | - | B 3 | No | No | No | No | No | No |

Continuation of Table 2

| Taxon / criteria, subcriteria | | | Compliance with Criterion A: The IPA contains ... | | | For compliance with the KBA criteria, the site contains ... | | Importance / Occurrence |
|---------------------------------|---|----|--|---|--|---|--|--|
| Taxon | A | B | ≥ 1 % global population (yes/no) | ≥ 5 % na- tional population (yes/no) | 1 of 5 best national sites (yes/no) | ≥ 10 % global pop- ulation (yes/no) | Entire global population (yes/no) | Socio- economic importance (yes/no) |
| <i>Peucedanum morisonii</i> | - | B3 | No | No | No | No | No | No |
| <i>Thymus pannonicus</i> | - | B3 | No | No | No | No | No | No |
| <i>Ziziphora clinopodioides</i> | - | B3 | No | No | No | No | No | No |

Table 3

Relationship with existing protected areas

| Protected area type | Name | Relationship with IPA | Area overlap (%) |
|----------------------------|--------|-----------------------|------------------|
| State National Nature Park | Ulytau | Partial overlap | ~80 % |

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9. Recommendations for conservation management and monitoring

To ensure the long-term conservation of the petrophytic steppes of Ulytau and the core localities of *Tanacetum ulutavicum*, the following priority management actions are proposed:

- formally delineate and approve IPA boundaries in GIS (two sites) and ensure inclusion in the national IPA registry;
- develop, in cooperation with Ulytau State National Nature Park, a long-term monitoring program for *T. ulutavicum*, including annual (seasonal) population censuses, assessment of population structure, habitat condition monitoring, documentation of anthropogenic impacts, and analysis of interannual trends;
- regulate grazing pressure within sensitive habitats and population loci of rare species, with temporary grazing restrictions during critical periods if necessary;
- restrict construction and other economic activities within IPA boundaries, prioritizing the preservation of rocky substrates and prevention of erosion;
- install informational materials along main routes, including the trail to Mount Aulietau, and implement measures to reduce trampling (marked trails, visitor routing, localized protective barriers).

Conclusion

The IPA “Petrophytic Steppes of Ulytau with *Tanacetum ulutavicum*” represents a compact yet highly valuable complex of petrophytic and dry-steppe habitats within the low-mountain zone, supporting the persistence of the narrow-range endemic *Tanacetum ulutavicum* and maintaining regional floristic diversity. The site clearly meets the Kazakhstan-adapted IPA subcriteria A3, A4, B2, and B3.

Despite its location within the protected boundaries of Ulytau State National Nature Park, key practical priorities include formal recognition of IPA boundaries, regulation of grazing and recreational impacts, and the establishment of long-term monitoring of focal populations and habitats.

Designation of the IPA within the structure of Ulytau National Park will enable a more targeted and scientifically grounded model of plant conservation, ensuring the protection of rare and endemic taxa, maintenance of essential ecosystem functions, and improved effectiveness of regional conservation strategies through strengthened protection measures and the implementation of regular research, monitoring, and adaptive management.

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Author Contributions

The manuscript was written through the contributions of all authors. All authors have approved the final version of the manuscript. CRediT: **Izbassarova Zh.S.** — conceptualization, data curation, investigation, analysis, methodology, writing draft; **Dimeyeva L.A.** — conceptualization, data curation, investigation, methodology, analysis, supervision, writing draft, editing; **Dubynin A.V.** — formal analysis, writing draft, registered in checklist dataset.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Anderson S. Identifying and conserving Important Plant Areas. — Salisbury (UK): Plantlife International, 2002. — 52 p.
- 2 Darbyshire I. Important Plant Areas: revised selection criteria for a global approach to plant conservation / I. Darbyshire, A. Anderson, A. Asatryan, A. Byfield, M. Cheek, C. Clubbe, E.A. Radford // *Biodiversity and Conservation*, 2017. — Vol. 26. — P. 1767–1800.
- 3 Plantlife. Identifying and conserving Important Plant Areas (IPAs) around the world: guide for botanists, conservationists, site managers, community groups and policy makers. — Salisbury (UK): Plantlife International, 2018. — 71 p.
- 4 Plantlife International. Important Plant Areas: Target 5 of the Global Strategy for Plant Conservation. — Salisbury (UK): Plantlife International, 2004. — 24 p.
- 5 Ишмуратова М.Ю. Флора гор Улытау (Центральный Казахстан) / М.Ю. Ишмуратова, Г.Ж. Мырзалы, В.И. Ивлева, А.Н. Матвеев. — Караганда, 2016. — 108 с.
- 6 Ишмуратова М.Ю. Эндемичные виды растений флоры Карагандинской области (Центральный Казахстан): монография / М.Ю. Ишмуратова, С.У. Тлеукенова, А.Ш. Додонова, Е.А. Гаврилькова. — Караганда, 2016. — 109 с.
- 7 Кубентаев С.А. Чек-лист редких растений флоры Улытауской области / С.А. Кубентаев, Д.Т. Алибеков, Ш.Т. Тустубаева, Б.Б. Кубентаева // *Вестник Карагандинского университета. Серия: Биология. Медицина. География*, 2024. — Т. 29. — Вып. 3(115). — С. 113–121.
- 8 Мырзалы Г.Ж. Анализ флоры гор Улытау / Г.Ж. Мырзалы, М.Ю. Ишмуратова, В.И. Ивлев, А.Н. Матвеев // *Вестник Карагандинского университета. Серия: Биология. Медицина. География*, 2014. — № 4. — С. 45–52.
- 9 Куприянов А.Н. Особенности флоры Большого Улытау / А.Н. Куприянов, И.А. Хрусталева // *Материалы VI Международной научной конференции, посвященной 100-летию со дня рождения А.В. Положий*. — Томск, 2017. — С. 67–69.
- 10 Ишмуратова М.Ю. Новые сведения о флоре гор Улытау (Центральный Казахстан) / М.Ю. Ишмуратова, В.И. Ивлев, Г.Ж. Мырзалы, А.Н. Матвеев // *Проблемы ботаники Южной Сибири и Монголии: материалы XIII Международной научно-практической конференции*, 2019. — С. 93–94.
- 11 Красная книга Казахстана. — Т. 2. — Ч. 2. Растения. Астана, 2014. — 452 с.
- 12 Артемов И.И. Критерии выделения ключевых ботанических территорий в Алтае-Саянском экорегионе / И.И. Артемов, А.Ю. Королук, Н.Н. Лашинский, И.Э. Смелянский. — Новосибирск: Сибирский экологический центр, 2007. — 106 с.
- 13 Димеева Л.А. Роль ключевых ботанических территорий в реализации стратегий сохранения биоразнообразия Казахстана / Л.А. Димеева, Г.М. Кудабаева, П.В. Веселова // *Труды XIII съезда РБО*. — Тольятти, 2013. — Т. 3. — С. 17–18.
- 14 Дубынин А.В. Ключевые ботанические территории Казахстана: адаптация критериев выделения / А.В. Дубынин, Л.А. Димеева // *Актуальные вопросы сохранения биологического разнообразия и рационального природопользования. Интродукция растений: материалы Международной конференции*. — Риддер, 2025. — С. 277–292.

- 15 Масловский О.М. Ключевые ботанические территории Беларуси / О.М. Масловский, Г.А. Пронькина, В.И. Парфенов, А.В. Пугачевский. — Минск; Москва: Представительство МСОП для России и стран СНГ, 2005. — 79 с.
- 16 Куприянов А.Н. Конспект флоры Казахского мелкосопочника / А.Н. Куприянов. — Новосибирск: Академическое изд-во «Гео», 2020. — 424 с.
- 17 Дубынин А.В. «Ландшафты Чу-Илийских гор»: первый опыт выделения ключевой ботанической территории по обновленным критериям / А.В. Дубынин, В.Г. Эпиктепов, Л.А. Димеева А.А. Курмантаева // Проблемы и перспективы сохранения биоразнообразия Центральной Азии. Международной конференции. Пленарные доклады (6–8 ноября). — Алматы, 2025.
- 18 Павлов П.Н. Флора Казахстана / П.Н. Павлов. — Алма-Ата: Изд-во АН КазССР, 1956. — Т. 1. — 354 с.; 1958. — Т. 2. — 292 с.; 1960. — Т. 3. — 460 с.; 1961. — Т. 4. — 548 с.; 1961. — Т. 5. — 515 с.; 1963. — Т. 6. — 465 с.; 1964. — Т. 7. — 497 с.; 1965. — Т. 8. — 447 с.; 1966. — Т. 9. — 640 с.
- 19 Мырзалы Г.Ж. Определитель сосудистых растений гор Улытау / Г.Ж. Мырзалы, В.И. Ивлев, М.Ю. Ишмуратова, А.Н. Матвеев. — Жезказган, 2016. — 221 с.
- 20 Ишмуратова М.Ю. Определитель сосудистых растений Центрального Казахстана / М.Ю. Ишмуратова, С.У. Тлеукенова, Е.А. Гаврилькова, А.Ш. Додонова. — Караганда: ТОО «Полиграфист», 2017. — 302 с.
- 21 Plantarium. — [Электронный ресурс]. — Режим доступа: <https://www.plantarium.ru/page/view/item/42736.html>
- 22 КазФлора. — [Электронный ресурс]. — Режим доступа: https://kazflora.kz/catalog/?ELEMENT_ID=122858
- 23 Plants of the World Online. — POWO, 2025. — [Electronic resource]. — Access mode: <https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:252559-1>
- 24 Комаров В.Л. (ред.). Флора СССР / В.Л. Комаров. — Москва; Ленинград: Изд-во АН СССР, 1961. — Т. 26. Сложноцветные (Asteraceae). — 938 с.
- 25 Стороженко Д.М. Почвы Карагандинской области / Д.М. Стороженко // Почвы Казахской ССР [в 16 вып.]. — Алма-Ата: Издательство Академии наук КазССР, 1967. — Т. 8. — 331 с.: ил.
- 26 Izbassarova Z. Checklist of vascular plant species in communities hosting the narrow-range Kazakh endemic *Tanacetum ulutavicum* Tzvelev (Version 1.1) [Dataset] / Z. Izbassarova, L. Dimeyeva, A. Dubynin. — Wings — Animal and Plant Conservation and Protection Fund, 2026. <https://doi.org/10.15468/n765pf>
- 27 Izbassarova Z. Occurrence records of *Tanacetum ulutavicum* Tzvelev from the Ulytau Mountains (Kazakhstan), supporting IUCN Red List assessment / Z. Izbassarova, L. Dimeyeva, A. Dubynin. — Wings — Animal and Plant Conservation and Protection Fund, 2026. Occurrence Dataset. <https://doi.org/10.15468/vr777q>
- 28 Грудзинская Л. М. Аннотированный список лекарственных растений Казахстана: Справочное издание / Л.М. Грудзинская, Г.Н. Гемеджиева, Н.В. Нелина, Ж.Ж. Каржаубекова // Труды Института ботаники и фитоинтродукции. — Алматы, 2014. — Т. 20(1). — 200 с.

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**«*Tanacetum ulutavicum* өсетін Ұлытау петрофитті далалары»
негізгі ботаникалық аумақ (Орталық Қазақстан):
анықтау негіздемесі және қорғау жөніндегі ұсыныстар**

Ұлытау аласа таулы массивіндегі (Ұлытау облысы, Қазақстан) 2025 жылғы далалық зерттеулер нәтижесіне сүйене отырып, «*Tanacetum ulutavicum* өсетін Ұлытау петрофитті далалары» негізгі ботаникалық аумағын анықтау негізделді. Аумақ екі участкені қамтиды, жалпы ауданы 1372 гектар (557 және 815 гектар). Көпшілігі «Ұлытау» Мемлекеттік ұлттық табиғи паркінің (МҰТП) шекарасында орналасқан және теңіз деңгейінен 508–1140 м биіктікте тасты субстраттардағы петрофитті қауымдастықтардың мозикасын қамтиды. Қорғаудың негізгі нысанасы — тас жердегі эндемик *Tanacetum ulutavicum* Tzvelev (Қазақстанның Қызыл кітабы). Ол жергілікті популяциялық учаскелерді 207–1200 м² көлемінде құрайды, тығыздығы 0,06–3 дана/м². *Tanacetum ulutavicum* Tzvelev өсетін өсімдік қауымдастықтары флоралық байлығымен (82 тамырлы өсімдік түрі) және бірқатар сирек кездесетін және аймақтық маңызды түрлерді қоса алғанда, қорғауға қатысты таксондардың шоғырлануымен сипатталады. Аумақтың Қазақстанға бейімделген негізгі ботаникалық аумақ кіші критерийлеріне сәйкестігі дәлелденді: А3 және А4 (эндемикалық және субэндемикалық түрлердің мекендеу ортасы), В2 және В3 (жоғары қорғалатын және әлеуметтік-экономикалық құндылығы бар түрлердің қауымдастықтары). Негізгі қауіптер — жайылымдық жүктеме, жердің тапталуы, ұйымдастырылмаған демалыс, сондай-ақ соқпақтар мен кіреберіс жолдардың жанындағы жергілікті субстраттың бұзылуымен байланысты. Шекараларды ГАЖ және негізгі ботаникалық аумағының тізілімінде тіркеу, *T. ulutavicum* популяциясын ұзақ мерзімді бақылау, жайылымдық және

рекреациялық ағындарды реттеу және бағыттар бойынша ақпаратты қолдау үшін басқару және мониторинг шаралары ұсынылды.

Кілт сөздер: Ұлытау, негізгі ботаникалық аумақ, петрофитті далалар, эндемикалық өсімдіктер, *Tanacetum ulutavicum*, флораны қорғау, «Ұлытау» МҰТП.

Ж.С. Избасарова, Л.А. Димеева, А.В. Дубынин

Ключевая ботаническая территория «Петрофитные степи Улытау с *Tanacetum ulutavicum*» (Центральный Казахстан): обоснование выделения и рекомендации по охране

По итогам полевых исследований 2025 года в низкогорном массиве Улытау (Улытауская область, Казахстан) обосновано выделение ключевой ботанической территории (КБТ) «Петрофитные степи Улытау с *Tanacetum ulutavicum*». Территория включает два участка общей площадью 1372 га (557 и 815 га), большая часть которой находится в границах Государственного национального природного парка (ГНПП) «Улытау», в высотном диапазоне 508–1140 м над у.м. и охватывает мозаику петрофитных сообществ на каменистых субстратах. Ключевым объектом охраны является узколокальный эндемик *Tanacetum ulutavicum* Tzvelev (Красная книга Казахстана), образующий локальные популяционные пятна площадью 207–1200 м² при плотности 0,06–3 экз./м². Растительные сообщества с участием пижмы улытавской характеризуются значительным флористическим богатством (82 вида сосудистых растений) и концентрацией значимых для охраны таксонов, включая ряд редких и регионально важных видов. Для территории обосновано соответствие адаптированным для Казахстана подкритериям КБТ А3 и А4 (местообитания эндемичных и субэндемичных видов), В2 и В3 (сообщества видов высокой природоохранной и социально-экономической ценности). Основные угрожающие факторы связаны с пастбищной нагрузкой, вытаптыванием и неорганизованной рекреацией, а также локальными нарушениями субстрата вблизи троп и подъездных дорог. Предложены меры по управлению и мониторингу: фиксация границ в ГИС и реестре КБТ, долговременный мониторинг популяций *T. ulutavicum*, регламентация выпаса и рекреационных потоков, информационное сопровождение на маршрутах.

Ключевые слова: Улытау; ключевая ботаническая территория (КБТ/ИРА); петрофитные степи; эндемики; *Tanacetum ulutavicum*; охрана флоры; ГНПП «Улытау».

References

- 1 Anderson, S. (2002). *Identifying and conserving Important Plant Areas*. Salisbury, UK: Plantlife International.
- 2 Darbyshire, I., Anderson, A., Asatryan, A., Byfield, A., Cheek, M., Clubbe, C., & Radford, E. A. (2017). Important Plant Areas: Revised selection criteria for a global approach to plant conservation. *Biodiversity and Conservation*, 26, 1767–1800.
- 3 (2018). *Plantlife. Identifying and conserving Important Plant Areas (IPAs) around the world: Guide for botanists, conservationists, site managers, community groups, and policy makers*. Salisbury, UK: Plantlife International.
- 4 (2004). *Plantlife International. Important Plant Areas: Target 5 of the Global Strategy for Plant Conservation*. Salisbury, UK: Plantlife International. 24 p.
- 5 Ishmuratova, M. Yu., Myrzaly, G. Zh., Ivlev, V. I., & Matveev, A. N. (2016). *Flora gor Ulytau (Tsentralnyi Kazakhstan)* [Flora of the Ulytau Mountains (Central Kazakhstan)]. Karaganda [in Russian].
- 6 Ishmuratova, M. Yu., Tleukenova, S. U., Dodonova, A. Sh., & Gavrilkova, E. A. (2016). *Endemichnye vidy rastenii flory Karagandinskoi oblasti (Tsentralnyi Kazakhstan): monografiia* [Endemic plant species of the flora of Karaganda Region (Central Kazakhstan): monograph]. Karaganda [in Russian].
- 7 Kubentaev, S. A., Alibekov, D. T., Tustubaeva, Sh. T., & Kubentaeva, B. B. (2024). Chek-list redkikh rastenii flory Ulytauskoi oblasti [Checklist of rare plants of the flora of Ulytau Region]. *Vestnik Karagandinskogo universiteta. Seriya «Biologiya. Meditsina. Geografiya» — Bulletin of the Karaganda University. "Biology. Medicine. Geography" Series*, 29, 3(115), 113–121 [in Russian].
- 8 Myrzaly, G. Zh., Ishmuratova, M. Yu., Ivlev, V. I., & Matveev, A. N. (2014). Analiz flory gor Ulytau [Analysis of the flora of the Ulytau Mountains]. *Vestnik Karagandinskogo universiteta. Seriya «Biologiya. Meditsina. Geografiya» — Bulletin of the Karaganda University. "Biology. Medicine. Geography" Series*, 4, 45–52 [in Russian].
- 9 Kupriyanov, A. N., & Khrustaleva, I. A. (2017). Osobennosti flory Bolshogo Ulytau [Features of the flora of Bolshoy Ulytau]. *Materialy VI Mezhdunarodnoi nauchnoi konferentsii, posviashchennoi 100-letiiu so dnia rozhdeniia A.V. Polozhii — Proceedings of the VI International Scientific Conference dedicated to the 100th anniversary of A.V. Polozhiy* (pp. 67–69). Tomsk [in Russian].

- 10 Ishmuratova, M. Yu., Ivlev, V. I., Myrzaly, G. Zh., & Matveev, A. N. (2019). Novye svedeniia o flore gor Ulytau (Tsentralnyi Kazakhstan) [New data on the flora of the Ulytau Mountains (Central Kazakhstan)]. *Problemy botaniki Yuzhnoi Sibiri i Mongolii: materialy XIII Mezhdunarodnoi nauchno-prakticheskoi konferentsii — Problems of Botany of Southern Siberia and Mongolia: Proceedings of the XIII International Scientific-Practical Conference* (pp. 93-94) [in Russian].
- 11 (2014). *Krasnaia kniga Kazakhstana* [Red Data Book of Kazakhstan]. Vol. 2, Part 2. *Rasteniia* [Plants]. Astana [in Russian].
- 12 Artemov, I. I., Korolyuk, A. Yu., Lashchinskiy, N. N., & Smelyanskiy, I. E. (2007). *Kriterii vydeleniia kliuchevykh botanicheskikh territorii v Altae-Saianskom ekoregione* [Criteria for identifying Important Plant Areas in the Altai–Sayan ecoregion]. Novosibirsk: Sibirskii ekologicheskii tsentr [in Russian].
- 13 Dimeyeva, L. A., Kudabaeva, G. M., & Veselova, P. V. (2013). Rol kliuchevykh botanicheskikh territorii v realizatsii strategii sokhraneniia bioraznobraziia Kazakhstana [The role of Important Plant Areas in the implementation of biodiversity conservation strategies in Kazakhstan]. *Trudy XIII sezda Rossiiskogo Botanicheskogo Obshchestvo — Proceedings of the XIII Congress of the Russian Botanical Society* (Vol. 3, pp. 17-18) [in Russian].
- 14 Dubynin, A. V., & Dimeyeva, L. A. (2025). Kliuchevye botanicheskie territorii Kazakhstana: adaptatsiia kriteriev vydeleniia [Important Plant Areas of Kazakhstan: Adaptation of selection criteria]. *Aktualnye voprosy sokhraneniia biologicheskogo raznobraziia i ratsionalnogo prirodopolzovaniia. Introduktsiia rastenii: materialy Mezhdunarodnoi konferentsii — Current issues of biodiversity conservation and rational nature use. Plant introduction: Proceedings of the international conference* (pp. 277–292). Ridder [in Russian].
- 15 Maslovskiy, O. M., Pronkina, G. A., Parfenov, V. I., & Pugachevskiy, A. V. (2005). *Kliuchevye botanicheskie territorii Belarusi* [Important Plant Areas of Belarus]. Minsk–Moscow: Predstavitelstvo Mezhdunarodnogo Soiuza Okhrany Prirody dlia Rossii i stran SNG [in Russian].
- 16 Kupriyanov, A. N. (2020). *Konspekt flory Kazakhskogo melkosopohnika* [Synopsis of the flora of the Kazakh uplands]. Novosibirsk: Akademicheskoe izdatelstvo «Geo» [in Russian].
- 17 Dubynin, A. V., Epiktetov, V. G., Dimeyeva, L. A., & Kurmantaeva, A. A. (2025). «Landshafty Chu-Iliiskikh gor»: pervyi opyt vydeleniia kliuchevoi botanicheskoi territorii po obnovlennym kriteriiam [“Chu-Ili Mountains Landscapes”: the First experience in Kazakhstan of designating in important Plant Area under updated criteria]. *Problemy i perspektivy sokhraneniia bioraznobraziia Tsentralnoi Azii. Mezhdunarodnoi konferentsii. Plenarnye doklady (6–8 noiabria) — Challenges and Prospects for Biodiversity Conservation in Central Asia. International scientific and practical conference. Plenary Reports (6–8 November)*. Almaty [in Russian].
- 18 Pavlov, P. N. (Ed.). (1956–1966). *Flora Kazakhstana* [Flora of Kazakhstan] (Vols. 1–9). Alma-Ata: Izdatelstvo Akademii Nauk Kazakhskoi SSR [in Russian].
- 19 Myrzaly, G. Zh., Ivlev, V. I., Ishmuratova, M. Yu., & Matveev, A. N. (2016). *Opredelitel sosudistykh rastenii gor Ulytau* [Identification guide to vascular plants of the Ulytau Mountains]. Zhezkazgan [in Russian].
- 20 Ishmuratova, M. Yu., Tleukenova, S. U., Gavrilkova, E. A., & Dodonova, A. Sh. (2017). *Opredelitel sosudistykh rastenii Tsentralnogo Kazakhstana* [Identification guide to vascular plants of Central Kazakhstan]. Karaganda: TOO «Poligrafist» [in Russian].
- 21 Plantarium (n.d.). *www.plantarium.ru*. Retrieved from <https://www.plantarium.ru/page/view/item/42736.html> [in Russian].
- 22 KazFlora (n.d.). *www.kazflora.kz*. Retrieved from https://kazflora.kz/catalog/?ELEMENT_ID=122858 [in Russian].
- 23 (2025). Plants of the World Online (POWO). (n.d.). *www.powo.science.kew.org*. Retrieved from <https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:252559-1>
- 24 Komarov, V. L. (Ed.). (1961). *Flora SSSR* [Flora of the USSR]. Vol. 26. *Slozhno-tsvetnye (Asteraceae)* [Difficult-colored (Asteraceae)]. Moscow–Leningrad: Izdatelstvo Akademii Nauk SSSR [in Russian].
- 25 Storozhenko, D. M. (1967). Pochvy Karagandinskoi oblasti [Soils of Karaganda Region]. *Pochvy Kasakhskoi SSR — Soils of the Kazakh SSR* (Vols. 1–16, Vol. 8). Alma-Ata: Izdatelstvo Akademii Nauk Kazakhskoi SSR [in Russian].
- 26 Izbassarova, Z., Dimeyeva, L., & Dubynin, A. (2026). *Checklist of vascular plant species in communities hosting the narrow-range Kazakh endemic Tanacetum ulutavicum Tzvelev (Version 1.1) [Dataset]*. Wings — Animal and Plant Conservation and Protection Fund. <https://doi.org/10.15468/n765pf>
- 27 Izbassarova, Z., Dimeyeva, L., & Dubynin, A. (2026). *Occurrence records of Tanacetum ulutavicum Tzvelev from the Ulytau Mountains (Kazakhstan), supporting IUCN Red List assessment*. Wings — Animal and Plant Conservation and Protection Fund. Occurrence Dataset. <https://doi.org/10.15468/vr777q>
- 28 Grudzinskaya, L. M., Gemedzhieva, N. G., Nelina, N. V., & Karzhaubekova, Zh. Zh. (2014). Annotirovannyi spisok lekarstvennykh rastenii Kazakhstana: Spravochnoe izdanie [Annotated list of medicinal plants of Kazakhstan: A reference edition]. *Trudy Instituta botaniki i fitointroduktsii — Proceedings of the Institute of Botany and Phytointroduction*, 20(1), 200 [in Russian].

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Wild-Growing Species of the Genus *Ribes* L. in Central Kazakhstan: Bioecological Characteristics

The genus *Ribes* L. (*Grossulariaceae*) comprises numerous species of ecological, nutritional, and medicinal importance that are widely distributed across temperate regions of the Northern Hemisphere. Central Kazakhstan represents a biogeographically complex area characterized by diverse landscapes and heterogeneous environmental conditions; however, information on wild-growing *Ribes* species in this region remains fragmented and insufficiently systematized. This review aims to synthesize and critically evaluate the available literature on the bioecological characteristics, phytochemical composition, and research prospects of wild *Ribes* species occurring in Central Kazakhstan, with particular focus on *Ribes aciculare* Pall., *Ribes nigrum* L., and representatives of the *Ribes saxatile* species complex. The review is based on an analysis of regional floristic sources, ecological studies, and phytochemical investigations published in international and regional scientific journals. Data on species distribution, habitat preferences, phenology, and ecological adaptations are summarized, together with information on major groups of bioactive compounds, including anthocyanins, flavonoids, proanthocyanidins, organic acids, and vitamins. Most phytochemical studies of the genus *Ribes* have focused on *Ribes nigrum*, which remains the best-studied species. In contrast, information on other wild *Ribes* taxa remains limited and scattered across different publications, making comprehensive evaluation difficult. Taxonomic uncertainties within the *Ribes saxatile* species complex further complicate regional research and highlight the importance of accurate species identification. The existing literature also reveals several important gaps, particularly regarding region-specific phytochemical characteristics, ecological variation among natural populations, and the influence of environmental factors on secondary metabolite accumulation. Further research integrating bioecological and phytochemical approaches is necessary to better understand wild *Ribes* diversity and support the sustainable use of these species in Central Kazakhstan.

Keywords: *Ribes* L.; Central Kazakhstan; bioecology; phytochemical composition; currants; medicinal plants, wild-growing species.

Introduction

The genus *Ribes* L., belonging to the family *Grossulariaceae*, comprises approximately 150–200 species distributed predominantly across the temperate and boreal regions of the Northern Hemisphere (Rehder, 1940; Takhtajan, 1986; Hummer & Barney, 2002). Species of this genus, commonly referred to as currants and gooseberries, are widely recognized as valuable biological resources due to their ecological significance, nutritional properties, and medicinal potential. Both wild and cultivated representatives of *Ribes* play an important role in natural ecosystems and agroecosystems, serving as components of forest understories, shrub communities, and ecotones, as well as sources of food for wildlife and humans (Brennan, 2008; Izteleuova et al., 2025).

From a biochemical and nutritional perspective, *Ribes* species are distinguished by their high content of biologically active compounds. Fruits and leaves contain diverse groups of secondary metabolites, including anthocyanins, flavonoids, proanthocyanidins, phenolic acids, vitamins (particularly vitamin C), organic acids, and polysaccharides, many of which exhibit pronounced antioxidant, anti-inflammatory, antimicrobial, and other health-promoting activities (Koponen et al., 2007; Dobson et al., 2012; Krüger & Dietrich, 2018; Izteleuova et al., 2025). Among the genus, *Ribes nigrum* L. has been studied most intensively, owing to its widespread cultivation and established use in food, pharmaceutical, and nutraceutical industries (Nour et al., 2011; Boda et al., 2025). In contrast, the phytochemical composition and biological properties of many wild-growing *Ribes* species remain poorly characterized, particularly in regions where these taxa occur exclusively or predominantly in natural habitats [1].

Central Kazakhstan represents a biogeographically complex and environmentally heterogeneous region, encompassing steppe, forest-steppe, and low- to mid-mountain ecosystems with pronounced continental climatic conditions. The region is characterized by strong seasonal temperature fluctuations, variable precipitation, and a mosaic distribution of habitats, including rocky slopes, river valleys, forest “islands”, and moist microhabitats within predominantly arid landscapes (Takhtajan, 1986; Sagdullaev & Ishmuratova, 2016). Such environmental heterogeneity creates favorable conditions for the persistence of relict, boreal, and mesophilous plant species, including representatives of the genus *Ribes*. However, despite the availability of regional floristic works, information on the ecology, distribution, and biological characteristics of wild *Ribes* species in Central Kazakhstan remains scattered and has not been comprehensively synthesized.

According to available floristic and regional botanical sources, several wild-growing *Ribes* taxa occur in Central Kazakhstan, including *Ribes aciculare* Pall., *Ribes nigrum* L., and representatives of the *Ribes saxatile* species complex (Sagdullaev & Ishmuratova, 2016; Bai et al., 2025). These taxa differ in ecological preferences, habitat requirements, and morphological traits, while also presenting taxonomic challenges due to synonymy, overlapping diagnostic characters, and varying species concepts adopted by different authors. In particular, the *R. saxatile* complex has been treated inconsistently in the literature, with related taxa such as *R. diacantha* Pall., *R. petraeum* Wulfen, and *R. rubrum* var. *saxatile* being interpreted either as distinct species or as intraspecific variants, depending on regional and taxonomic approaches (Rehder, 1940; Pikunova et al., 2022; Zhao et al., 2025) [2].

Despite the growing global interest in *Ribes* species as sources of functional foods and phytopharmaceuticals, most phytochemical and pharmacological studies are based on cultivated material or populations from Western and Eastern Europe, East Asia, and North America (Ośmiański & Wojdyło, 2009; McDougall & Stewart, 2005; Minasyan et al., 2025). Consequently, there is a notable lack of data on wild-growing populations from Central Asia, including Central Kazakhstan, where environmental stress factors such as drought, temperature extremes, and edaphic heterogeneity may significantly influence both bioecological traits and secondary metabolite profiles. Understanding these relationships is essential for assessing the adaptive potential of wild *Ribes* species, their value as genetic resources, and their prospects for conservation and sustainable use.

The aim of the present review is to synthesize and critically analyze available literature on the wild-growing species of the genus *Ribes* in Central Kazakhstan, with a focus on their bioecological characteristics, phytochemical composition, and research perspectives. Specifically, this review addresses (i) the taxonomic status and species composition of *Ribes* in the region; (ii) patterns of distribution, habitat preferences, and key bioecological traits; (iii) the current state of knowledge on phytochemical constituents and reported biological activities; and (iv) existing gaps in research and future directions for integrated ecological, phytochemical, and conservation-oriented studies (Fig. 1).





Figure 1. Appearance of blackcurrant populations (Karaganda Region)

Experimental

2. Materials and Methods

2.1. Literature Search Strategy

This review is based on an analysis of scientific publications devoted to wild-growing species of the genus *Ribes* L., with particular attention to taxa recorded in Central Kazakhstan. Relevant literature was identified through searches in major international databases, including Scopus, Web of Science, PubMed, Google Scholar, and ScienceDirect, as well as in regional botanical publications and national scientific sources.

Additional relevant publications were identified through manual screening of reference lists from key review articles and floristic monographs (Rehder, 1940; Takhtajan, 1986; Sagdullaev & Ishmuratova, 2016; Izteleuova et al., 2025) [3].

Search queries were constructed using combinations of keywords such as “*Ribes*”, “*wild species*”, “*bioecology*”, “*phytochemistry*”, “*anthocyanins*”, “*phenolic compounds*”, “*Central Kazakhstan*”, “*Species distribution*”, and “*Grossulariaceae*”. Both English- and Russian-language publications were considered in order to capture regional floristic and ecological studies that are often underrepresented in international databases. The primary time frame of the literature search covered publications from 1990 to 2025, while earlier classical taxonomic and floristic works were included where necessary to clarify species concepts and nomenclature (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975).

2.2. Inclusion and Exclusion Criteria

Publications were included in the review if they met one or more of the following criteria: (i) provided data on the distribution, ecology, or bioecological characteristics of *Ribes* species occurring in Central Kazakhstan or adjacent regions with comparable environmental conditions; (ii) reported phytochemical composition or biological activity of *Ribes* species, particularly *Ribes nigrum*, *Ribesaciculare*, or taxa related to the *Ribes saxatile* species complex; (iii) addressed taxonomic, systematic, or genetic aspects relevant to species delimitation within the genus *Ribes*.

Priority was given to studies focusing on wild-growing populations rather than cultivated material, especially when discussing ecological traits, habitat preferences, and natural variability. Experimental and analytical studies based on cultivated varieties were included only when data on wild populations were unavailable or when such studies provided essential background information on phytochemical classes or biological activities characteristic of the genus (Dobson et al., 2012; Krüger & Dietrich, 2018; Izteleuova et al., 2025).

Publications were excluded if they:

(i) focused exclusively on unrelated genera or species not taxonomically associated with *Ribes*; (ii) addressed only agronomic practices or commercial cultivation without relevance to wild taxa; (iii) lacked sufficient methodological detail or clear taxonomic identification of the studied material [4].

2.3. Data Extraction and Synthesis

Relevant information was extracted from selected publications and systematically organized into thematic categories corresponding to the objectives of the review. Data on species distribution, habitat characteristics, phenology, life forms, and ecological adaptations were summarized to provide an integrated overview of bioecological traits. Phytochemical data were grouped according to major classes of compounds, including phenolic compounds, anthocyanins, flavonoids, proanthocyanidins, vitamins, organic acids, and volatile constituents, with particular emphasis on compounds reported consistently across multiple studies (Koponen et al., 2007; Oszmiański & Wojdyło, 2009; Nour et al., 2011).

Where available, information on analytical methods (e.g., HPLC-DAD, LC-MS/MS, GC-MS) was recorded to facilitate comparison between studies and to assess the reliability and comparability of reported results (Lee et al., 2005; Prior et al., 2005). Biological and pharmacological activities were evaluated qualitatively based on experimental models, target systems, and reported effect sizes, without extrapolation beyond the evidence provided in the original sources (Mc Dougall & Stewart, 2005; Minasyan et al., 2025).

The synthesized data were subsequently used to identify patterns, knowledge gaps, and inconsistencies in the current literature, forming the basis for the discussion of research perspectives and future directions presented in later sections of this review [5].

3. Taxonomic Notes and Species Concept

The genus *Ribes* L. is traditionally placed in the family Grossulariaceae, which is widely recognized as a distinct taxonomic unit within the order Saxifragales (Rehder, 1940; Takhtajan, 1986). Representatives of *Ribes* are deciduous shrubs characterized by palmately lobed leaves, racemose or solitary inflorescences, inferior ovaries, and berry-type fruits. The genus includes both currants and gooseberries and is distributed predominantly in temperate and boreal regions of the Northern Hemisphere, with centers of diversity in Eurasia and North America (Hummer & Barney, 2002; Brennan, 2008).

Historically, the taxonomic circumscription of *Ribes* has been subject to debate, particularly regarding its relationship with the genus *Grossularia* Mill. In older classifications, gooseberries were often treated as a separate genus (*Grossularia*), based primarily on morphological characters such as the presence of spines and differences in inflorescence structure (Rehder, 1940). However, most modern taxonomic treatments incorporate *Grossularia* within *Ribes*, recognizing these taxa as part of a single, morphologically variable genus supported by anatomical, cytological, and molecular evidence (Graham et al., 1996; Hummer & Barney, 2002; Pikunova et al., 2022). In the present review, *Ribes* is treated in this broadly accepted sense (*Ribes sensulato*), in accordance with contemporary floristic and systematic sources.

Within the genus, species delimitation remains problematic for several taxonomic groups, particularly those characterized by high morphological plasticity and overlapping diagnostic features. One of the most challenging groups is the *Ribes saxatile* species complex, which has been interpreted differently by various authors depending on geographic region and taxonomic tradition. In the literature, taxa such as *Ribes saxatile* Pall., *Ribes diacantha* Pall., *Ribes petraeum* auct. non Wulfen, and *Ribes rubrum* var. *saxatile* have been treated either as distinct species, subspecies, or intraspecific variants (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975; Pikunova et al., 2022; Zhao et al., 2025) [6].

The name *Ribes petraeum* has frequently been applied in a broad and sometimes incorrect sense (*auct. Non Wulfen*) to rocky or montane forms of *Ribes* with reduced leaf size and compact growth habit. Such usage has contributed to taxonomic ambiguity, particularly in regional floras, where morphological variation may reflect ecological adaptation rather than clear species-level differentiation. Similarly, *Ribes diacantha* Pall. has been variably regarded as an independent species or remember its treatment as part of the *R. saxatile* aggregate, depending on the diagnostic weight assigned to spine development, inflorescence structure, and fruit characteristics (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975).

Molecular and population-level studies conducted on *Ribes* in other regions have demonstrated that morphological traits traditionally used for species delimitation may exhibit considerable plasticity under varying environmental conditions (Graham et al., 1996; Palmieri et al., 2009; Pikunova et al., 2022). These findings support the view that the *R. saxatile* group represents a species complex rather than a set of clearly isolated taxa, particularly in ecologically heterogeneous regions. However, comparable genetic and integrative taxonomic studies are currently lacking for populations occurring in Central Kazakhstan, limiting the possibility of definitive taxonomic conclusions for this region [7].

In floristic treatments of Central Kazakhstan, including regional monographs and checklists, the presence of *Ribes aciculare* Pall., *Ribes nigrum* L., and taxa attributed to the *Ribes saxatile* group has been con-

sistently reported, although the taxonomic interpretation of the latter varies among sources (Sagdullaev & Ishmuratova, 2016; Bai et al., 2025). To avoid taxonomic overinterpretation and to maintain consistency with available data, the present review adopts a conservative approach and refers to these taxa collectively as the *Ribes saxatile complex (sensulato)* when discussing distribution, ecology, and phytochemical data in Central Kazakhstan.

Such an approach allows for the integration of heterogeneous literature sources while acknowledging existing uncertainties in species delimitation. At the same time, it highlights the need for future integrative studies combining detailed morphological analysis, molecular markers, and ecological data to clarify the taxonomic status of *Ribes* taxa in Central Kazakhstan and adjacent regions [8].

4. Study Area: Central Kazakhstan

Central Kazakhstan represents a distinct natural–geographical region located in the central part of the Republic of Kazakhstan and largely corresponding to the territory of the Kazakh Uplands (Saryarka). The region is characterized by a complex geological history and a pronounced heterogeneity of landscapes, forming a mosaic of steppe plains, low mountain ranges, rocky massifs, intermontane depressions, and river valleys. Such landscape diversity plays a key role in shaping the floristic composition and ecological differentiation of plant communities, including habitats suitable for wild-growing species of the genus *Ribes* (Takhtajan, 1986; Sagdullaev & Ishmuratova, 2016).

The climate of Central Kazakhstan is sharply continental, with cold winters, hot and dry summers, and high interannual variability in temperature and precipitation. Mean annual air temperatures are generally low, while seasonal amplitudes may exceed 35–40 °C. Precipitation is unevenly distributed throughout the year and across the region, with annual totals typically ranging from 200 to 350 mm, increasing locally in mountainous and foothill areas (Takhtajan, 1986). These climatic conditions impose significant constraints on vegetation development and favor the formation of drought-tolerant steppe communities, interspersed with mesophilous vegetation in ecologically favorable microhabitats [9].

Vegetation cover in Central Kazakhstan is dominated by steppe and dry steppe ecosystems; however, forested areas occur as isolated “islands” within mountainous regions and along river valleys. These forest and shrub communities are often confined to north-facing slopes, shaded ravines, rocky outcrops, and zones with increased soil moisture availability. Such microhabitats provide refugial conditions for mesophilous shrub species, including representatives of *Ribes*, which are otherwise unable to persist in the open steppe under arid climatic conditions (Sagdullaev & Ishmuratova, 2016).

Soil cover in the region is similarly heterogeneous, ranging from chestnut and dark chestnut soils in steppe zones to mountain meadow, forest, and skeletal soils on rocky slopes and uplands. River valleys and temporary watercourses create localized zones of increased soil moisture and nutrient availability, supporting riparian and shrub vegetation. These edaphic factors, in combination with topography and microclimate, are critical determinants of the distribution and persistence of wild *Ribes* populations in Central Kazakhstan (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016) [10].

5. Distribution and Habitat Preferences of Central Kazakhstan *Ribes*

The distribution of wild *Ribes* species in Central Kazakhstan is closely related to the strong environmental contrasts characteristic of the region. Although the landscape is dominated by arid steppe ecosystems, these plants tend to occur in localized habitats where moisture conditions are relatively more favorable for mesophilous vegetation. According to regional floristic treatments and botanical surveys, representatives of the genus *Ribes* occur sporadically and are confined to ecologically favorable sites, rather than being continuously distributed across the region (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016) [11].

Available data indicate that *Ribes aciculare* Pall., *Ribes nigrum* L., and taxa attributed to the *Ribes saxatile* complex are primarily associated with mountainous and submontane areas of Central Kazakhstan, including the Ulytau mountain system and adjacent uplands. These species are typically recorded in shaded ravines, moist rocky slopes, forested valleys, and along permanent or temporary watercourses, where soil moisture availability is higher and microclimatic conditions are less extreme than in surrounding open steppe areas (Sagdullaev & Ishmuratova, 2016; Bai et al., 2025).

Habitat preferences of *Ribes* species in the region reflect their general ecological requirements for moderate moisture, partial shading, and protection from extreme temperature fluctuations. North-facing slopes, narrow gorges, and rock fissures provide refugial conditions that reduce evapotranspiration and buffer

against summer heat and winter cold. In such habitats, *Ribes* shrubs often occur as components of shrub-herbaceous communities or forest undergrowth, rather than forming dense or extensive populations (Flora of Kazakhstan Editorial Board, 1961–1975).

Edaphic conditions also play a critical role in shaping the distribution of *Ribes* species. In Central Kazakhstan, these taxa are most frequently associated with well-drained but moisture-retentive soils, including mountain meadow soils, forest soils, and skeletal substrates enriched with organic matter in rock crevices and slope accumulations. In riparian habitats, *Ribes* may occur on alluvial soils with periodic moisture supply, particularly along small streams and seasonal watercourses (Sagdullaev & Ishmuratova, 2016) [12].

Altitude represents an additional factor influencing the occurrence of *Ribes* species in the region. Although precise altitudinal ranges are not consistently reported in the literature, available observations suggest that wild *Ribes* populations in Central Kazakhstan are mainly confined to low- and mid-mountain belts, where climatic conditions are comparatively milder and precipitation levels are slightly higher than in surrounding plains (Takhtajan, 1986; Bai et al., 2025). The absence or rarity of *Ribes* species in lowland steppe areas underscores their limited tolerance to prolonged drought and high summer temperatures.

Overall, the distribution pattern of *Ribes* species in Central Kazakhstan can be characterized as fragmented and habitat-dependent, shaped by the presence of localized mesic microhabitats within a broader arid matrix. This spatial fragmentation has important implications for population structure, regeneration dynamics, and genetic diversity, as well as for the conservation and sustainable use of wild *Ribes* resources in the region. The observed habitat specificity also suggests that environmental factors may significantly influence bioecological traits and phytochemical profiles of wild-growing *Ribes* populations, a topic that warrants further investigation in subsequent sections of this review (Table 1).

Table 1

Wild-growing *Ribes* species reported for Central Kazakhstan and their main habitat characteristics

| Species | Accepted species / taxonomic note | Habitat type in Central Kazakhstan | Typical microhabitats | Altitudinal range (if reported) | Main sources |
|----------------------------------|---|--|---|---|---|
| <i>Ribes aciculare</i> Pall. | Accepted species | Mountain slopes, forest edges, rocky ravines | Shaded rocky slopes, moist gullies, forest understory | Low–mid mountain belt (not consistently reported) | Flora of Kazakhstan (1961–1975); Sagdullaev & Ishmuratova (2016) |
| <i>Ribes nigrum</i> L. | Accepted species | Riparian forests, moist valleys, shrub communities | Riverbanks, stream valleys, moist forest margins | Low–midmountain belt | Flora of Kazakhstan (1961–1975); Sagdullaev & Ishmuratova (2016); Bai et al. (2025) |
| <i>Ribes saxatile</i> Pall. s.l. | Species complex (incl. <i>R. diacantha</i> , <i>R. petr aeuum</i> auct. non Wulfen, <i>R. rubrum</i> var. <i>saxatile</i>) | Rocky slopes, mountains hrublands | Rock crevices, north-facing slopes, screes | Mainly mountainbelt | Rehder (1940); Flora of Kazakhstan (1961–1975); Pikunova et al. (2022); Bai et al. (2025) |

Note.

- Habitat descriptions are summarized from regional floristic sources; detailed quantitative ecological data are limited for Central Kazakhstan.
- The *Ribes saxatile* group is treated here as a species complex (sensulato) due to taxonomic inconsistencies among sources.
- Altitudinal ranges are reported only when explicitly mentioned in the literature.

6. Bioecological Characteristics of Wild-Growing *Ribes* Species

Wild-growing species of the genus *Ribes* in Central Kazakhstan exhibit a range of bioecological traits that reflect their adaptation to heterogeneous and often stressful environmental conditions. These traits include life form characteristics, phenological patterns, reproductive strategies, mechanisms of seed dispersal

and regeneration, as well as responses to limiting environmental and anthropogenic factors. Available information on these aspects is derived mainly from regional floristic accounts and general ecological studies, while species-specific quantitative data remain limited for the region (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016) [13].

6.1. Life Forms and Population Traits

All wild *Ribes* species reported from Central Kazakhstan are perennial deciduous shrubs. They typically form multi-stemmed bushes with well-developed root systems, allowing them to persist in rocky substrates, shallow soils, and periodically dry habitats. Plant height and crown architecture vary depending on species, habitat conditions, and moisture availability. In shaded and relatively moist microhabitats, individuals may attain greater height and biomass, whereas in exposed rocky sites plants often exhibit reduced stature and compact growth forms (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975).

Populations of wild *Ribes* in the region are generally sparse and spatially fragmented, reflecting the patchy distribution of suitable habitats. Dense, continuous stands are uncommon; instead, plants occur as isolated individuals or small groups within shrub–herbaceous or forest communities. Such population structure may limit gene flow and regeneration potential, particularly under increasing anthropogenic pressure (Sagdullaev & Ishmuratova, 2016) [14].

6.2. Phenology

Phenological development of *Ribes* species in Central Kazakhstan follows a pronounced seasonal pattern typical of continental climates. Flowering usually occurs in spring to early summer, shortly after leaf emergence, while fruit ripening takes place in mid to late summer. The exact timing of phenological phases varies depending on altitude, slope exposure, and local microclimatic conditions. North-facing slopes and shaded valleys often exhibit delayed flowering and fruiting compared to more exposed sites (Flora of Kazakhstan Editorial Board, 1961–1975). Interannual variability in temperature and precipitation may further influence phenological timing, potentially affecting reproductive success and fruit yield in wild populations.

6.3. Seed Dispersal and Regeneration

The fruits of *Ribes* species are fleshy berries, which indicate that their seeds are most likely dispersed by animals, mainly birds and mammals. This type of dispersal can help the plants spread to suitable microhabitats and may also support gene flow between populations that are otherwise spatially separated. In Central Kazakhstan, seedling establishment is likely constrained by moisture availability, soil depth, and competition with herbaceous vegetation, particularly in steppe-dominated landscapes (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975).

Regeneration of wild *Ribes* populations appears to be episodic and dependent on favorable climatic conditions. Periods of increased precipitation may enhance seed germination and seedling survival, whereas prolonged droughts can severely limit recruitment. Empirical data on regeneration dynamics in the region are scarce and largely qualitative [15].

6.4. Limiting Factors

The distribution and viability of wild *Ribes* populations in Central Kazakhstan may be constrained by a combination of environmental and human-related factors. Natural limitations include climatic aridity, high summer temperatures, and low or irregular precipitation. At the same time, anthropogenic pressures such as grazing, trampling, fire, and local habitat disturbance can further reduce population size and hinder natural regeneration, particularly in easily accessible mountain valleys and riparian habitats (Sagdullaev & Ishmuratova, 2016).

Because suitable habitats are often fragmented and spatially limited, even relatively small disturbances can have significant consequences for small and isolated populations. Under such conditions, maintaining stable habitats becomes particularly important. These circumstances underline the need for habitat protection and regular monitoring in order to conserve the genetic resources of wild *Ribes* species in the region (Table 2) [16].

Bioecological traits of wild *Ribes* species recorded in Central Kazakhstan

| Species | Life form | Typical plant height | Flowering period | Fruiting period | Reproduction | Main limiting factors | Main sources |
|--------------------------------------|---------------------------|----------------------|---------------------|-----------------|--|---|--|
| <i>Ribes aciculare</i> Pall. | Perennial deciduous shrub | Up to 1–1.5 m | Spring–early summer | Midlate summer | Mainly sexual; possible vegetative shoots | Drought; habitat fragmentation | Flora of Kazakhstan (1961–1975); Sagdullaev & Ishmuratova (2016) |
| <i>Ribes nigrum</i> L. | Perennial deciduous shrub | Up to 1.5–2 m | Spring | Summer | Sexual; insect pollination; vegetative propagation | Moisture deficit; anthropogenic disturbance | Flora of Kazakhstan (1961–1975); Hummer & Barney (2002); Sagdullaev & Ishmuratova (2016) |
| <i>Ribes saxatile</i> complex (s.l.) | Perennial deciduous shrub | Usually ≤1 m | Late spring | Summer | Predominantly sexual; zoochorous dispersal | Rocky substrates; limited soil moisture | Rehder (1940); Flora of Kazakhstan (1961–1975); Pikunova et al. (2022) |

Note.

1. Phenological periods are generalized based on available regional floristic data; precise timing may vary with altitude and microclimatic conditions.
2. Data on reproductive biology are largely inferred from studies conducted outside Central Kazakhstan or on cultivated material.
3. The *Ribes saxatile* group is treated as a species complex (sensulato) due to unresolved taxonomic boundaries.

7. Species Accounts**7.1. *Ribes aciculare* Pall. Taxonomic and Diagnostic Notes**

Ribes aciculare Pall. is a well-recognized species within the genus *Ribes*, characterized by its spiny shoots, relatively small leaves with shallow lobation, and compact shrub habit. The species is morphologically adapted to continental and often xeric or semi-xeric environments, which is reflected in its reduced leaf surface area and the presence of spines that may contribute to protection against herbivory (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975). In contrast to some other members of the genus, *R. aciculare* exhibits comparatively low morphological plasticity, which facilitates its identification in the field and in herbarium material.

Distribution and Habitats in Central Kazakhstan

In Central Kazakhstan, *Ribes aciculare* is reported primarily from mountainous and upland areas, where it occurs sporadically in ecologically sheltered sites. According to regional floristic sources, the species is confined to shaded ravines, rocky slopes, and forest margins, often associated with north-facing exposures that provide reduced solar radiation and improved moisture retention (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016). The fragmented distribution of *R. aciculare* reflects the patchy availability of suitable microhabitats within the predominantly arid steppe matrix of the region [17].

The species is typically encountered in small populations or as isolated individuals rather than forming continuous stands. Such distribution patterns suggest limited dispersal opportunities and a strong dependence on local environmental conditions. Similar habitat preferences have been reported for *R. aciculare* populations in adjacent regions of Central Asia, supporting the view that the species is ecologically specialized and sensitive to habitat alteration (Takhtajan, 1986).

Ecological Role and Associated Plant Communities

In Central Kazakhstan, *Ribes aciculare* usually occurs as part of shrub–herbaceous or forest-edge communities and rarely forms dominant stands. It may co-occur with other shrubs and woody plants adapted to mesic microhabitats, contributing to structural diversity and providing food resources for wildlife through its fruits. Although detailed phytosociological studies focusing specifically on *R. aciculare* are lacking, its presence in forested ravines and rocky slopes suggests a role in stabilizing soils and supporting local biodiversity (Sagdullaev & Ishmuratova, 2016).

Conservation Notes

At present, *Ribes aciculare* is not widely recognized as a threatened species at the national level; however, its fragmented distribution and dependence on specific microhabitats may render local populations vulnerable to environmental change. Potential threats include habitat disturbance, overgrazing, and increased aridity associated with climate change. Given the limited data on population size, structure, and regeneration dynamics in Central Kazakhstan, targeted field surveys are required to assess the conservation status of the species more accurately [18].

7.2. *Ribes nigrum* L.

Taxonomic and Diagnostic Notes

Ribes nigrum L. (black currant) is one of the most widely recognized and economically important species of the genus *Ribes*. It is characterized by erect to spreading deciduous shrubs, palmately lobed leaves with glandular dots, racemose inflorescences, and black aromatic berries rich in phenolic compounds [19]. The species shows considerable morphological variability across its range, partly reflecting ecological plasticity and adaptation to different climatic conditions (Rehder, 1940; Hummer & Barney, 2002). Despite extensive research on cultivated forms, wild-growing populations remain less well documented in many regions, including Central Kazakhstan.

Ecological Role and Associated Plant Communities

In Central Kazakhstan, *Ribes nigrum* usually occurs as a minor component of riparian and forest-edge plant communities rather than forming dominant stands. It commonly grows together with other moisture-demanding shrubs and herbaceous plants. Within these communities, the species contributes to the understory structure and may play an ecological role by helping stabilize soils and providing food resources for various wildlife species. The berries are consumed by birds and mammals, facilitating zoochorous seed dispersal and potentially enhancing gene flow among fragmented populations (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975) [20].

Although *R. nigrum* rarely forms dense stands in the region, its presence in ecologically sensitive habitats underscores its potential role as an indicator species for mesic microhabitats within arid landscapes. Disturbance of riparian zones and forest fragments may therefore disproportionately affect local populations.

Conservation Notes

At present, *Ribes nigrum* is not considered a threatened species in Central Kazakhstan; nevertheless, wild populations may be vulnerable to habitat degradation, hydrological changes, and increasing anthropogenic pressure in riparian zones. The fragmented nature of suitable habitats, combined with limited data on

population size and regeneration, complicates conservation assessment. Protection of moist habitats and forest fragments is therefore essential for maintaining wild *R. nigrum* populations and preserving their potential value as genetic resources for breeding and adaptation studies (Sagdullaev & Ishmuratova, 2016) [21].

7.3. *Ribes saxatile* Species Complex (*sensulato*)

Taxonomic Background and Rationale for the “Species Complex” Concept

The taxon traditionally referred to as *Ribes saxatile* Pall. represents one of the most taxonomically challenging groups within the genus *Ribes*. Across different floristic and systematic treatments, this group has been variously interpreted as a single polymorphic species, a set of closely related species, or a collection of intraspecific taxa adapted to rocky and montane habitats (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975). Names such as *Ribes diacantha* Pall., *Ribes petraeumaut.* non Wulfen, and *Ribes rubrum* var. *saxatile* have frequently been applied to morphologically similar plants, often without consistent diagnostic criteria [22].

In many cases, the application of these names reflects regional taxonomic traditions rather than clear biological discontinuities. As a result, the same or closely similar populations may be treated under different names in different parts of Eurasia. This situation has led to considerable ambiguity in the interpretation of distributional and ecological data, particularly in regions where detailed taxonomic revisions are lacking.

Treatment of the *Ribes saxatile* Complex in Central Kazakhstan

In floristic accounts of Central Kazakhstan, including regional monographs and checklists, taxa attributable to the *Ribes saxatile* group are consistently reported; however, their exact taxonomic circumscription varies among sources (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016). Some authors recognize *R. saxatile* Pall. as a distinct species, while others refer to related forms under alternative names or treat them as variants within a broader species concept.

Given the absence of integrative taxonomic studies (combining morphology, genetics, and ecology) for Central Kazakhstan populations, a conservative approach is adopted in the present review [23]. All records corresponding to this group are therefore treated collectively as the *Ribes saxatile species complex* (*sensulato*), encompassing plants referred to in the literature as *R. saxatile* Pall., *R. diacantha* Pall., *R. petraeumaut.* non Wulfen, and *R. rubrum* var. *saxatile*. This approach allows for the synthesis of available data without imposing potentially unsupported taxonomic decisions.

Distribution and Habitat Preferences

In Central Kazakhstan, representatives of the *Ribes saxatile* complex are primarily associated with mountainous and rocky habitats. They are most frequently recorded on rocky slopes, screes, cliff faces, and north-facing exposures, where shallow soils, reduced competition, and localized moisture retention create suitable conditions for shrub establishment (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016) [24].

Reproductive Biology and Regeneration

Information on the reproductive biology of *Ribes saxatiles*.l. in Central Kazakhstan is extremely limited. As with other members of the genus, reproduction is presumed to be predominantly sexual, with insect pollination and zoochorous seed dispersal via fleshy berries. However, direct observations of pollination biology, seed dispersal agents, and regeneration dynamics are lacking for regional populations (Flora of Kazakhstan Editorial Board, 1961–1975) [25].

The fragmented distribution of suitable rocky habitats suggests that populations may be small and isolated, potentially limiting gene flow and increasing vulnerability to environmental change. At the same time, the persistence of *R. saxatiles*.l. in extreme microhabitats indicates a degree of ecological resilience, which may be of interest for future studies on stress tolerance and adaptation.

Conservation Considerations

Although taxa of the *Ribes saxatile* complex are not currently recognized as threatened in Central Kazakhstan, their restriction to specialized rocky habitats may increase sensitivity to localized disturbances, such as mining activities, infrastructure development, and changes in hydrological regimes. The lack of detailed population-level data hampers accurate assessment of conservation status [26].

From a conservation and research perspective, the *Ribes saxatile* complex represents an important target for future integrative studies aimed at clarifying species boundaries, assessing genetic diversity, and evaluat-

ing adaptive traits under continental and montane conditions. Such studies would not only resolve long-standing taxonomic questions but also contribute to the sustainable management of wild *Ribes* genetic resources in Central Kazakhstan.

8. Major Compound Classes

Phenolic Compounds

Phenolic compounds represent the dominant class of secondary metabolites in *Ribes* species. These include flavonols, flavan-3-ols, proanthocyanidins, and phenolic acids, which contribute significantly to antioxidant capacity and other biological effects (Oszmiański & Wojdyło, 2009; Dobson et al., 2012). In *Ribes nigrum*, numerous phenolic constituents have been identified, including derivatives of quercetin, myricetin, and kaempferol, as demonstrated by chromatographic analyses of fruit and leaf extracts (Koponen et al., 2007; Izteleuova et al., 2025) [27].

Anthocyanins

Anthocyanins are particularly abundant in the fruits of *Ribes nigrum* and represent key phytochemical markers of the species. The major anthocyanins commonly reported include delphinidin-3-O-rutinoside, cyanidin-3-O-rutinoside, delphinidin-3-O-glucoside, and cyanidin-3-O-glucoside (Koponen et al., 2007; Krüger & Dietrich, 2018). These compounds are largely responsible for the intense coloration of black currant fruits and their strong antioxidant properties.

Vitamins, Organic Acids, and Sugars

In addition to phenolic compounds, *Ribes* fruits are known to contain considerable amounts of vitamins, particularly vitamin C, as well as various organic acids and sugars that influence nutritional value and sensory properties (Nour et al., 2011; Izteleuova et al., 2025). Citric and malic acids are frequently reported as dominant organic acids in the genus, although quantitative profiles may vary depending on species, environmental conditions, and developmental stage [28].

Seed Lipids and Fatty Acids

Seeds and pomace of *Ribes nigrum* have attracted attention as potential sources of biologically active lipids and fatty acids, particularly in the context of by-product utilization and sustainable processing. Studies employing green extraction technologies, such as supercritical CO₂ extraction, highlight the relevance of seed-derived fractions for functional food and nutraceutical applications (Krüger & Dietrich, 2018) (Table 3) [29].

Table 3

Key phytochemical marker groups and analytical methods reported for *Ribes* (with relevance to Central Kazakhstan review)

| Taxon (Central Kazakhstan) | Major reported compound classes | Representative markers (examples) | Typical analytical methods | Evidence base in provided sources |
|--------------------------------------|--|--|---|---|
| <i>Ribes aciculare</i> | Phenolics expected at genus level | (Data insufficient for CK wild populations in provided set) | HPLC-DAD / LC-MS/MS (commonly used in <i>Ribes</i>) | Genus-level summary only |
| <i>Ribes nigrum</i> | Anthocyanins, flavonols, phenolic acids; also seed-related lipids in by-products | Delphinidin- and cyanidin-glycosides (rutinosides/glucosides); quercetin-/myricetin-/kaempferol-glycosides | HPLC-DAD-ESI-MS;UVC postharvest experiments with phenolic profiling; SFE-CO ₂ for pomace fractions | Strong (multiple experimental review sources) |
| <i>Ribes saxatile</i> complex (s.l.) | Phenolics expected at genus level; species-level specificity unresolved | (Data insufficient for CK wild populations in provided set) | HPLC-DAD / LC-MS/MS (commonly used in <i>Ribes</i>) | Genus-level summary only |

Note. “CK” = Central Kazakhstan. Where Central Kazakhstan-specific datasets are missing, the table explicitly indicates insufficient evidence rather than extrapolating.

9. Biological and Pharmacological Activities

Biological and pharmacological activities reported for species of the genus *Ribes* are largely attributed to their rich phytochemical composition, particularly phenolic compounds such as anthocyanins, flavonols, proanthocyanidins, and phenolic acids. Numerous experimental and review studies indicate that extracts and isolated fractions from *Ribes* species exhibit a broad spectrum of biological effects, including antioxidant, anti-inflammatory, antimicrobial, and other health-related activities (Brennan, 2008; Krüger & Dietrich, 2018; Izteleuova et al., 2025) [30, 31].

It should be emphasized that the majority of available evidence originates from cultivated material or wild populations outside Central Kazakhstan. Consequently, the activities summarized below reflect genus- and species-level knowledge, while data specifically obtained from wild-growing *Ribes* populations in Central Kazakhstan remain extremely limited.

10. Ethnobotany and Traditional Uses

Species of the genus *Ribes* have a long history of traditional use as food and medicinal plants across Eurasia and other temperate regions. Ethnobotanical records indicate that fruits, leaves, and, less frequently, buds of various *Ribes* species have been utilized in traditional diets, folk medicine, and household practices, primarily due to their perceived health-promoting properties and pleasant organoleptic characteristics (Moerman, 1998; Brennan, 2008; Izteleuova et al., 2025) [32].

Among the species occurring in Central Kazakhstan, *Ribes nigrum* L. is the most widely documented in ethnobotanical and traditional contexts. Its fruits have been traditionally consumed fresh or processed into juices, preserves, and fermented beverages, while leaves have been used in herbal infusions and decoctions. These practices are commonly associated with the treatment or prevention of colds, fever, inflammatory conditions, and general weakness, reflecting the high vitamin and polyphenol content reported for the species (Brennan, 2008; Krüger & Dietrich, 2018) [33].

In contrast, ethnobotanical information specifically referring to *Ribes aciculare* Pall. and taxa belonging to the *Ribes saxatile* species complex is scarce and largely anecdotal. In several regions of Eurasia, related taxa have been reported as minor food sources or as components of local herbal remedies; however, detailed descriptions of preparation methods, dosage, or therapeutic efficacy are generally lacking (Moerman, 1998). For Central Kazakhstan in particular, no systematic ethnobotanical surveys focusing on wild-growing *Ribes* species have been published to date, and available regional floristic works provide little or no information on traditional uses (Sagdullaev & Ishmuratova, 2016) [34].

It is important to emphasize that much of the ethnobotanical knowledge reported for *Ribes* species originates from cultivated material or from regions with long-standing horticultural traditions, such as Europe and East Asia. Extrapolation of these uses to wild-growing populations in Central Kazakhstan should therefore be approached with caution. Environmental conditions, genetic differentiation, and phytochemical variability may all influence the suitability and efficacy of plant material used for food or medicinal purposes.

Despite these limitations, the presence of well-documented traditional uses for *Ribes nigrum* and related taxa suggests a potential cultural and practical relevance of wild *Ribes* species in Central Kazakhstan. However, this aspect remains poorly explored and represents a promising direction for future interdisciplinary research integrating ethnobotany, phytochemistry, and conservation biology. Systematic documentation of local knowledge, where available, could help broaden our understanding of the role of *Ribes* species in regional human–plant relationships and may also support the development of sustainable use strategies [35].

Conclusion

1. Wild-growing species of the genus *Ribes* occurring in Central Kazakhstan (*Ribes aciculare*, *Ribes nigrum*, and the *Ribes saxatile* species complex) represent ecologically specialized taxa adapted to fragmented and heterogeneous habitats within a predominantly arid continental landscape.

2. The distribution of *Ribes* species in the region is strongly associated with localized mesophilous microhabitats, including moist ravines, riparian zones, forest edges, and rocky slopes, resulting in small, spatially isolated populations with limited connectivity.

3. At present, bioecological information on *Ribes* species in Central Kazakhstan is based mainly on qualitative floristic observations, while quantitative data on population structure, regeneration dynamics, and reproductive success are still largely lacking.

4. Although the antioxidant, anti-inflammatory, and antimicrobial properties of *Ribes* species are well documented in the international literature, direct evidence from wild populations in Central Kazakhstan remains very limited and should not be generalized without empirical verification.

5. The taxonomic complexity of the *Ribes saxatile* species complex represents a significant challenge for ecological interpretation and conservation planning in the region. This situation highlights the need for integrative studies that combine taxonomic and genetic approaches.

6. Future interdisciplinary research integrating field ecology, phytochemistry, molecular taxonomy, and bioactivity assessment is essential to advance understanding of *Ribes* species in Central Kazakhstan and to support evidence-based conservation and utilization strategies.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Zhanayeva M.B.** — investigation, visualization, manuscript writing; **Shmakov A.I.** — checking manuscripts, correcting comments, data curation.

Conflict of Interest

The authors declare no conflict of interest.

References

- Bai, H., Zhao, X., Deng, R., Liu, Y., Du, Y., & Zheng, B. (2025). Species diversity and distribution patterns of wild *Ribes* in China. *Bulletin of Botanical Research*, 45(6), 975–983. <https://doi.org/10.7525/j.issn.1673-5102.2025.06.014>
- Boda, F., Ștefănescu, R., Sebestyen, M., Râștei, I., Laczkó-Zöld, E., & Farczádi, L. (2025). Pharmacognostic evaluation and antioxidant profiling of five varieties of *Ribes nigrum* grown in Romania. *Plants*, 14(11), 1604. <https://doi.org/10.3390/plants14111604>
- Brennan, R. M. (2008). Currants and gooseberries. In J. F. Hancock (Ed.). *Temperate fruit crop breeding* (pp. 177–196). Springer.
- Brennan, R. M., & Graham, J. (2009). Improving fruit quality in *Ribes* species. *Plant Breeding Reviews*, 31, 203–243.
- Charters, Y. M., Wilkinson, M. J., & Kingsnorth, C. S. (2002). Molecular analysis of *Ribes* species and cultivars. *Theoretical and Applied Genetics*, 104(5), 879–888.
- Ciesarová, Z., Murkovic, M., Cejpek, K., Kreps, F., Tobolková, B., Koplík, R., Belajová, E., Kukurová, K., & Daško, L. (2020). Why is *Ribes nigrum* a good source of antioxidants. *Journal of Food Composition and Analysis*, 85, 103309.
- Clifford, M. N. (2000). Anthocyanins — nature, occurrence and dietary burden. *Journal of the Science of Food and Agriculture*, 80(7), 1063–1072.
- Dobson, G., Shepherd, T., Verrall, S. R., Conner, S., Mc Dougall, G. J., Stewart, D., & Davies, H. V. (2012). Phyto chemical diversity in *Ribes*. *Phyto chemistry*, 76, 45–56.
- Flora of Kazakhstan Editorial Board. (1961–1975). *Flora of Kazakhstan* (Vols. 1–9). Academy of Sciences of the Kazakh SSR.
- Graham, J., Brennan, R., & McNicol, J. W. (1996). Genetic diversity in *Ribes*. *Theoretical and Applied Genetics*, 92(2), 164–170.
- Hummer, K. E., & Barney, D. L. (2002). Currants. In J. Janick & A. Whipkey (Eds.). *Trends in new crops and new uses* (pp. 494–500). ASHS Press.
- Izteleuova, E. Y., Zhumashova, G. T., Bekezhanova, T. S., Allambergenova, Z. B., Zhaparkulova, K. A., Karaubayeva, A. A., Kaldybayeva, A. K., Sakipova, Z. B., Ibragimova, L. N., & Korona-Glowniak, I. (2025). The current state of knowledge on *Ribes* spp. plants. *Plants*, 14(20), 3196. <https://doi.org/10.3390/plants14203196>
- Kalendar, R., Tanskanen, J., Immonen, S., Nevo, E., & Schulman, A. H. (2000). Genome evolution of wild *Ribes*. *Genome*, 43(6), 1021–1029.
- Karakaya, S., & El, S. N. (1999). Phenolic composition of *Ribes* fruits. *Food Chemistry*, 67(1), 27–31.
- Kaur, C., & Kapoor, H. C. (2001). Antioxidants in fruits and vegetables – the millennium’s health. *International Journal of Food Science & Technology*, 36(7), 703–725.

- 16 Klongsiriwet, C., Purintrapibal, W., Paphochanang, P., Prammanon, A., Huipaod, N., & Hiranyachattada, S. (2025). Effect of condensed tannins from black currant (*Ribes nigrum*) on acetylcholine-induced intestinal contractility. *Science Asia*, 51(5), 1–11.
- 17 Koponen, J. M., Happonen, A. M., Mattila, P. H., & Törrönen, A. R. (2007). Contents of anthocyanins in *Ribes*. *Journal of Agricultural and Food Chemistry*, 55(16), 6907–6913.
- 18 Krüger, E., & Dietrich, H. (2018). Black currant (*Ribes nigrum*): chemistry and functionality. *Journal of Berry Research*, 8(1), 1–12.
- 19 Lee, J., Durst, R. W., & Wrolstad, R. E. (2005). Determination of total monomeric anthocyanin pigment content. *Journal of AOAC International*, 88(5), 1269–1278.
- 20 Minasyan, A., Pires, V., Gondcaille, C., Ginovyan, M., Mróz, M., Savary, S., Cherkaoui-Malki, M., Kusznierevich, B., Bartoszek, A., Andreoletti, P., & Sahakyan, N. (2025). *Ribes nigrum* leaf extract regulates redox balance in microglial cells. *BMC Complementary Medicine and Therapies*, 25, 49. <https://doi.org/10.1186/s12906-025-04780-7>
- 21 Mamyrova, G., Moldaliev, Z., Kaarova, M., Kolomiets, Y., & Kalinichenko, A. (2025). Biotechnological aspects of sawflies control in blackcurrant plantations. *Scientific Horizons*, 28(6), 65–76.
- 22 Pikunova, A., Goryunova, S., Goryunov, D., Golyaeva, O., Dolzhikova, M., & Pavlenko, A. (2022). Genetic diversity and pedigree analysis of red currant germplasm. *Plants*, 11(13), 1623. <https://doi.org/10.3390/plants11131623>
- 23 Prior, R. L., Wu, X., & Schaich, K. (2005). Standardized methods for antioxidant capacity. *Journal of Agricultural and Food Chemistry*, 53(10), 4290–4302.
- 24 Rehder, A. (1940). *Manual of cultivated trees and shrubs*. Macmillan.
- 25 Rice-Evans, C. A., Miller, N. J., & Paganga, G. (1997). Antioxidant properties of phenolic compounds. *Trends in Plant Science*, 2(4), 152–159.
- 26 Sagdullaev, S. S., & Ishmuratova, M. Y. (2016). *Flora of the Ulytau Mountains (Central Kazakhstan)*. Karaganda State University Press.
- 27 Scalzo, J., Politi, A., Pellegrini, N., Mezzetti, B., & Battino, M. (2005). Plant genotype affects antioxidant capacity. *Journal of Agricultural and Food Chemistry*, 53(23), 108–110.
- 28 Stintzing, F. C., & Carle, R. (2004). Functional properties of anthocyanins. *Trends in Food Science & Technology*, 15(1), 19–38.
- 29 Tattini, M., Landi, M., Brunetti, C., Giordano, C., Remorini, D., & Gould, K. S. (2014). Flavonoids as antioxidants. *Environmental and Experimental Botany*, 114, 3–14.
- 30 Wang, S. Y., & Lin, H. S. (2000). Antioxidant activity in fruits. *Journal of Agricultural and Food Chemistry*, 48(2), 140–146.
- 31 Zhao, X., Zhao, D., Ge, X., Zhang, Y., Du, Y., Liu, J., Liu, Y., Wang, H., & Zheng, B. (2025). Research on the species diversity and distribution patterns of wild *Ribes* in Northeast Asia. *Plants*, 14(12), 1780. <https://doi.org/10.3390/plants14121780>
- 32 Sagdullaev, S. S., & Ishmuratova, M. Y. (2016). *Flora of the Ulytau Mountains (Central Kazakhstan)*. Karaganda State University Press.
- 33 Seeram, N. P. (2008). Berry fruits for cancer prevention. *Journal of Agricultural and Food Chemistry*, 56(3), 630–635.
- 34 Tattini, M., Landi, M., Brunetti, C., Giordano, C., Remorini, D., & Gould, K. S. (2014). Flavonoids as antioxidants. *Environmental and Experimental Botany*, 114, 3–14.
- 35 Xu, J., Li, T., Liu, X., Shi, W., Zhang, D., & Chang, Y. (2025). Reference genes for expression normalization in *Ribes odoratum*. *Scientific Reports*, 15, 29214. <https://doi.org/10.1038/s41598-025-12051-1>

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Орталық Қазақстанда *Ribes L.* тұқымдасының жабайы өсетін түрлері: биоэкологиялық сипаттамасы

Ribes L. (Grossulariaceae) туысы экологиялық, тағамдық және дәрілік маңызы бар, Солтүстік жарты шардың қоңыржай аймақтарында кең таралған көптеген түрлерді қамтиды. Орталық Қазақстан — ландшафтарының алуан түрлілігімен және табиғи климаттық жағдайларының гетерогендігімен сипатталатын биогеографиялық тұрғыдан күрделі өңір. Алайда осы аймақта өсетін *Ribes* туысының жабайы түрлері туралы мәліметтер әлі де бытыраңқы әрі жеткілікті деңгейде жүйеленбеген. Шолудың мақсаты — Орталық Қазақстан аумағында таралған *Ribes* туысының жабайы түрлеріне, атап айтқанда *Ribes aciculare* Pall., *Ribes nigrum L.* және *Ribes saxatile* түрлік кешенінің өкілдеріне қатысты биоэкологиялық ерекшеліктерді, фитохимиялық құрамды және зерттеу перспективаларын сипаттайтын әдеби деректерді жинақтау және сыни тұрғыдан талдау. Шолу халықаралық және аймақтық ғылыми журналдарда жарияланған флористикалық деректерге, экологиялық зерттеулерге және фитохимиялық еңбектерге негізделген. Түрлердің таралуы, мекен ету ортасы, фенологиясы және экологиялық бейімделу ерекшеліктері туралы мәліметтер, сондай-ақ антоциандар, флавоноидтер, проантоцианидиндер, органикалық қышқылдар мен витаминдер сияқты биологиялық белсенді қосылыстардың негізгі топтары жөніндегі ақпарат жүйелендірілді. *R. nigrum* туысының ең жақсы зерттелген түрі ретінде фитохимиялық тұрғыдан кеңірек қарастырылып, басқа жабайы таксондар

бойынша деректердің шектеулі әрі үзінді сипатта екендігі атап өтілді. Сонымен қатар *R. saxatile* түрлік кешеніне байланысты таксономиялық белгісіздіктер талданып, аймақтық зерттеулерде түрлерді нақты ажыратудың маңыздылығы көрсетілді. Жүргізілген талдау қазіргі білімдегі елеулі олқылықтарды, әсіресе аймаққа тән фитохимиялық профильдер, популяциялық деңгейдегі экологиялық өзгергіштік және қоршаған орта факторлары мен екінші реттік метаболиттердің жиналуы арасындағы байланыстар жөніндегі мәліметтердің жеткіліксіздігін анықтады. Болашақ зерттеулердің негізгі бағыттары ретінде биоэкологиялық және фитохимиялық тәсілдерді кешенді қолдану, жабайы генетикалық ресурстарды сақтау және Орталық Қазақстандағы *Ribes* туысы түрлерін тұрақты пайдалану ұсынылады.

Кілт сөздер: *Ribes* L., Орталық Қазақстан, биоэкология, фитохимиялық құрам, қарақат, дәрілік өсімдіктер, жабайы өсетін түрлер.

М.Б. Жанаева, А.И. Шмаков

Дикорастущие виды рода *Ribes* L. в Центральном Казахстане: биоэкологические характеристики

Род Ribes L. (*Grossulariaceae*) включает многочисленные виды, обладающие экологической, пищевой и лекарственной ценностью и широко распространённые в умеренных регионах Северного полушария. Центральный Казахстан представляет собой биогеографически сложную территорию, характеризующуюся разнообразием ландшафтов и гетерогенностью природно-климатических условий; вместе с тем сведения о дикорастущих видах рода *Ribes* в данном регионе остаются фрагментарными и недостаточно систематизированными. Цель настоящего обзора — обобщение и критическая оценка литературных данных, посвящённых биоэкологическим особенностям, фитохимическому составу и перспективам изучения дикорастущих видов *Ribes*, произрастающих в Центральном Казахстане, с акцентом на *Ribes aciculare* Pall., *Ribes nigrum* L. и представителей видового комплекса *Ribes saxatile*. Обзор основан на анализе региональных флористических источников, экологических исследований и фитохимических работ, опубликованных в международных и региональных научных журналах. Систематизированы данные о распространении видов, их местообитаниях, фенологии и экологических адаптациях, а также сведения об основных группах биологически активных соединений, включая антоцианы, флавоноиды, проантоцианидины, органические кислоты и витамины. Особое внимание уделено фитохимическим исследованиям *R. nigrum* как наиболее изученного вида рода, при одновременном подчёркивании ограниченного и фрагментарного характера данных по другим дикорастущим таксонам. Кроме того, рассматриваются таксономические неопределённости, связанные с видовым комплексом *R. saxatile*, что указывает на необходимость более точной делимитации видов в региональных исследованиях. Проведённый анализ выявил существенные пробелы в современных знаниях, прежде всего в отношении регионально-специфических фитохимических профилей, популяционной экологической изменчивости и взаимосвязи факторов среды с накоплением вторичных метаболитов. В заключение обозначены перспективные направления дальнейших исследований, ориентированные на интеграцию биоэкологических и фитохимических подходов, сохранение диких генетических ресурсов и устойчивое использование видов рода *Ribes* в Центральном Казахстане.

Ключевые слова: *Ribes* L., Центральный Казахстан, биоэкология, фитохимический состав, смородина, лекарственные растения, дикорастущие виды.

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First remarks on the spider fauna (Arachnida: Araneae) of the Karkaraly State National Natural Park: the extension of data for Central Kazakhstan

This paper presents the first scientific data on the diversity of spiders (order Araneae) in the Karkaraly State National Natural Park (Karaganda Region, Kazakhstan). Field material was collected in the Kendara Valley, near of Lake Shaitankol, and at the field practice station of the E.A. Buketov Karaganda National Research University using trap lines, soil sampling, and manual collection during July and August 2025. Fifty two species of spiders were identified; 5 families and 40 species are reported for the first time for Central Kazakhstan according to non-digitized literature data and the Global Biodiversity Information Facility. The results considerably expanded the information available through GBIF on the species diversity of the order Araneae in Central Kazakhstan. Differences were identified in the species diversity recorded via the iNaturalist app and based on collections using traditional field methods. It was concluded that large-scale field studies of spiders in Central Kazakhstan are necessary, as well as the digitization and mobilization of data published in the literature through the GBIF portal.

Keywords: spiders, Central Kazakhstan, Karaganda Region, GBIF, iNaturalist.

Introduction

Invertebrates are still poorly represented in open biodiversity data repositories such as the Global Biodiversity Information Facility (GBIF) [1–3]. This limits the possibilities for using the data and leads to bias in the estimates obtained [4, 5]; as well as to a situation where widespread species may be wrongly considered as rare. Therefore, the filling gaps in the digital biodiversity map are a relevant problem.

In recent years, the study of the spider fauna (order Araneae) of Kazakhstan has intensified once again [6–8]. However, most research is located in Southern, Western, and Northern parts of the country [9]. The spider fauna of Central Kazakhstan (modern Karaganda and Ulytau Regions) has poorly been studied. Only a few studies from Central Kazakhstan are known. Obtained results have been published [10–19] but remain non-digitized and inaccessible to researchers. To this day 94.6 % GBIF occurrences of spiders from Central Kazakhstan are derived from the iNaturalist citizen science platform [20].

Our study focuses on providing high-quality digital scientific data on the spider fauna of the Karkaraly State National Natural Park and assessing the contribution of this information to the GBIF and non-digitized literature data on spiders in Central Kazakhstan.

Experimental

Karkaraly State National Natural Park is located in the east part of Karaganda Region, about 220 km east from Karaganda city. The Park was established in 1998 for preserving and restoring the unique natural complexes of the Karkaraly and Kent mountain boreal forests. The total area is 112,120 hectares, of which, 40,341 hectares are forested. The climate is sharply continental [21]. The average annual air temperature is +3.6, the average annual precipitation is 293 mm [22].

The current work is based on the material collected in the Park in June, July, and August 2025. In August spiders were sampled by participants of the IX Field School on Soil Zoology and Ecology for Young Scientists that was organized by Buketov Karaganda National Research University. Spiders were sampled using pitfall-traps, hand sorting and manual collection. The material was collected by authors (FDS — Fetisov D.S., INV — Ivanova N.V., KLV — Kim L.V., PEV — Plakkhina E.V., FAA — Fedorova A.A.) and our colleague (SMP — Shashkov M.P.). When no collector is specified, the material was sampled collectively by the participants of the Field School. Type of habitats of occurrences specified if available. Spiders were collected in the following locations: Kendara Valley (1), Karaganda Buketov University field station (2), Shaitankol Lake vicinity (3) and Three caves (4) (Fig. 1).

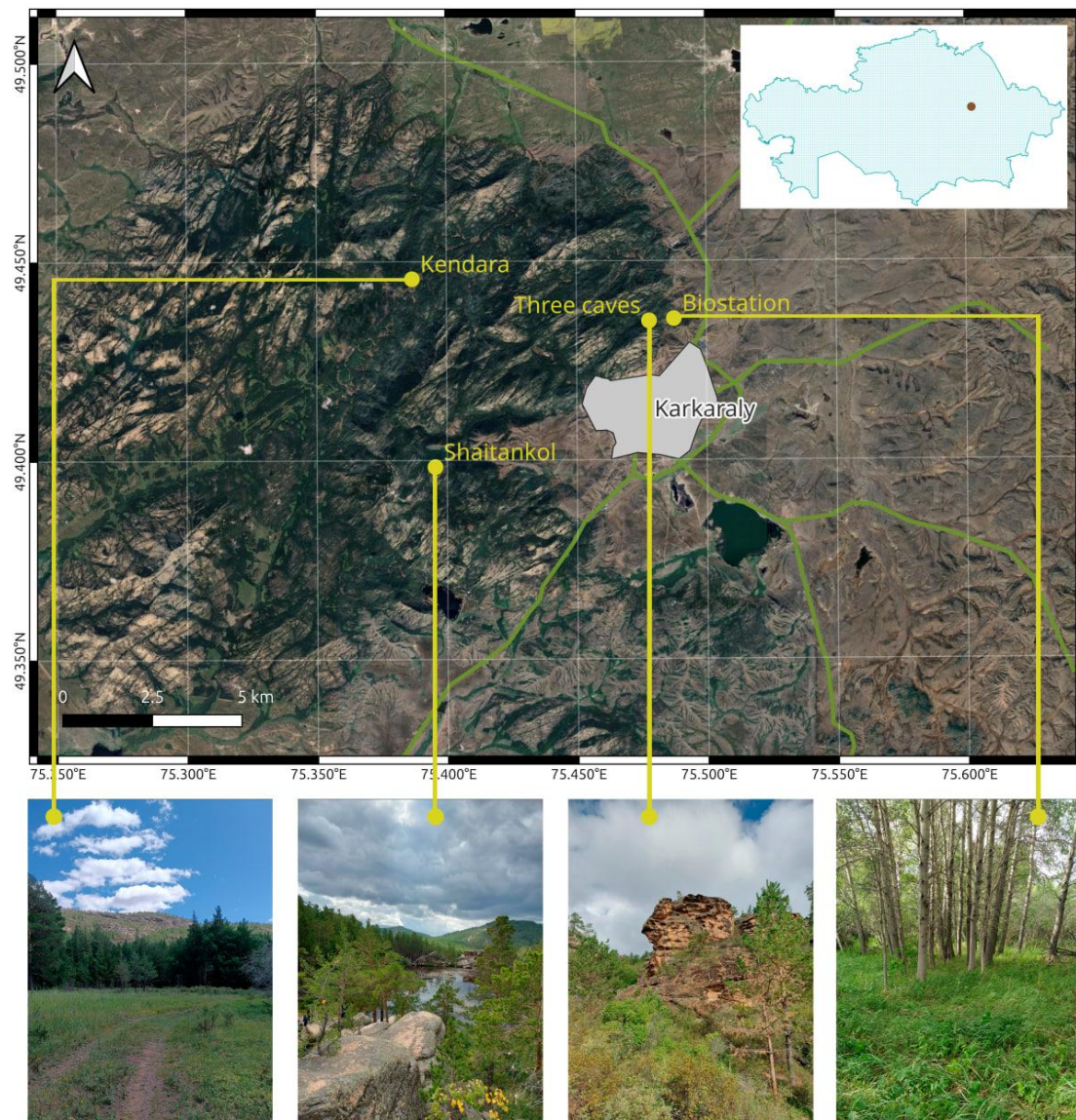


Figure 1. The map of locations: Kendara — Kendara Valley (1), Biostation — Karaganda Buketov University field station (2), Shaitankol — Shaitankol Lake vicinity (3), Three Caves (4)

The identification of spiders was carried out at the Invertebrate Zoology Department of Perm State University (Russia) by prof. S.L. Esyunin, at the Center of Forest Ecology and Productivity of the Russian Academy of Science by PhD student D.S. Fetisov, at the Institute of Zoology of Republic of Kazakhstan by master of science L.V. Kim. Species list follows the World Spider Catalog [23]. Data on species distribution are taken from “Catalogue of the spiders (Arachnida, Aranei) of Left-Bank Ukraine” [24] and “Spiders of the

Udmurt Republic: fauna, ecology, phenology and distribution" [25]. All species occurrence data were digitized and published through the GBIF [26, 27].

The obtained spider species list was compared with data available through GBIF for Central Kazakhstan [28] and Karkaraly State National Natural Park [29], as well as non-digitized literature data. For this we georeferenced collected sites from published articles [10–19] and compiled the species list mentioned there. The taxonomical analysis was performed in the R environment [30] using Venn diagrams (library ggVennDiagram [31]).

Results and Discussion

During the summer 2025 survey 228 spider specimens, belonging to 52 species, 30 genera, and 15 families were recorded. A total of 107 specimens were identified to species level. In terms of zoogeographical composition, species with Trans-Eurasian (21.2 %), Trans-Palaeartic (19.2 %) and Circum-Holarctic (13.46 %) ranges predominate in our collection. The list of recorded species is provided below. The species marked for the first time for the region are highlighted with an asterisk (*).

ARANEIDAE

Aculepeira ceropegia (Walckenaer, 1802)* MATERIAL. 1♀ (1), 49.44994 N, 75.39511 E, manual collection, 11-14.VII.2025, leg. NVI, FAA; 1♀ (1), 49.44994 N, 75.39511 E, manual collection, 11-14.VII.2025, leg. NVI, FAA. RANGE TYPE. West-Central Eurasian.

Araneus angulatus Clerck, 1757 MATERIAL. 1♀ (1), 49.43588 N, 75.48829 E, manual collection, 22.VIII.2025, leg. FDS; 2♀♀ (1), 49.43915 N, 75.38949 E, manual collection, 12.VII.2025, leg. NVI, PEV; 1 juv (1), 49.44994 N, 75.39511 E, manual collection, 11-14.VII. 2025, leg. NVI, FAA. RANGE TYPE. Trans-Palaeartic.

Araneus diadematus Clerck, 1757 MATERIAL. 2♀♀ (2), 49.43588 N, 75.48829 E, manual collection, 22.VIII.2025, leg. FDS; 3♂♂, 1♀ (1), 49.43915 N, 75.38949 E, manual collection, 12.VII.2025, leg. NVI, FAA; 1♂, 2♀♀ (1), 49.44994 N, 75.39511 E, manual collection, 11-14.VII.2025, leg. NVI, FAA. RANGE TYPE. Trans-Palaeartic.

Araneus marmoreus Clerck, 1757* MATERIAL. 1♀ (1), 49.43915 N, 75.38949 E, manual collection, 12.VII. 2025, leg. NVI, FAA. RANGE TYPE. Circum-Holarctic.

Araniella tbilisiensis (Mcheidze, 1997)* MATERIAL. 1♀ (1), 49.44994 N, 75.39511 E, manual collection, 11-14.VII. 2025, leg. NVI, FAA. RANGE TYPE. Central — Ancient Mediterranean.

Cyclosa oculata (Walckenaer, 1802)* MATERIAL. 1♂ (2), 49.43588 N, 75.48829 E, manual collection, 22-24.VIII.2025, leg. PEV. RANGE TYPE. Trans-Eurasian.

CLUBIONIDAE

Clubiona pallidula (Clerck, 1757)* MATERIAL. 1♀ (2), 49.43319 N, 75.48624 E, birch forest, hand sorting, 23.VIII.2025. RANGE TYPE. Trans-Eurasian.

DOLOMEDIDAE

Dolomedes fimbriatus (Clerck, 1757)* MATERIAL. 1♂, 1 sub♀ (1), 49.4609 N, 75.38732 E, manual collection, 15.VII.2025, leg. INV, FAA. RANGE TYPE. Trans-Eurasian.

GNAPHOSIDAE

Gnaphosa pilosa Savelyeva, 1972 MATERIAL. 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII. 2025, leg. KLV. RANGE TYPE. Central-Asian. Karaganda Region, Karkaraly District, Kent mountains (now part of the National Park). 49.20511 N, 75.95193 E [13].

Haplodrassus umbratilis (L.Koch, 1866)* MATERIAL. 1♀ (2), 49.43496 N, 75.48955 E, hill slope, pitfall-traps, 22-24.VIII.2025. RANGE TYPE. European — West Siberian.

LINYPHIIDAE

Bolyphantes alticeps (Sundevall, 1833)* MATERIAL. 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 22-24.VIII.2025, leg. PEV; 1♀ (4), 49.4291 N, 75.4782 E, manual collection, 23.VIII.2025, leg. FDS. RANGE TYPE. Trans-Eurasian.

Drapetisca socialis (Sundevall, 1833)* MATERIAL. 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 22-24.VIII.2025, leg. PEV; 1♂, 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg.

FDS; 2♂♂, 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg. KLV. RANGE TYPE. Trans-Eurasian.

Erigone dentipalpis (Wider, 1834)* MATERIAL. 1♂ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg. FDS. RANGE TYPE. Trans-Palaeartic.

Gongylidium rufipes (Linnaeus, 1758)* MATERIAL. 2 sub♀ (2), 49.43319 N, 75.48624 E, birch forest, hand sorting, 23.VIII.2025. RANGE TYPE. Trans — Euro Siberian.

Helophora insignis (Blackwall, 1841)* MATERIAL. 1♂1♀ (2), 49.43319 N, 75.48624 E, birch forest, hand sorting, 23.VIII.2025. RANGE TYPE. Circum-Holarctic.

Linyphia triangularis (Clerck, 1757)* MATERIAL. 1♀ (4), 49.4291 N, 75.4782 E, manual collection, 23.VIII.2025, leg. KLV; 1♀ (3), 49.3997 N, 75.3993 E, manual collection, 23.VIII.2025, leg. KLV. RANGE TYPE. Trans-Eurasian.

Megalephthiphantes kronebergi (Tanasevitch, 1989) MATERIAL. 1♂ (4), 49.4291 N, 75.4782 E, manual collection, 23.VIII.2025, leg. KLV; 1♂ (4), 49.4291 N, 75.4782 E, manual collection, 23.VIII.2025, leg. FDS. RANGE TYPE. Central Asian.

Neriere radiata (Walckenaer, 1841)* MATERIAL. 1♀ (4), 49.4291 N, 75.4782 E, manual collection, 23.VIII.2025, leg. FDS. RANGE TYPE. Circum-Holarctic.

Tapinocyba insecta (L.Koch, 1869)* MATERIAL. 1♀ (3), 49.4039 N, 75.40567 E, pine forest, hand sorting, 23.VIII.2025. RANGE TYPE. European — West Siberian.

Trichonoides piscator (Simon, 1884) MATERIAL. 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 22.VIII.2025, leg. FDS. RANGE TYPE. West-Central Ancient Mediterranean.

LYCOSIDAE

Alopecosa steppica Ponomarev, 2007* MATERIAL. 4♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg. KLV. RANGE TYPE. Ancient Mediterranean (West — European Kazakhstan).

Alopecosa taeniopus (Kulczyński, 1895)* MATERIAL. 3♂, 1♀, 4juv (2), 49.43496 N, 75.48955 E, hill slope, pitfall-traps, 22-24.VIII.2025. RANGE TYPE. West European — Central Ancient Mediterranean.

Pardosa agrestis (Westring, 1861)* MATERIAL. 1♀ (2), 49.43496 N, 75.48955 E, hill slope, pitfall-traps, 22-24.VIII.2025; 1♀ (2), 49.43319 N, 75.48624 E, aspen forest, pitfall-traps, 22-24.VIII.2025. RANGE TYPE. West-Eurasian.

Pardosa lugubris (Walckenaer, 1802)* MATERIAL. 1♂, 5♀ (2), 49.43319 N, 75.48624 E, aspen forest, pitfall-traps, 22-24.VIII.2025; 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.25, leg. KLV; 1♀ (3), 49.3997 N, 75.3993 E, 23.VIII.25, leg. KLV; 1♀ (1), 49.44994 N, 75.39511 E, manual collection, leg. INV, FAA. RANGE TYPE. West-Eurasian.

Piratula hygrophila (Thorell, 1872)* MATERIAL. 1♂ (2), 49.43319 N, 75.48624 E, aspen forest, pitfall-traps, 22-24.VIII.2025; 1♀ (1), 49.45195 N, 75.38371 E, pine forest in the floodplain of the creek, hand sorting, leg. SMP. RANGE TYPE. West-Eurasian.

Trochosa terricola Thorell, 1856* MATERIAL. 1♂ (2), 49.43319 N, 75.48624 E, aspen forest, pitfall-traps, 22-24.VIII.2025; 1♂ (2), 49.43496 N, 75.48955 E, hill slope, pitfall-traps, 22-24.VIII.2025; 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg. KLV; 1♀ (1), 49.44414 N, 75.38085 E, aspen forest with birch and pine trees, hand sorting, 8.VI.2015, leg. SMP; 1♀, 1juv (1), 49.44476 N, 75.37503 E, abandoned cattle pen with ruderal vegetation, hand sorting, 10.VI.2015, leg. SMP; 1♀ (1), 49.44423 N, 75.37658 E, last year's abandoned vegetable garden, ruderal vegetation, hand sorting, 11.VI.2025, leg. SMP. RANGE TYPE. Circum-Holarctic.

Xerolycosa nemoralis (Westring, 1861)* MATERIAL. 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg. KLV. RANGE TYPE. Trans-Eurasian.

MIMETIDAE

Mimetus laevigatus (Keyserling, 1863)* MATERIAL. 1♂ (2), 49.43588 N, 75.48829 E, manual collection, 22.VIII.2025, leg. FDS. RANGE TYPE. West-Central Ancient Mediterranean.

MITURGIDAE

Zora pardalis Simon, 1878* MATERIAL. 1 sub♂ (2), 49.43588 N, 75.48829 E, manual collection, 22-24.VIII.2025, leg. PEV. RANGE TYPE. West-Central Ancient Mediterranean.

PHILODROMIDAE

Emargidromus emarginatus (Schrank, 1803)* MATERIAL. 1♀ (1), 49.44994 N, 75.39511 E, manual collection, 11-14.VII.2025, leg. INV, FAA. RANGE TYPE. Trans-Eurasian.

Philodromus cespitum (Walckenaer, 1802)* MATERIAL. 1♀ (1), 49.43915 N, 75.38949 E, manual collection, 12.VII.2025, leg. INV, FAA. RANGE TYPE. Circum-Holarctic.

PHOLCIDAE

Pholcus ponticus Thorell, 1875 MATERIAL. 1♂ (2), 49.43588 N, 75.48829 E, manual collection, 22.VIII.2025, leg. FSD. RANGE TYPE. Eastern-Europe — Central Ancient Mediterranean.

SALTICIDAE

Dendryphantès rudis (Sundevall, 1833)* MATERIAL. 1♀ (3), 49.3997 N, 75.3993 E, manual collection, 23.VIII.2025, leg. KLV. RANGE TYPE. Trans — Euro-Siberian.

Evarcha arcuata (Clerck, 1757) MATERIAL. 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg. FDS; 1♂ (1), 49.44994 N, 75.39511 E, manual collection, 11-14.VII.2025, leg. INV, FAA. RANGE TYPE. Trans-Palaeartic.

TETRAGNATHIDAE

Metellina segmentata (Clerck, 1757)* MATERIAL. 1♀ (1), 49.45195 N, 75.38371 E, pine forest in the floodplain of the creek, hand sorting, 12.VII.2025, leg. SMP. RANGE TYPE. Trans-Palaeartic.

Pachygnatha degeeri Sundevall, 1830* MATERIAL. 1♂ (2), 49.43319 N, 75.48624 E, aspen forest, pitfall-traps, 22-24.VIII.2025. RANGE TYPE. Trans-Palaeartic.

Tetragnatha montana Simon, 1874* MATERIAL. 1♀ (1), 49.43915 N, 75.38949 E, manual collection, 12.VII.2025, leg. INV, FAA. RANGE TYPE. Trans-Eurasian.

THERIDIIDAE

Enoplognatha latimana Hippa & Oksala, 1982* MATERIAL. 1♀ (3), 49.39903 N, 75.39529 E, pine forest, hand sorting, 23.VIII.2025. RANGE TYPE. West-Palaeartic.

Enoplognatha ovata (Clerck, 1757)* MATERIAL. 1♀ (1), 49.45195 N, 75.38371 E, pine forest in the floodplain of the creek, hand sorting, 12.VII.2025, leg. SMP; 1 sub♀ (1), 49.44414 N, 75.38085 E, aspen forest with birch and pine trees, hand sorting, leg. SMP. RANGE TYPE. Trans-Palaeartic.

Episinus truncatus Latreille, 1809* MATERIAL. 1♀ (1), 49.44994 N, 75.39511 E, manual collection, 11-14.VII.2025, leg. INV, FAA. RANGE TYPE. West-Palaeartic.

Euryopsis flavomaculata (C.L. Koch, 1836)* MATERIAL. 1 sub♂ (2), 49.43781 N, 75.49352 E, birch forest, hand sorting, 23.VIII.2025. RANGE TYPE. Trans-Palaeartic

Parasteatoda tabulata (Levi, 1980)* MATERIAL. 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg. KLV. RANGE TYPE. Cosmopolitan.

Robertus lividus (Blackwall, 1836)* MATERIAL. 1♂ (2), 49.43319 N, 75.48624 E, aspen forest, pitfall-traps, 22-24.VIII.2025; 3♀ (1), 49.45195 N, 75.38371 E, pine forest in the floodplain of the creek, hand sorting, 12.VII.2015, leg. SMP. RANGE TYPE. Trans-Palaeartic — West-Nearctic.

Steatoda albomaculata (De Geer, 1778) MATERIAL. 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 22.VIII.2025, leg. FDS. RANGE TYPE. Circum-Holarctic. Karaganda Region, near Barshino. 49.61666 N, 69.46666 E [19].

Steatoda castanea (Clerck, 1757) MATERIAL. 1♂1♀ (4), 49.4291 N, 75.4782 E, manual collection, 23.VIII.2025, leg. KLV. RANGE TYPE. Trans-Eurasian.

Theridion varians Hahn, 1833* MATERIAL. 3♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg. KLV. RANGE TYPE. Trans-Palaeartic.

THOMISIDAE

Ebrechtella tricuspadata (Fabricius, 1775) MATERIAL. 1 sub♀ (1), 49.44994 N, 75.39511 E, manual collection, 11-14.VII.2025, leg. INV, FAA. RANGE TYPE. Trans-Eurasian.

Misumena vatia (Clerck, 1757) MATERIAL. 1 sub♀ (2), 49.43588 N, 75.48829 E, manual collection, 22-24.VIII.2025, leg. PEV; 1♂ (2), 49.43588 N, 75.48829 E, manual collection, 22.VIII.2025, leg. FDS; 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg. FDS; 1♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg. KLV. RANGE TYPE. Circum-Holarctic.

Ozyptila trux* (Blackwall, 1846) MATERIAL. 1 ♀ (2), 49.43781 N, 75.49352 E, birch forest, hand sorting, 23.VIII.2025. RANGE TYPE. Trans — Euro-Siberian.

***Spiracme striatipes* (L.Koch, 1870)** MATERIAL. 1 sub♂ (1), 49.44994 N, 75.39511 E, manual collection, 11-14.VII.2025, leg. INV, FAA; 1 sub♀ (1), 49.44476 N, 75.37503 E, abandoned cattle pen with ruderal vegetation, hand sorting, 10.VI.2025, leg. SMP; 1 sub♀ (1), 49.44384 N, 75.37603 E, planting poplar trees in the floodplain of the creek, hand sorting, 7.VI.2025, leg. SMP. RANGE TYPE. West-Central Ancient Mediterranean.

Xysticus cristatus* (Clerck, 1757) MATERIAL. 1 ♀ (1), 49.44994 N, 75.39511 E, manual collection, 11-14.VII.2025, leg. INV, FAA. RANGE TYPE. Trans-Palaeartic.

Xysticus viduus* Kulczyński, 1898 MATERIAL. 1 ♂ (2), 49.43319 N, 75.48624 E, aspen forest, pitfall-traps, 22-24.VIII.2025; 1 ♀ (2), 49.43588 N, 75.48829 E, manual collection, 23.VIII.2025, leg. KLV. RANGE TYPE. Euro — Middle-Siberian.

Individuals of the following genera were also found in the study area: *Lathys* Simon, 1884, *Drassodes* Westring, 1851, *Zelotes* Gistel, 1848, *Agyneta* Hull, 1911, *Palliduphantes* Saaristo & Tanasevitch, 2001, *Arctosa* Koch, 1847, *Tibellus* Simon, 1875, *Heliophanus* C.L. Koch, 1833, *Ipa* Saaristo, 2007, *Phylloneta* Archer, 1950. In addition, two species of harvestmen (Opiliones) were identified: *Opilio parietinus* (DeGeer, 1778) and *Phalangium opilio* Linnaeus, 1758.

A comparison with non-digitized literature and available GBIF data demonstrated that our collection significantly contributes to the knowledge of spider diversity in Central Kazakhstan. Five families (Clubionidae, Dolomedidae, Mimetidae, Miturgidae, and Tetragnathidae) and 40 species are reported for this region for the first time. For the area of the Karkaraly State National Natural Park only 2 species have previously been reported in the literature (Kent Mountains) [13, 14], as well as 10 species were available through GBIF portal (iNaturalist observations) [29].

We also found the differences in family composition between our results, non-digitized literature and GBIF data (Fig. 2A). The families Linyphiidae (19.2 %), Theridiidae (17.3 %), Lycosidae (13.5 %), Araneidae (11.5 %), and Thomisidae (11.5 %) were most abundant in our study. The diversity of families in the literature data was lower, and the Gnaphosid spiders were most represented. The high diversity of families in our study is explained by the use of different field collection methods (pitfall traps, hand sorting, manual collection) and the covering of various habitat types (plain and mountain forests, dry grasslands, steppes). Most spider occurrences from literature were collected in steppes using pitfall traps method [19]. For this habitat type Gnaphosid spider diversity is always high. The most diverse families in GBIF data were Araneidae (16 %), Salticidae and Thomisidae (14 %), Lycosidae and Theridiidae (10 %). This is an expected result because most of GBIF data about spiders in Central Kazakhstan derived from iNaturalist [20]. It is known that iNaturalist users most often record conspicuous species of plants and animals that can usually be identified from photographs [32]. In our study almost a half of observations registered through iNaturalist relate to *Argiope lobata* (Pallas, 1772), *Lycosa singoriensis* (Laxmann, 1770), *Thomisus onustus* Walckenaer, 1805, *Aculepeira armida* (Audouin, 1826), *A. diadematus*, *Larinioides ixobolus* (Thorell, 1873), and *Argiope bruennichi* (Scopoli, 1772). All these species are large and colourful spiders that are easily visible to the naked eye.

We have shown that our collection, non-digitized literature, and GBIF data make a comparable contribution to the overall species diversity of spiders in Central Kazakhstan (Fig. 2B). This result confirms the critical need to digitize and publish the literary heritage on the spiders of Kazakhstan through GBIF. According to “Bibliographia Araneologica Rossica 1770–2022” [33], more than 170 articles have been published on the diversity of spiders in Kazakhstan. But a huge amount of this data is still non-digitized and not available to researchers. The only known GBIF dataset of digitized literature covers the territory of the Balkhash-Alakol basin [34].

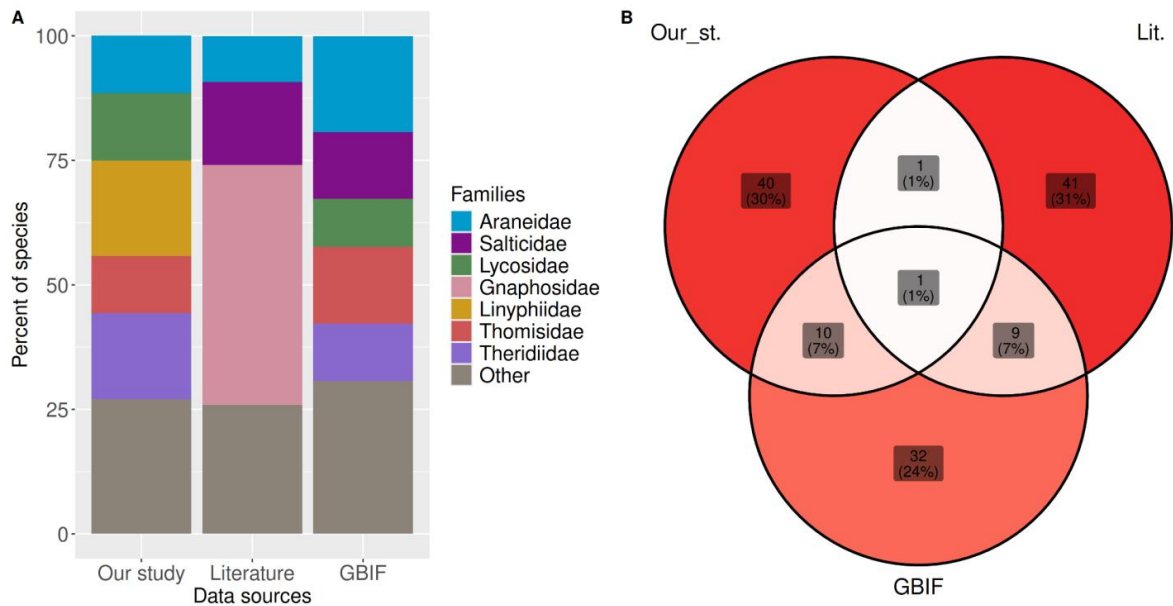


Figure 2. Taxonomic coverage on spider data of Central Kazakhstan.
 A: the most represented spider families according to different data sources (Our study, non-digitized literature, GBIF),
 B: Venn diagrams for species diversity based on three data sources (Our_st. – our study, Lit. – non-digitized literature, GBIF)

These results (Fig. 2B) also show that iNaturalist users and scientists collect different species. Combining these data sources provides more complete information about spider species diversity. At the same time, iNaturalist is limited in the number of species that can be identified, although observations have the widest spatial coverage among our data sources (Fig. 3). To fill the gap in the diversity of spiders in Kazakhstan on the GBIF digital map, large-scale field research and digitization of scientific heritage are required. These data will enable the building of more accurate models of biodiversity dynamics in the context of global climate change on a regional and global scale.

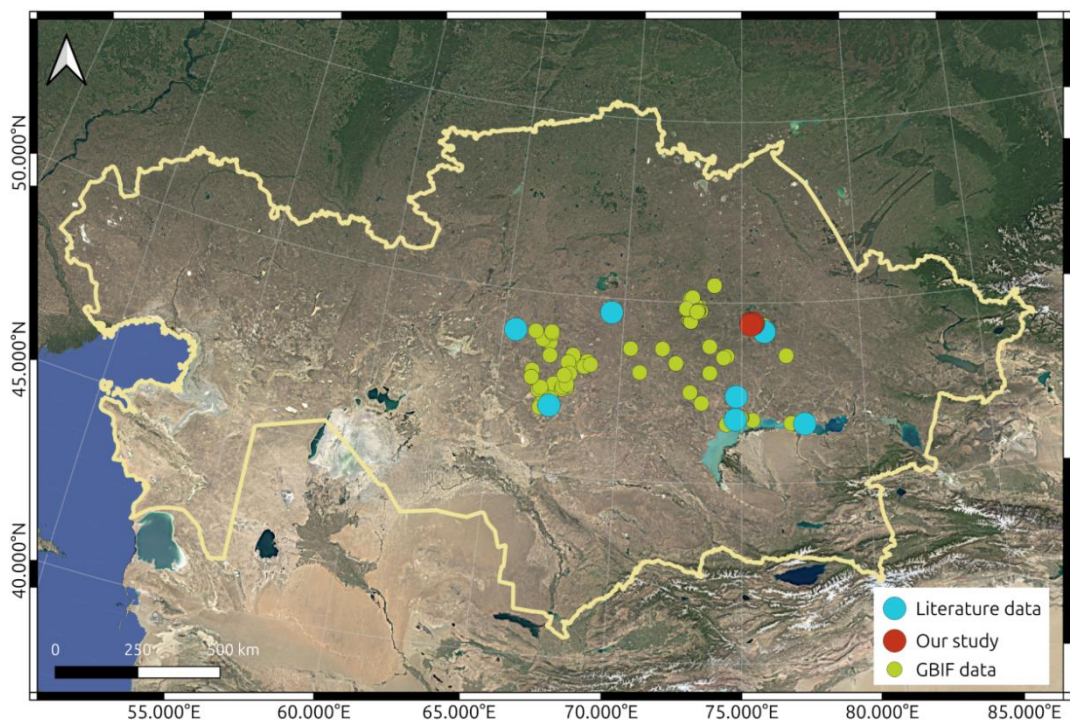


Figure 3. Spatial coverage of various data sources on spider data for Central Kazakhstan

Conclusion

As a result of the study, 52 species of spiders (order Araneae) were identified in the Karkaraly State National Natural Park. Among these 5 families and 40 species are recorded for Central Kazakhstan for the first time. The results of our local study have significantly expanded the GBIF digital data on spiders in Central Kazakhstan. Differences in species diversity identified by iNaturalist observations and scientific collection methods are shown.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CREDIT: **Plakkhina E.V.** — field data collection, data curation, data analysis, manuscript preparing; **Esyunin S.L.** — data identification, manuscript preparing; **Fetisov D.S.** — field data collection, data identification; **Kim L.V.** — field data collection, data identification; **Fedorova A.A.** — field data collection, manuscript preparing; **Ivanova N.V.** — GBIF datasets preparing and publishing, data analysis, manuscript preparing.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Cameron E.K. Global mismatches in aboveground and belowground biodiversity / E.K. Cameron, I.S. Martins, P. Lavelle, et al. // *Conservation Biology* — 2019. — No. 33. — P. 1187–1192. <https://doi.org/10.1111/cobi.13311>
- 2 Potapov A.M. Global fine-resolution data on springtail abundance and community structure / A.M. Potapov, T. -W. Chen, A.V. Striuchkova et al. // *Scientific Data*. — 2024. — No. 11. — Article number: 63. <https://doi.org/10.1038/s41597-023-02784-x>
- 3 Schultheiss P. The abundance, biomass, and distribution of ants on Earth / P. Schultheiss, S.S. Nooten, R. Wang, et al. // *PNAS*. — 2022. — No. 119 (40). — e2201550119. <https://doi.org/10.1073/pnas.2201550119>
- 4 James S.W. Comment on “Global distribution of earthworm diversity” / S.W. James, C. Csuzdi, C.-H. Chang, et al. // *Science*. — 2021. — No. 371 (6525). — 1–3. <https://doi.org/10.1126/science.abe4629>
- 5 Ivanova N.V. Diversity of earthworm communities in the European part of Russia: field data and model estimations / N.V. Ivanova, M.P. Shashkov, S.A. Ermolov // *Ecosystem Transformation*. — 2025. — No. 8 (4). — 120–137. <https://doi.org/10.23859/estr-240206>
- 6 Kim L. On the jumping spider (Araneae, Salticidae) fauna of Almaty city (Republic of Kazakhstan) / L. Kim, M. Salmenova, A. Yeszhanov // *Bulletin of the Karaganda University. Biology, Medicine, Geography Series*. — 2023. — No. 3(111). — P. 99–104. <https://doi.org/10.31489/2023BMG3/99-104>
- 7 Nekhaeva A. New data on the spider fauna (Arachnida: Aranei) of the East Kyzylkum Desert, Kazakhstan / A. Nekhaeva, L. Kim, A. Yeszhanov // *Arthropoda Selecta*. — 2024. — No. 33 (3). — P. 431–444. <https://doi.org/10.15298/arthsel.33.3.08>
- 8 Esyunin S.L. New data on the spider (Arachnida: Aranei) fauna of Mangystau Oblast, Kazakhstan / S.L. Esyunin, V.E. Efimik, A.N. Nekhaeva et al. // *Arthropoda Selecta*. — 2025. — No. 34 (3). — 426–446. <https://doi.org/10.15298/arthsel.34.3.15>
- 9 Logunov D.V. Spiders of Kazakhstan / D.V. Logunov, A.V. Gromov // Manchester: Siri Scientific Press. — 2012. — 232 p.
- 10 Овчаренко В.Н. Систематический список пауков сем. Gnaphosidae (Aranei) европейской части СССР и Кавказа / В.Н. Овчаренко // *Энтомологическое обозрение*. — 1982. — № 61 (4). — С. 830–844.
- 11 Марусик Ю.М. Каталог пауков-кругопрядов Казахстана. Семейство Araneidae / Ю.М. Марусик, Ч.К. Тарабаев, А.М. Литовченко // *Известия АН КазССР. Серия биологическая*. — 1990. — № 4. — С. 14–23.
- 12 Marusik Yu.M. The crab spiders of Middle Asia, USSR (Aranei, Thomisidae). 1. Descriptions and notes on distribution of some species / Yu.M. Marusik, D.V. Logunov // *Korean Arachnology*. — 1990. — № 6 (1). — С. 31–62.
- 13 Ovtsharenko V.I. A review of the North Asian ground spiders of the genus *Gnaphosa* (Araneae, Gnaphosidae) / V.I. Ovtsharenko, N.I. Platnick, D.X. Song // *Bulletin of the American museum of natural history*. — New York: American Museum of Natural History. — 1992. — 88 p.

- 14 Lyakhov O.V. Contribution to the Middle Asian fauna of the spider genus *Thanatus* C.L. Koch, 1837 (Aranei: Philodromidae) / O.V. Lyakhov // *Arthropoda Selecta*. — 2000. — No. 8(4). — 221–230.
- 15 Azarkina G.N. New and poorly known Palaearctic species of the genus *Phlegra* Simon, 1876 (Araneae, Salticidae) / G.N. Azarkina // *Review Arachnology*. — 2003. — No. 14 (6). — 73–108.
- 16 Громов А.В. Интересные находки пауков (Arachnida: Aranei) в Центральном Казахстане / А.В. Громов // Зоологические исследования за 20 лет независимости Республики Казахстан: Материалы Международной научной конференции посвященной 20-летию независимости Республики Казахстан (22-23 сентября). — Алматы: РГПИ Институт зоологии, 2011. — С. 70–75.
- 17 Marusik Yu.M. Redescription of *Asagena semideserta* (Ponomarev, 2005) comb. n. (Araneae: Theridiidae) / Yu. M. Marusik, A.A. Fomichev, T.K. Tuneva // *Acta Zoologica Bulgarica*. — 2016. — No. 68 (4). — P. 477–482.
- 18 Esyunin S.L. A review of the family Gnaphosidae in the fauna of the Urals (Aranei), 6. Taxonomic remarks and new records, with description of a new species / S.L. Esyunin, T.K. Tuneva // *Arthropoda Selecta*. — 2020. — No. 29 (1). — 103–120.
- 19 Триликаускас Л.А. Распределение пауков (Arachnida: Araneae) в зонально-катенной матрице степей Центрального Казахстана / Л.А. Триликаускас, И.И. Любечанский // *Сибирский экологический журнал*. — 2020. — № 5. — С. 587–599. <https://doi.org/10.15372/SEJ20200503>
- 20 GBIF.org. Spiders of Central Kazakhstan (01 December 2025). GBIF Occurrence Download. — [Electronic resource]. — 2025. — Access mode: <https://www.gbif.org>. (Date of request: 01.12.2025).
- 21 Максутова П.А. Физическая география Карагандинской области / П.А. Максутова, Ш.Е. Дюсекеева, А.О. Кулмаганбетова. — Караганда: Изд-во КарГУ. — 2005. — 59 с.
- 22 Погода и климат. — [Электронный ресурс]. — Режим доступа: www.pogodaiklimat.ru (дата обращения: 05.12.2025).
- 23 World Spider Catalog. Version 26. — [Electronic resource]. — Natural History Museum Bern, 2025. — Access mode: <http://wsc.nmbe.ch> (Date of request: 03.12.2025). <https://doi.org/10.24436/2>
- 24 Polchaninova N. Catalogue of the spiders (Arachnida, Aranei) of Left-Bank Ukraine / N. Polchaninova, E. Prokopenko // *Arthropoda Selecta*. — 2013. — No. 23. — 1–268.
- 25 Sozontov A. Spiders of the Udmurt Republic: fauna, ecology, phenology and distribution / A. Sozontov, S. Esyunin. — Moscow: KMK Scientific Press. — 2022. — 285 p.
- 26 Shashkov M.P. Invertebrates from the Kendara Valley (Karkaraly National Park, Kazakhstan). Version 1.1. / M.P. Shashkov, N.V. Ivanova, A. Fedorova, et al. Occurrence dataset. — Karaganda Buketov University. — 2025. <https://doi.org/10.15468/3z7x4u> (Date of request: 17.11.2025).
- 27 Shashkov M. Soil invertebrates collected during the IX Field School on Soil Zoology and Ecology for Young Scientists (Karkaraly National Park, Kazakhstan). Version 1.8. / M. Shashkov, K. Gongalsky, N. Ivanova, et al. Occurrence dataset. — Karaganda Buketov University. — 2025. <https://doi.org/10.15468/7qurj7> (Date of request: 14.11.2025).
- 28 GBIF.org. Checklist of spiders in Central Kazakhstan (01 December 2025). GBIF Occurrence Download. — 2025. <https://doi.org/10.15468/dl.t8t8ay> (Date of request: 01.12.2025).
- 29 GBIF.org. Checklist of spiders in Karkaraly National Park (01 December 2025). GBIF Occurrence Download. — 2025. — <https://doi.org/10.15468/dl.hs29pc> (Date of request: 01.12.2025).
- 30 R Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. — 2025. — [Electronic resource]. — Access mode: <https://www.R-project.org/>
- 31 Gao C-H. ggVennDiagram: Intuitive Venn diagram software extended / C-H. Gao, C. Chen, T. Akyol, et al. // *iMeta*. — No. 3 (1). — e177. Access mode: <https://doi.org/10.1002/imt2.177>
- 32 Hochmair H.H. Evaluating the data quality of iNaturalist termite records / H.H. Hochmair, R.H. Scheffrahn, M. Basille, M. Boone // *PLoS ONE*. — 2020. — № 15 (5). — e0226534. — Access mode: <https://doi.org/10.1371/journal.pone.0226534>
- 33 Михайлов К.Г. Bibliographia Araneologica Rossica 1770–2022. Библиография по паукам России и республик бывшего СССР, 1770–2022 / К.Г. Михайлов // *Зоологические исследования*. — 2024. — № 22. — 227 с. — Москва: КМК.
- 34 Nekhaeva A. Spider (Arachnida, Araneae) fauna of the lowland part of the Balkhash–Alakol basin (SE Kazakhstan). Part 1: Literature data. Version 1.8. / A. Nekhaeva, L. Kim, A. Ishaeva, A. Sozontov Occurrence dataset. — Institute of Zoology of the Republic of Kazakhstan. — 2025. <https://doi.org/10.15468/7qrc2k> (Date of request: 03.12.2025).

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«Қарқаралы» Мемлекеттік ұлттық табиғи паркінің өрмекшілер фаунасы (Arachnida: Araneae) туралы алғашқы ғылыми мәліметтер: Орталық Қазақстан бойынша деректерді толықтыру

Мақалада Қазақстанның Қарағанды облысында орналасқан «Қарқаралы» Мемлекеттік ұлттық табиғи паркі өрмекшілерінің (Araneae отряды) алуан түрлілігі жөніндегі алғашқы ғылыми деректер келтірілген. Далалық материал Кендара аңғарында, Шайтанкөл көлінің маңында және академик Е.А. Бөкетов атындағы Қарағанды ұлттық зерттеу университетінің далалық практика базасында 2025

жылдың шілде–тамыз айларында сызықты тұзақтар, топырақ үлгілерін талдау және колмен жинау әдістері арқылы жиналды. Барлығы 52 өрмекші түрі анықталды, олардың 40 түрі мен 5 тұқымдасы GBIF жаһанды биоалуантүрлілік жүйесінің деректері мен цифрландырылмаған әдеби мәліметтерге сәйкес Орталық Қазақстан үшін алғаш рет тіркеліп отыр. Алынған нәтижелер Орталық Қазақстандағы Araneae отряды өкілдерінің түр құрамына қатысты GBIF арқылы қолжетімді мәліметтерді едәуір толықтырды. iNaturalist қосымшасы арқылы тіркелген түрлік әртүрлілік пен дәстүрлі далалық тәсілдер арқылы жиналған материалдар негізіндегі мәліметтер арасында айырмашылықтар анықталды. Орталық Қазақстанның өрмекшілерін ауқымды далалық зерттеулердің қажеттілігі, сондай-ақ әдебиетте жарияланған деректерді цифрландыру және оларды GBIF порталы арқылы қолжетімді ету қажеттігі туралы қорытынды жасалды.

Кілт сөздер: өрмекшілер, Орталық Қазақстан, Қарағанды облысы, GBIF, iNaturalist.

Е.В. Плакхина, С.Л. Есюнин, Д.С. Фетисов, Л.В. Ким, А.А. Федорова, Н.В. Иванова

Первые сведения о фауне пауков (Arachnida: Araneae) Каркаралинского государственного национального природного парка: расширение данных по Центральному Казахстану

В работе представлены первые научные данные о разнообразии пауков (отряд Araneae) Каркаралинского государственного национального природного парка (Казахстан, Карагандинская область). Полевой материал собран в долине Кендара, в окрестностях озера Шайтанколь и на базе проведения полевых практик Карагандинского национального исследовательского университета имени академика Е.А. Букетова методами линий ловушек, разбора почвенных проб и ручного сбора в июле и августе 2025 г. Идентифицировано 52 вида пауков; 40 видов и 5 семейств впервые приводятся для Центрального Казахстана согласно глобальной системе о биоразнообразии GBIF и неоцифрованным литературным данным. Полученные результаты существенно расширили доступные через GBIF сведения о видовом составе представителей отряда Araneae в Центральном Казахстане. Выявлены различия в видовом разнообразии, регистрируемом через приложение iNaturalist и на основе сборов традиционными полевыми методами. Сделан вывод о необходимости масштабных полевых исследований пауков Центрального Казахстана, а также оцифровки и публикации через портал GBIF опубликованных в литературе данных.

Ключевые слова: пауки, Центральный Казахстан, Карагандинская область, GBIF, iNaturalist.

References

- 1 Cameron, E.K., Martins, I.S., Lavelle, P., et al. (2019). Global mismatches in aboveground and belowground biodiversity. *Conservation Biology*, 33, 1187–1192. <https://doi.org/10.1111/cobi.13311>
- 2 Potapov, A.M., Chen, T.-W., Striuchkova, A.V., et al. (2024). Global fine-resolution data on springtail abundance and community structure. *Scientific Data*, 11, Article number: 63. <https://doi.org/10.1038/s41597-023-02784-x>
- 3 Schultheiss, P., Nooten, S.S., Wang, R., et al. (2022). The abundance, biomass, and distribution of ants on Earth. *PNAS*, 119(40), e2201550119. <https://doi.org/10.1073/pnas.2201550119>
- 4 James, S.W., Csuzdi, C., Chang, C.-H., et al. (2021). Comment on “Global distribution of earthworm diversity”. *Science*, 371(6525), 1–3. <https://doi.org/10.1126/science.abe4629>
- 5 Ivanova, N.V., Shashkov, M.P., & Ermolov, S.A. (2025). Diversity of earthworm communities in the European part of Russia: field data and model estimations. *Ecosystem Transformation*, 8(4), 120–137. <https://doi.org/10.23859/estr-240206>
- 6 Kim, L., Salmenova, M., & Yeszhanov, A. (2023). On the jumping spider (Araneae, Salticidae) fauna of Almaty city (Republic of Kazakhstan). *Bulletin of the Karaganda University. Biology, Medicine, Geography Series*, 3(111), 99–104. <https://doi.org/10.31489/2023BMG3/99-104>
- 7 Nekhaeva, A., Kim, L., & Yeszhanov, A. (2024). New data on the spider fauna (Arachnida: Aranei) of the East Kyzylkum Desert, Kazakhstan. *Arthropoda Selecta*, 33(3), 431–444. <https://doi.org/10.15298/arthsel.33.3.08>
- 8 Esyunin, S.L., Efimik, V.E., Nekhaeva, A.N., et al. (2025). New data on the spider (Arachnida: Aranei) fauna of Mangystau Oblast, Kazakhstan. *Arthropoda Selecta*, 34(3), 426–446. <https://doi.org/10.15298/arthsel.34.3.15>
- 9 Logunov, D.V., & Gromov A.V. (2012). *Spiders of Kazakhstan*. Manchester: Siri Scientific Press.
- 10 Ovcharenko, V.N. (1982). Sistematischeskii spisok paukov semeistva Gnaphosidae (Aranei) evropeiskoi chasti SSSR i Kavkaza [A systematic list of spiders of the family Gnaphosidae (Aranei) on the European part of the USSR and the Caucasus]. *Entomologicheskoe obozrenie — Entomological review*, 61(4), 830–844 [in Russian].

- 11 Marusik, Yu.M., Tarabaev, Ch.K., & Litovchenko, A.M. (1990). Katalog paukov-krugopriadov Kazakhstana. Semeistvo Araneidae [Catalog of orb-weaving spiders of Kazakhstan, family Araneidae]. *Izvestiia Akademii Nauk KazSSR. Serii biologicheskaiia — News of the Academy of Sciences of the Kazakh SSR. Biological series*, 4, 14–23 [in Russian].
- 12 Marusik, Yu.M., & Logunov, D.V. (1990). The crab spiders of Middle Asia, USSR (Aranei, Thomisidae). 1. Descriptions and notes on distribution of some species. *Korean Arachnology*, 6(1), 31–62.
- 13 Ovtsharenko, V.I. Platnick, N.I., & Song, D.X. (1992). A review of the North Asian ground spiders of the genus *Gnaphosa* (Araneae, Gnaphosidae). *Bulletin of the American museum of natural history*, 88 p. New York: American Museum of Natural History.
- 14 Lyakhov, O.V. (2000). Contribution to the Middle Asian fauna of the spider genus *Thanatus* C.L. Koch, 1837 (Aranei: Philodromidae). *Arthropoda Selecta*, 8(4), 221–230.
- 15 Azarkina, G.N. (2003). New and poorly known Palaeartic species of the genus *Phlegra* Simon, 1876 (Araneae, Salticidae). *Revue Arachnologique*, 14(6), 73–108.
- 16 Gromov, A.V. (2011). Interesnye nakhodki paukov (Arachnida: Aranei) v Tsentralnom Kazakhstane [Interesting spiders finds (Arachnida: Aranei) in central Kazakhstan]. *Zoologicheskie issledovaniia za 20 let nezavisimosti Respubliki Kazakhstan: Materialy Mezhdunarodnoi nauchnoi konferentsii, posviashchennoi 20-letiiu nezavisimosti Respubliki Kazakhstan — Zoological research over 20 years of independence of the Republic of Kazakhstan: Proceedings of the International Scientific Conference dedicated to the 20th anniversary of Independence of the Republic of Kazakhstan* (pp. 70–75). Almaty: Institut zoologii [in Russian].
- 17 Marusik, Yu.M., Fomichev, A.A., & Tuneva, T.K. (2016). Redescription of *Asagena semideserta* (Ponomarev, 2005) comb. n. (Araneae: Theridiidae). *Acta Zoologica Bulgarica*, 68(4), 477–482.
- 18 Esyunin, S.L., & Tuneva, T.K. (2020). A review of the family Gnaphosidae in the fauna of the Urals (Aranei), 6. Taxonomic remarks and new records, with description of a new species. *Arthropoda Selecta*, 29(1), 103–120.
- 19 Trilikauskas, L.A., & Liubechanskii, I.I. (2020). Raspredelenie paukov (Arachnida: Araneae) v zonalno-katennom matritse stepei Tsentralnogo Kazakhstana [Distribution of spider (Arachnida: Araneae) in the zonal-catenary matrix of the steppes of central Kazakhstan]. *Sibirskii ekologicheskii zhurnal — Siberian Ecological Journal*, 5, 587–599. <https://doi.org/10.15372/SEJ20200503> [in Russian].
- 20 GBIF.org. *Spiders of Central Kazakhstan* (01 December 2025). GBIF Occurrence Download. Retrieved from <https://doi.org/10.15468/dl.h7chuv> (accessed 01 December 2025).
- 21 Maksutova, P.A., Dyusekeeva, Sh.E., & Kulmagambetova, A.O. (2005). *Fizicheskaiia geografiia Karagandinskoi oblasti* [Physical geography of the Karaganda region]. Karaganda: Izdatelstvo Karagandinskogo gosudarstvennogo universiteta [in Russian].
- 22 (2025). Pogoda i klimat [Weather and Climate]. www.pogodaiklimat.ru. Retrieved from www.pogodaiklimat.ru (accessed 05 December 2025) [in Russian].
- 23 (2025). World Spider Catalog. Version 26. Natural History Museum Bern. <http://wsc.nmbe.ch>. Retrieved from <http://wsc.nmbe.ch> (accessed 03 December 2025). <https://doi.org/10.24436/2>
- 24 Polchaninova, N., & Prokopenko, E. (2013). Catalogue of the spiders (Arachnida, Aranei) of Left-Bank Ukraine. *Arthropoda Selecta*, 23, 1–268.
- 25 Sozontov, A., & Esyunin, S. (2022). *Spiders of the Udmurt Republic: fauna, ecology, phenology and distribution*. Moscow: KMK Scientific Press, 285 p.
- 26 Shashkov, M.P., Ivanova, N.V., Fedorova, A., et al. (2025). *Invertebrates from the Kendar Valley (Karkaraly National Park, Kazakhstan), Version 1.1*. Occurrence dataset. Karaganda Buketov University. <https://doi.org/10.15468/3z7x4u> (accessed 17 November 2025).
- 27 Shashkov, M., Gongalsky, K., Ivanova, N., et al. (2025). *Soil invertebrates collected during the IX Field School on Soil Zoology and Ecology for Young Scientists (Karkaraly National Park, Kazakhstan), Version 1.8*. Occurrence dataset. Karaganda Buketov University. <https://doi.org/10.15468/7qurj7> (accessed 14 November 2025).
- 28 GBIF.org. Checklist of spiders in Central Kazakhstan (01 December 2025). GBIF Occurrence Download. <https://doi.org/10.15468/dl.t8t8ay> (accessed 01 December 2025).
- 29 GBIF.org. Checklist of spiders in Karkaraly National Park (01 December 2025). GBIF Occurrence Download. <https://doi.org/10.15468/dl.hs29pc> (accessed 01 December 2025).
- 30 R Core Team. (2025). *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from <https://www.R-project.org/>
- 31 Gao, C.-H., Chen, C., Akyol, T., et al. (2024). *ggVennDiagram*: Intuitive Venn diagram software extended. *iMeta*, 3(1), e177. <https://doi.org/10.1002/imt2.177>
- 32 Hochmair, H.H., Scheffrahn, R.H., Basille, M., & Boone, M. (2020). Evaluating the data quality of iNaturalist termite records. *PLoS ONE*, 15(5), e0226534. <https://doi.org/10.1371/journal.pone.0226534>
- 33 Mikhailov, K.G. (2024). Bibliographia Araneologica Rossica 1770–2022. Bibliografiia po paukam Rossii i respublik byvshego SSSR, 1770–2022 [Bibliography on spiders of Russia and the republics of the former USSR, 1770–2022]. *Zoologicheskie issledovaniia — Zoological research*, 22, 227. Moscow [in Russian].
- 34 Nekhaeva, A., Kim, L., Ishaeva, A., & Sozontov A. (2025). *Spider (Arachnida, Araneae) fauna of the lowland part of the Balkhash–Alakol basin (SE Kazakhstan). Part 1: Literature data. Version 1.8*. Occurrence dataset. Institute of Zoology of the Republic of Kazakhstan. <https://doi.org/10.15468/7qrc2k> (accessed 03 December 2025).

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Surveillance of West Nile Fever in the Republic of Kazakhstan, 2023–2025

In 2023–2025, comprehensive monitoring of West Nile fever (WNF) was conducted across 14 regions of the Republic of Kazakhstan to assess virus circulation in natural foci. The study included the main potential reservoirs and vectors of the pathogen, namely wild migratory birds, mosquitoes, ixodid ticks, and bats. A total of 362 biological samples from wild birds, 84 samples from bats, 679 ticks, and 1,554 mosquitoes were examined. Laboratory diagnostics were performed using polymerase chain reaction (PCR) with primers specific to West Nile virus. According to the results, West Nile virus RNA was detected exclusively in wild birds—in 5 of 362 samples, corresponding to a prevalence of 1.38 % (95 % CI: 0.45–3.19 %). No West Nile virus RNA was detected in samples obtained from mosquitoes, ticks, or bats. Positive samples were detected in wild birds from the Pavlodar and Karaganda regions. The obtained data confirm the leading role of migratory birds in the introduction of West Nile virus into the territory of Kazakhstan and indicate the need for continued systematic epizootiological and molecular monitoring to assess the risk of the formation and maintenance of natural infection foci.

Keywords: monitoring, PCR, West Nile fever, flaviviruses, wild birds, mosquitoes, ticks, bats, epizootiological monitoring.

Introduction

West Nile fever (WNF) is a zoonotic arboviral disease with a global distribution. The virus was first isolated in Uganda in 1937, and since the late 1990s it has caused epidemic outbreaks in North America, Europe, and Asia [1–6], making it one of the most significant arboviral infections worldwide, alongside Zika, Chikungunya, and Dengue viruses.

Virus circulation is maintained through an enzootic “mosquito–bird” cycle, in which wild birds, particularly migratory species, serve as the main reservoir and play a key role in long-distance virus dissemination [7, 8].

Most West Nile virus infections are asymptomatic; however, a proportion of patients develop uncomplicated febrile illness, and in rare cases severe neuroinvasive forms occur [9–11]. Mortality in neuroinvasive disease may exceed 10 % among elderly individuals, and survivors often experience long-term neurological sequelae. Recent studies have confirmed the first clinical cases of neuroinvasive WNF in the Almaty region in 2019, indicating a real public health threat and confirming active virus circulation in southern regions of Kazakhstan [12].

Over the past two decades, the nosoarea of WNF has been continuously expanding, including territories of the Russian Federation and regions bordering Kazakhstan. Positive results for West Nile virus have been reported in the West Kazakhstan region, while in Almaty an increase in the incidence of serous meningitis during the summer period has been observed, the etiology of which remains unidentified [13].

Kazakhstan, located at the intersection of the Central Asian and Siberian–South Asian bird migration flyways, is at risk of West Nile virus introduction. Climatic conditions, including warm summer periods and the presence of numerous water bodies, favor mass breeding of *Culex* mosquitoes, the primary vectors of the virus. Early studies conducted in 2013–2014 detected virus circulation in seven bird species in the vicinity of major water bodies in the Almaty region—Sorbulak, Aksu, and Alakol [14]. Subsequent investigations in 2022–2023 in the Almaty and Zhambyl regions confirmed the presence of the virus in the hooded crow

(*Corvus corone*), Eurasian jackdaw (*Corvus monedula*), and Eurasian sparrowhawk (*Accipiter nisus*), indicating long-term circulation of WNF in southern Kazakhstan [15].

In contrast to European countries and the United States, where systematic epidemiological surveillance of WNF is conducted, studies in Kazakhstan have been sporadic and have not encompassed all key components of the epizootic chain, including birds, mosquitoes, ticks, and bats. The lack of comprehensive long-term studies hampers accurate assessment of the current epizootiological situation and limits the ability to predict risks to human and animal health.

Therefore, large-scale epizootiological monitoring of West Nile virus in Kazakhstan during 2023–2025 among potential reservoirs and vectors is critically important for identifying areas and intensity of virus circulation, developing an effective epidemiological surveillance system, and integrating Kazakhstan into international arbovirus control programs.

Experimental

Sample Collection

Sampling was conducted during the active seasons of vectors, primarily from May to September, with peak sampling occurring in June–August, corresponding to the highest activity of mosquitoes. Samples were obtained from clinically healthy animals in natural biotopes (wetlands, river floodplains, forest belts) located near human settlements and agricultural areas.

Samples from free-living migratory and synanthropic birds were collected using ornithological mist nets, as well as from birds obtained during legally authorized hunting activities.

Bats were captured in old and abandoned buildings, attics, caves, and tunnels. An ultrasonic detector Batbox Baton (NHBS, United Kingdom) was used to locate bat colonies. Individuals were captured using entomological nets and mist nets in caves or manually in buildings. Swabs from mucosal surfaces and guano samples were collected from bats. After sampling, all animals were released at the capture sites.

Mosquitoes were collected using entomological nets, CDC light traps, and aspirators during daytime and nighttime in areas of mass breeding and resting. Ticks were collected by flagging (dragging) vegetation and shrubs, as well as by removal from the bodies of captured mammals. For each sample, the date of collection, species, number of individuals, and geographic coordinates were recorded. Transportation to the laboratory was carried out on the day of collection; when immediate delivery was not possible, adult ticks were temporarily stored in tubes with moistened filter paper at +4 °C for no more than 10 days. In the laboratory, live ticks were surface-sterilized by double washing in 70 % ethanol for 30 s.

To improve PCR efficiency mosquitoes and ticks were pooled according to species, sampling location, and collection date, with pool sizes ranging from 9 to 15 individuals for mosquitoes and from 1 to 5 individuals for ticks, depending on their size and degree of blood engorgement (Table 2). All samples were immediately placed in transport medium and stored at –80 °C until laboratory analysis.

RNA Extraction and cDNA Synthesis

RNA was extracted from homogenized tissue samples and arthropod pools using the QIAamp Viral RNA Mini Kit (Qiagen, Germany) in accordance with the manufacturer's instructions. Reverse transcription for first-strand cDNA synthesis was performed using SuperScript™ III Reverse Transcriptase (Invitrogen, USA) and random hexamer primers.

PCR Detection of West Nile Virus

Detection of viral RNA was performed using a two-round PCR assay with primers recommended by the OIE (Table 1) [16].

Table 1

Primers used for detection of West Nile virus by RT-PCR

| No. | Primer name | Sequence (5'→3') | Product size |
|-----|-------------|----------------------------|--------------|
| 1 | 1401F | ACC-AAC-TAC-TGT-GGA-GTC | 445 bp |
| | 1845R | TTC-CAT-CTT-CAC-TCT-ACA-CT | |
| 2 | 1485F | GCC-TTC-ATA-CAC-ACT-AAA-G | 248 bp |
| | 1732R | CCA-ATG-CTA-TCA-CAG-ACT | |

PCR amplification was performed in a Mastercycler thermal cycler (Eppendorf, Germany) using the OneStep RT-PCR Kit (Qiagen, Germany). The total reaction volume was 20 μ L per sample.

The amplification program for the first round included: 45 °C for 45 min (reverse transcription); 95 °C for 11 min; followed by 35 cycles of 95 °C for 30 s, 55 °C for 45 s, and 72 °C for 60 s, with a final extension at 72 °C for 5 min. For the second round, the program consisted of 95 °C for 11 min followed by 35 cycles of 95 °C for 30 s, 55 °C for 45 s, and 72 °C for 62 s.

Amplification products were visualized by electrophoresis in a 1.5 % agarose gel stained with ethidium bromide.

Additionally, commercial real-time RT-PCR kits were used:

AmpliSens® WNV-FL (Central Research Institute of Epidemiology, Rospotrebnadzor, Russia). Analysis was performed on a Rotor-Gene Q amplifier (Qiagen, Germany) according to the manufacturer's instructions, with fluorescence detection in the FAM and JOE channels.

West Nile Virus (WNV) TaqMan RT-PCR Kit (Norgen Biotek, Canada). Real-time RT-PCR was conducted strictly following the manufacturer's protocol using a Rotor-Gene Q instrument.

Sequencing and Phylogenetic Analysis

Sequencing was performed using the dideoxy chain-termination (Sanger) method with fluorescently labeled dideoxynucleotides on an automated 16-capillary Genetic Analyzer 3130xl (Applied Biosystems, USA). POP-7 polymer was used for capillary electrophoresis. Sequencing reactions were generated using the cycle sequencing method.

Phylogenetic analysis was conducted using MEGA version 6.06 [17] with the following parameters: statistical method—Neighbor-Joining; test of phylogeny—bootstrap method; number of bootstrap replications—500; model/method—Kimura 2-parameter model; substitutions included—transitions and transversions; gaps/missing data treatment—complete deletion; codons included—1st + 2nd + 3rd + non-coding positions.

Statistical and Geospatial Analysis

Statistical analysis was performed using GraphPad Prism software. Descriptive statistics were applied to calculate overall and regional prevalence rates. Chi-square tests were used to assess significant differences in prevalence between regions. A p-value < 0.05 was considered statistically significant. Results were presented as percentages with 95 % confidence intervals to reflect uncertainty around the estimates.

Geographic coordinates of sampling sites were mapped using QGIS version 3.34.

Results and Discussion

During 2023–2025, biological samples were collected in 14 regions of the Republic of Kazakhstan (Zhambyl, Almaty, Zhetisu, Turkestan, Kyzylorda, West Kazakhstan, Atyrau, Aktobe, Mangystau, Akmola, North Kazakhstan, Karaganda, Abay, and East Kazakhstan regions). In total, samples were obtained from 362 wild migratory birds, 84 bats, 679 ticks, and 1,554 mosquitoes. Survey locations, sampling sites, and numbers of collected samples are presented in Table 2 and Figures 1-2. During field investigations, no diseased or dead animals were detected. Samples from birds and bats were collected exclusively from clinically healthy individuals.

Table 2

Number of samples collected in the regions of Kazakhstan

| No. | Region | Birds | Ticks | Ticks (pools) | Mosquitoes | Mosquitoes (pools) | Bats |
|-------------|----------|-------|-------|---------------|------------|--------------------|------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 2023 | | | | | | | |
| 1 | Kostanay | 10 | 10 | 3 | - | - | - |
| 2 | Akmola | 6 | - | - | - | - | - |
| 3 | Zhambyl | 60 | 25 | 8 | - | - | 1 |
| 4 | Atyrau | - | 5 | 5 | - | - | 17 |

Continuation of Table 2

| No. | Region | Birds | Ticks | Ticks (pools) | Mosquitoes | Mosquitoes (pools) | Bats |
|-------------|------------------|-------|-------|---------------|------------|--------------------|------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 2023 | | | | | | | |
| 5 | Aktobe | - | 5 | 3 | - | - | 12 |
| 6 | Abay | - | 10 | 3 | - | - | - |
| 7 | West Kazakhstan | - | 10 | 3 | - | - | 22 |
| 8 | Almaty | - | 17 | 7 | - | - | - |
| 9 | Zhetisu | - | 15 | 6 | - | - | - |
| | Total | 76 | 97 | 38 | - | - | 52 |
| 2024 | | | | | | | |
| 1 | Aktobe | 13 | - | - | 208 | 20 | - |
| 2 | Pavlodar | 3 | - | - | 12 | 1 | - |
| 3 | Zhambyl | 27 | 18 | 13 | 12 | 1 | - |
| 4 | Karaganda | 32 | - | - | - | - | - |
| 5 | Kyzylorda | 29 | 45 | 21 | 41 | 4 | - |
| 6 | Turkestan | 3 | 90 | 40 | 30 | 3 | 32 |
| 7 | Zhetisu | 12 | 49 | 20 | - | - | - |
| 8 | Almaty | 20 | 38 | 13 | - | - | - |
| 9 | Abay | - | 45 | 26 | - | - | - |
| 10 | West Kazakhstan | - | 35 | 11 | 51 | 5 | - |
| 11 | Atyrau | - | - | - | - | - | - |
| 12 | Mangystau | - | - | - | - | - | - |
| | Total | 139 | 320 | 144 | 354 | 34 | 32 |
| 2025 | | | | | | | |
| 1 | Almaty | 131 | 43 | 16 | 101 | 10 | - |
| 2 | Zhambyl | 2 | 7 | 7 | 100 | 10 | - |
| 3 | Karaganda | 14 | - | - | - | - | - |
| 4 | West Kazakhstan | - | 74 | 64 | 100 | 10 | - |
| 5 | North Kazakhstan | - | 50 | 22 | 84 | 8 | - |
| 6 | Zhetisu | - | 45 | 41 | 103 | 10 | - |
| 7 | Atyrau | - | 13 | 13 | 100 | 10 | - |
| 8 | Mangystau | - | 30 | 21 | - | - | - |
| 9 | Aktobe | - | - | - | 100 | 10 | - |

Continuation of Table 2

| No. | Region | Birds | Ticks | Ticks (pools) | Mosquitoes | Mosquitoes (pools) | Bats |
|-------------|-----------------|-------|-------|---------------|------------|--------------------|------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 2025 | | | | | | | |
| 10 | Kostanay | - | - | - | 99 | 10 | - |
| 11 | Turkestan | - | - | - | 100 | 10 | - |
| 12 | Kyzylorda | - | - | - | 100 | 10 | - |
| 13 | Akmola | - | - | - | 116 | 12 | - |
| 14 | East Kazakhstan | - | - | - | 97 | 10 | - |
| | Total | 147 | 262 | 184 | 1200 | 120 | - |
| | Total | 362 | 679 | 366 | 1554 | 154 | 84 |

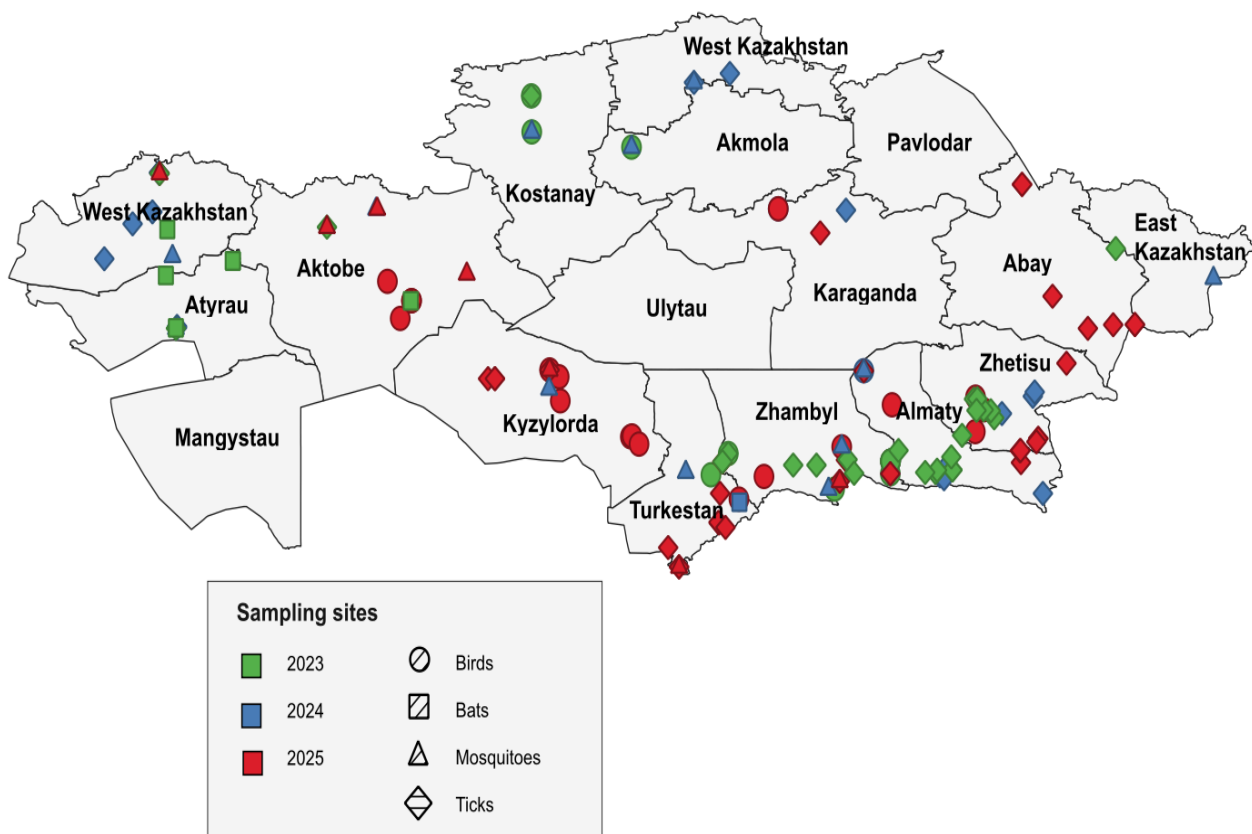


Figure 1. Survey and sampling sites for birds in 2023–2025

All collected samples were tested for the presence of West Nile virus (WNV) RNA. As a result of the study, WNV was detected only in samples from five birds (Table 3). The overall prevalence of WNV among wild birds was 1.38 %, including 2.16 % in 2024 and 2.04 % in 2025. WNV RNA was detected in samples from wild birds—common shelduck, duck, and black-headed gull—collected in the Pavlodar region in 2024 (prevalence 100 %), as well as in two samples—Eurasian jackdaw and magpie—collected in the Karaganda region in 2025 (prevalence 35.7 %). The geographic distribution of WNV among birds is shown in Figure 3.

Table 3

Results of PCR testing of wild bird samples for West Nile virus

| No. | Region | Tested | Positive | % Positive | 95 % CI (%) | p-value* |
|-------------|--------------|--------|----------|------------|-------------|----------|
| 2023 | | | | | | |
| 1 | Kostanay | 10 | 0 | 0.0 | 0.0–4.7 | — |
| 2 | Akmola | 6 | 0 | 0.0 | 0.0–4.7 | — |
| 3 | Zhambyl | 60 | 0 | 0.0 | 0.0–4.7 | — |
| | Total | 76 | 0 | 0.0 | 0.0–4.7 | — |
| 2024 | | | | | | |
| 1 | Aktobe | 13 | 0 | 0.0 | 0.0–2.7 | — |
| 2 | Pavlodar | 3 | 3 | 100.0 | 29.2–100 | 0.000001 |
| 3 | Zhambyl | 27 | 0 | 0.0 | 0.0–2.7 | — |
| 4 | Karaganda | 32 | 0 | 0.0 | 0.0–2.7 | — |
| 5 | Kyzylorda | 29 | 0 | 0.0 | 0.0–2.7 | — |
| 6 | Turkestan | 3 | 0 | 0.0 | 0.0–2.7 | — |
| 7 | Zhetisu | 12 | 0 | 0.0 | 0.0–2.7 | — |
| 8 | Almaty | 20 | 0 | 0.0 | 0.0–2.7 | — |
| | Total | 139 | 3 | 2.16 | 0.45–6.2 | 0.27 |
| 2025 | | | | | | |
| 1 | Almaty | 131 | 0 | 0.0 | 0.0–2.8 | — |
| 2 | Zhambyl | 2 | 0 | 0.0 | 0.0–2.8 | — |
| 3 | Karaganda | 14 | 2 | 35.7 | 1.78–42.8 | 0.013 |
| | Total | 147 | 2 | 1.36 | 0.17–4.8 | 0.27 |
| | Total | 362 | 5 | 1.38 | 0.45–3.2 | — |

* p<0,05



Figure 2. Geographic distribution of West Nile virus among wild birds in Kazakhstan

Analysis of published data indicates that more than 300 bird species are involved as hosts and carriers of West Nile virus (WNV) [18]. In the present study, the sampled avifauna included representatives of different ecological groups, including waterfowl (*Anas platyrhynchos*, *Tadorna tadorna*), synanthropic and passerine birds (*Corvidae* and other passerines, including *Coloeus monedula* and *Pica pica*), and semi-aquatic species (*Chroicocephalus ridibundus*). Raptor species were also represented to a limited extent (e.g., *Accipiter nisus*).

WNV-positive samples were detected in the common shelduck (*Tadorna tadorna*), mallard (*Anas platyrhynchos*), and black-headed gull (*Chroicocephalus ridibundus*) from the Pavlodar region, as well as in the Eurasian jackdaw (*Coloeus monedula*) and magpie (*Pica pica*) from the Karaganda region (Table 4).

Table 4

Characteristics of WNV-positive bird samples by species, location, and sampling date

| Species | Region | District | Sampling site | Date | Ecological group | Result |
|-----------------------------------|-----------|----------|-----------------|------------|------------------|----------|
| <i>Tadorna tadorna</i> | Pavlodar | Bayanaul | Lake Shalkarkol | 17.08.2024 | Waterfowl | Positive |
| <i>Anas platyrhynchos</i> | Pavlodar | Bayanaul | Lake Shalkarkol | 17.08.2024 | Waterfowl | Positive |
| <i>Chroicocephalus ridibundus</i> | Pavlodar | Bayanaul | Lake Shalkarkol | 17.08.2024 | Semi-aquatic | Positive |
| <i>Coloeus monedula</i> | Karaganda | Nura | Lake Balkhash | 31.03.2025 | Passerine | Positive |
| <i>Pica pica</i> | Karaganda | Nura | Lake Balkhash | 31.03.2025 | Passerine | Positive |

Previously, in the Almaty region, WNV RNA had been detected in seven avian species serving as virus carriers of West Nile fever. In 2015, WNV RNA was identified in samples from the common chiffchaff (*Phylloscopus collybita*), Turkestan shrike (*Lanius phoenicuroides*), mallard (*Anas platyrhynchos*), great cormorant (*Phalacrocorax carbo*), common whitethroat (*Sylvia communis*), common sandpiper (*Actitis hypoleucos*), and Caspian gull (*Larus cachinnans*) [14].

Subsequently, during 2021–2023, in addition to the seven previously identified avian carriers, four more bird species were identified as WNV carriers [15, 19]. In 2021, WNV was detected in samples from the barn swallow (*Hirundo rustica*) and common chiffchaff (*Phylloscopus collybitus*) in the Zhambyl region, while in 2022–2023 it was identified in samples from the hooded crow (*Corvus corone*), Eurasian jackdaw (*Corvusmonedula*), and Eurasian sparrowhawk (*Accipiter nisus*). Based on these findings, it can be assumed that many bird species previously given little attention actively participate in WNV circulation and likely play a significant role in the maintenance and persistence of natural WNV foci. Occupying diverse ecological niches, these bird species may serve as natural reservoirs of WNV.

Detection of WNV in birds in the Pavlodar region (2024) and Karaganda region (2025) is consistent with the hypothesis that migratory birds play a leading role in virus introduction [20, 21]. While earlier WNV activity had been documented mainly in western Kazakhstan [22], the present data provide the first evidence of virus detection in birds from central and northeastern regions of the country. This may indicate both an expansion of the virus activity range and the existence of previously unrecognized local foci along migratory flyways.

Our recent studies also confirm the expansion of the WNV distribution range in Kazakhstan [23]. In the present study, the role of horses in WNV circulation in Kazakhstan was demonstrated for the first time. Antibodies to WNV were detected in horse sera from the Aktobe, Turkestan, Almaty, Zhetisu, West Kazakhstan, and Atyrau regions. The overall seroprevalence among horses was 8.7 %, indicating active virus circulation in these regions and highlighting the need for targeted monitoring in equine populations. Horses, like humans, are dead-end hosts [24] and do not play a significant role in further virus transmission; however, their high susceptibility and pronounced clinical manifestations make them highly valuable sentinel animals [25, 26]. Detection of WNV-specific antibodies or clinical cases among horses that have not traveled outside the region provides direct evidence of local virus transmission and serves as a warning signal of increased risk to public health.

At the same time, WNV RNA was not detected in any of the analyzed samples from mosquitoes (n = 1,554), ticks (n = 679), or bats (n = 84).

The absence of virus detection in mosquitoes in regions where WNV was identified in birds may be explained by several factors, including sporadic virus introduction, insufficient density of competent vector populations (*Culex spp.*) for sustained transmission, sampling outside peak transmission seasons, or extremely low circulation intensity below the detection limit of the applied methods [27]. When interpreting these results, several limitations of the study should be considered: sampling may not have fully covered key periods of bird migration and peaks of mosquito activity; reliance solely on PCR screening without parallel serological monitoring may have led to underestimation of overall infection prevalence; and variation in sample numbers across regions and years complicates assessment of long-term trends.

Within the framework of the present study, one sequence fragment of the WNV E gene with a length of 546 bp was obtained. Phylogenetic analysis showed that this sequence was most closely related to isolates previously detected in the West Kazakhstan region of Kazakhstan and the Volgograd region of the Russian Federation. The analysis assigned the virus to genotype 1.

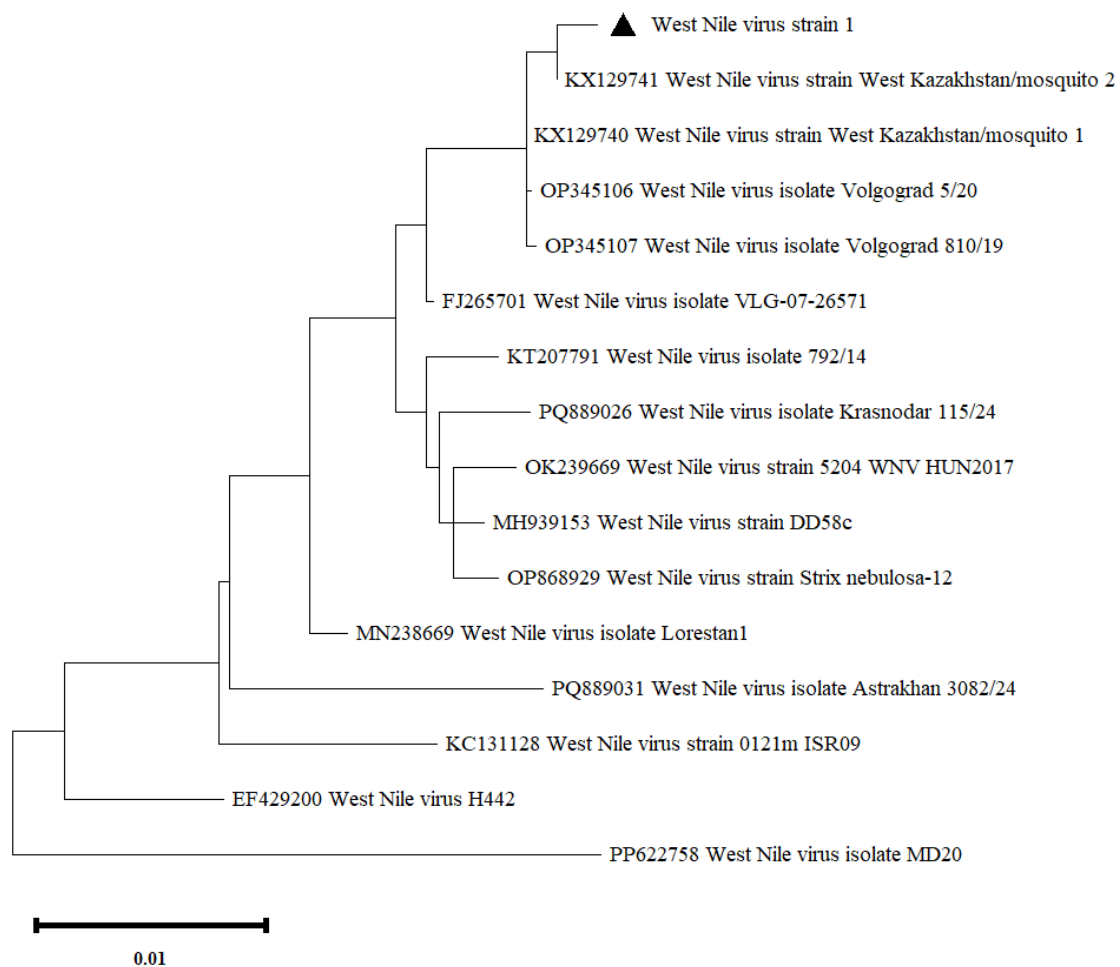


Figure 3. Phylogenetic analysis of the Kazakhstan West Nile virus isolate

Phylogenetic analysis demonstrated that the obtained E gene sequence, classified as genotype 1a, showed the highest similarity to isolates from the West Kazakhstan region of Kazakhstan and the Volgograd region of the Russian Federation [28, 29]. This finding supports the hypothesis of a unified transboundary circulation area of West Nile virus [30] and once again highlights the key role of migratory birds in virus dissemination.

These findings highlight the need to improve West Nile virus surveillance in Kazakhstan. Monitoring efforts should be focused on priority targets, including wild migratory birds at key stopover sites and *Culex* mosquitoes. It is critically important to incorporate regular serological screening (ELISA) of horses into the

national surveillance system, particularly in regions identified in this study as potential points of virus introduction (Pavlodar and Karaganda). To accurately track virus dissemination routes and evolutionary dynamics, further studies aimed at sequencing complete genomes of Kazakhstan West Nile virus isolates are required.

Conclusion

Based on the results of epizootiological monitoring conducted in 2023–2025 across 14 regions of Kazakhstan, the following conclusions can be drawn. A total of 362 samples from wild migratory birds, 84 from bats, 679 from ticks, and 1,554 from mosquitoes were collected from clinically healthy animals and analyzed. The overall prevalence of West Nile virus (WNV) RNA among wild birds was 1.38 %, with positive results detected only in 2024 and 2025 (2.16 % and 1.36 %, respectively) and geographically confined to the Pavlodar and Karaganda regions. These findings confirm the role of migratory birds in the introduction of WNV into the central and northeastern regions of the country. No viral RNA was detected in any samples from mosquitoes, ticks, or bats, which may indicate a sporadic introduction of the virus or a low level of local circulation.

Phylogenetic analysis of the obtained nucleotide sequence of the E gene fragment (546 bp) classified the isolate as genotype 1a and revealed its closest similarity to strains circulating in the West Kazakhstan region of Kazakhstan and the Volgograd region of the Russian Federation, supporting the existence of a unified transboundary circulation area of WNV. The obtained results substantiate the need for further optimization of the surveillance system, with emphasis on monitoring wild birds and mosquito vectors, as well as the inclusion of serological screening of horses as a sensitive indicator of local virus transmission in the identified high-risk areas.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Alibekova D.A.** — conceptualization, data curation, methodology, investigation, visualization, manuscript drafting; **Omarova Z.D.** — data curation, methodology, investigation, manuscript drafting; **Rystayeva R.A.** — data curation, methodology; **Argimbayeva T.U.** — methodology, investigation, visualization; **Tulendibayev A.B.** — methodology, investigation; **Aubakir N.A.** — methodology, investigation; **Yermekbay T.T.** — methodology, investigation; **Barakbayev K.B.** — conceptualization, data curation, study management, project administration, funding; **Smith G.J.** — conceptualization, data curation, formal analysis, writing draft, editing; **Orynbayev M.B.** — conceptualization, data curation, formal analysis, supervision, writing draft, editing.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Nash D. The outbreak of West Nile virus infection in the New York City area in 1999 / D. Nash, F. Mostashari, A. Fine, et al. // *New England Journal of Medicine*. — 2001. — Vol. 344, No. 24. — P. 1807–1814.
- 2 Chancey C. The global ecology and epidemiology of West Nile virus / C. Chancey, A. Grinev, E. Volkova, M. Rios // *BioMed Research International*. — 2015. — Vol. 2015. — Art. ID 376230. DOI: 10.1155/2015/376230.
- 3 Balanca G. Low West Nile virus circulation in wild birds in an area of recurring outbreaks in Southern France / G. Balanca, N. Gaidet, G. Savini, et al. // *Vector-Borne and Zoonotic Diseases*. — 2009. — Vol. 9, No. 6. — P. 737–741. DOI: 10.1089/vbz.2008.0147.
- 4 Bernkopf H. Isolation of West Nile virus in Israel / H. Bernkopf, S. Levine, R. Nerson // *Journal of Infectious Diseases*. — 1953. — Vol. 93, No. 3. — P. 207–218.
- 5 Jupp P.G. The ecology of West Nile virus in South Africa and the occurrence of outbreaks in humans / P.G. Jupp // *Annals of the New York Academy of Sciences*. — 2001. — Vol. 951. — P. 143–152.

- 6 Murgue B. West Nile virus in the Mediterranean basin: 1950–2000 / B. Murgue, S. Murri, H. Triki, V. Deubel, H.G. Zeller // *Annals of the New York Academy of Sciences*. — 2001. — Vol. 951. — P. 117–126.
- 7 Hayes E.B. Epidemiology and transmission dynamics of West Nile virus disease / E.B. Hayes, N. Komar, R.S. Nasci, S.P. Montgomery, D.R. O’Leary, G.L. Campbell // *Emerging Infectious Diseases*. — 2005. — Vol. 11, No. 8. — P. 1167–1173.
- 8 Swetnam D. Terrestrial bird migration and West Nile virus circulation, United States / D. Swetnam, S.G. Widen, T.G. Wood, et al. // *Emerging Infectious Diseases*. — 2018. — Vol. 24, No. 12. — P. 2184–2194.
- 9 Campbell G.L. West Nile virus / G.L. Campbell, A.A. Marfin, R.S. Lanciotti, D.J. Gubler // *The Lancet Infectious Diseases*. — 2002. — Vol. 2, No. 9. — P. 519–529.
- 10 Petersen L.R. West Nile virus: review of the literature / L.R. Petersen, A.C. Brault, R.S. Nasci // *JAMA*. — 2013. — Vol. 310, No. 3. — P. 308–315.
- 11 World Health Organization. West Nile virus: Fact sheet. — Geneva: WHO, 2017. — [Electronic resource]. — Access mode: <https://www.who.int/news-room/fact-sheets/detail/west-nile-virus>.
- 12 Ostapchuk Y.O. Two case reports of neuroinvasive West Nile Virus infection in the Almaty region, Kazakhstan / Y.O. Ostapchuk, A.V. Zhigailov, Y.V. Perfilyeva, A.G. Shumilina, L.T. Yeraliyeva, A.S. Nizkorodova, T.V. Kuznetsova, F.A. Iskakova, Z.A. Berdygulova, A.S. Neupokoeva, S.M. Mamadaliyev, A.M. Dmitrovskiy // *IDCases*. — 2020. — Art. e00872. DOI: 10.1016/j.idcr.2020.e00872.
- 13 Егембердиева Р.А. Лихорадка Западного Нила: клинико-эпидемиологические проявления / Р.А. Егембердиева, Ж.Ж. Шапиева, А.М. Дмитровский, Н.С. Майканов, Л.З. Мусралина, А.А. Ергалиева // *Вестник КазНМУ*. — 2019. — № 2. — С. 17–20.
- 14 Керимбаев А.А. Мониторинг лихорадки Западного Нила среди диких птиц на территории РК / А.А. Керимбаев, Г.К. Мусаева, З.Д. Омарова, Р.А. Рыстаева, С.К. Копеев, Н.М. Раметов, М.Б. Орынбаев // *Вестник Государственного университета имени Шакарима города Семей*. — 2015. — № 4 (72). — С. 150–162.
- 15 Әлібекова Д.Ә. Лихорадка Западного Нила среди диких птиц в южных регионах Казахстана / Д.Ә. Әлібекова, Г.Дж. Смит, Т.У. Аргимбаева, З.Д. Омарова, Р.А. Рыстаева, Т.Т. Ермакбай, А.Б. Тулендибаев, Н.А. Әубәкір, М.Б. Орынбаев // *Биотехнология и биологическая безопасность: достижения и перспективы развития. Материалы Международной научно-практической конференции, посвященной 65-летию Научно-исследовательского института проблем биологической безопасности МЗ РК (6–8 сентября)*. — Алматы, 2023. — С. 170–171.
- 16 World Organisation for Animal Health. Manual of Diagnostic Tests and Vaccines for Terrestrial Animals. Chapter 2.1.24. West Nile fever. — 13th ed. — Paris: WOAH, 2024.
- 17 Tamura K. MEGA6: Molecular Evolutionary Genetics Analysis version 6.0 / K. Tamura, G. Stecher, D. Peterson, A. Filipski, S. Kumar // *Molecular Biology and Evolution*. — 2013. — Vol. 30. — № 12. — P. 2725–2729. DOI: 10.1093/molbev/mst197.
- 18 Palmieri C. Pathology and immunohistochemical findings of West Nile virus infection in Psittaciformes / C. Palmieri, M. Franca, F. Uzal, M. Anderson, B. Barr, L. Woods, J. Moore, P. Woolcock, H.L. Shivaprasad // *Veterinary Pathology*. — 2011. — Vol. 48. — P. 975–984.
- 19 Sultankulova K.T. Detection of West Nile fever among wild birds in Kazakhstan / K.T. Sultankulova, A.M. Melisbek, N.S. Kozhabergenov, Y.D. Burashev, N.N. Mukhami, K.D. Zakarya, M.B. Orynbaev // *Eurasian Journal of Ecology*. — 2021. — Vol. 68, No. 3. — P. 64–71. DOI: 10.26577/EJE.2021.v68.i3.07.
- 20 Hook S.A. West Nile virus: biology, transmission, and human infection / S.A. Hook, C.A. Nelson, P.S. Mead // *Clinical Microbiology Reviews*. — 2021. — Vol. 35, No. 1. — e00103-21. DOI: 10.1128/CMR.00103-21.
- 21 Anderson J.F. Isolation of West Nile virus from mosquitoes, crows, and a Cooper’s hawk in Connecticut / J.F. Anderson, T.G. Andreadis, C.R. Vossbrinck, S. Tirrell, E.M. Wakem, R.A. French, A.E. Garmendia // *Science*. — 1999. — Vol. 286. — P. 2331–2333. DOI: 10.1126/science.286.5448.2331.
- 22 Гражданов А.К. О выявлении новых природных очагов актуальных инфекционных болезней на западе Казахстана / А.К. Гражданов, Т.З. Аязбаев, А.В. Топорков, Ф.Г. Бидашко, А.В. Захаров, Л.Б. Белоножкина, М.В. Пак, А.В. Андриющенко // *Проблемы особо опасных инфекций*. — 2014. — № 3. — С. 20–24.
- 23 Alibekova D.A. Serological investigations on West Nile virus in horses in Kazakhstan / D.A. Alibekova, K.B. Barakbayev, Z.D. Omarova, R.A. Rystaeva, K.T. Sultankulova, Y.D. Burashev, T.U. Argimbayeva, A.B. Tulendibayev, N.A. Aubakir, T.T. Yermekbay, K.B. Abeuov, A.A. Kerimbayev, M.B. Orynbayev // *Microorganisms*. — 2025. — Vol. 13. — Art. 2541. DOI: 10.3390/microorganisms13112541.
- 24 World Organisation for Animal Health. West Nile Fever // *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals*. — Paris: WOAH, 2023.
- 25 Metz M.B.C. Systematic review and meta-analysis of seroprevalence studies of West Nile virus in equids in Europe between 2001 and 2018 / M.B.C. Metz, O.T. Olufemi, J.M. Daly, M. Barba // *Transboundary and Emerging Diseases*. — 2021. — Vol. 68, No. 4. — P. 1814–1823. DOI: 10.1111/tbed.13866.
- 26 Centers for Disease Control and Prevention. West Nile Virus: Veterinary Impact. — Atlanta: CDC, 2022. — [Electronic resource]. — Access mode: <https://www.cdc.gov/westnile/veterinarians/index.html> (Date of request: ...2025).
- 27 Platonov A.E. Epidemiology of West Nile infection in Volgograd, Russia, in relation to climate change and mosquito bionomics / A.E. Platonov, M.V. Fedorova, L.S. Karan, T.A. Shopenskaya, O.V. Platonova, V.L. Zhuravlev // *Parasitology Research*. — 2008. — Vol. 103, Suppl. 1. — P. S45–S53. DOI: 10.1007/s00436-008-1050-0.

28 Platonov A.E. Outbreak of West Nile virus infection, Volgograd Region, Russia, 1999 / A.E. Platonov, G.A. Shipulin, O.Y. Shipulina, E.N. Tyutyunnik, T.I. Frolochkina, R.S. Lanciotti, S. Yazyshina, O.V. Platonova, I.L. Obukhov, A.N. Zhukov, Y.Y. Vengerov, V.I. Pokrovskii // *Emerging Infectious Diseases*. — 2001. — Vol. 7, No. 1. — P. 128–132. DOI: 10.3201/eid0701.010118.

29 Nurmakhanov T. Phylogenetic characteristics of West Nile virus isolated from *Culex modestus* mosquitoes in West Kazakhstan / T. Nurmakhanov, Y. Sansyzbaev, B. Atshabar, V. Berlin, D. Kobzhasarov, O. Yeskhojayevev, A. Vilkova, T. Ayazbayev, A. Andryushchenko, F. Bidashko, J. Hay, A. Shvetsov // *Frontiers in Public Health*. — 2021. — Vol. 8. — Art. 575187. DOI: 10.3389/fpubh.2020.575187.

30 Гражданов А.К. Сравнительный анализ проявлений опасных инфекций в Саратовской и Западно-Казахстанской областях в целях современной оценки эпидемиологических рисков / А.К. Гражданов, О.И. Кожанова, А.В. Топорков, Т.З. Аязбаев, Н.И. Матвеева, И.Г. Карнаухов, Н.В. Попов, А.С. Раздорский, Г.Н. Архипова // *Проблемы особо опасных инфекций*. — 2013. — № 4. — С. 38–44.

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2023–2025 жылдары Қазақстан Республикасындағы Батыс Ніл қызбасына мониторинг

2023–2025 жылдары Қазақстан Республикасының 14 облысының аумағында Батыс Ніл қызбасы вирусының табиғи ошақтардағы айналымын бағалау мақсатында кешенді эпизоотологиялық және молекулалық мониторинг жүргізілді. Зерттеу жұмыстары әртүрлі табиғи-климаттық аймақтарды қамтып, қоздырғыштың негізгі ықтимал резервуарлары мен тасымалдаушыларын анықтауға бағытталды. Зерттеу объектілері ретінде жабайы қоныс аударатын және синантропты құстар, масалар, иксодты кенелер және жарқанаттар қарастырылды. Биологиялық материалдар табиғи биотоптарда, су айдындарына жақын аумақтарда және елдімекендер маңында клиникалық сау жануарлардан алынды. Барлығы жабайы құстардан алынған 362 үлгі, жарқанаттардан 84 үлгі, 679 кене және 1554 маса зерттелді. Зертханалық диагностика Батыс Ніл қызбасы вирусына спецификалық праймерлерді қолдана отырып, полимеразды тізбекті реакция (ПТР) әдісімен жүргізілді. Зерттеу нәтижесінде БНҚ вирусының РНҚ-сы тек жабайы құстардан алынған үлгілерде ғана анықталды, яғни 362 үлгінің 5-еуінде, бұл жалпы таралу деңгейінің 1,38 %-ын құрады (95 % СА: 0,45–3,19 %). Масалардан, кенелерден және жарқанаттардан алынған үлгілерде вирус РНҚ-сы анықталған жоқ. Оң нәтижелер Павлодар және Қарағанды облыстарында тіркелді, бұл қоныс аударатын құстардың Батыс Ніл вирусын Қазақстан аумағына енгізудегі жетекші ролін растайды. Алынған деректер инфекцияның табиғи ошақтарының қалыптасуы мен сақталу қаупін уақтылы бағалау үшін жүйелі эпизоотологиялық және молекулалық мониторингті жалғастырудың маңыздылығын көрсетеді.

Кілт сөздер: мониторинг, ПТР, Батыс Ніл қызбасы, флавивирустар, жабайы құстар, масалар, кенелер, жарқанаттар, эпизоотологиялық мониторинг.

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Мониторинг лихорадки западного Нила в Республике Казахстан в 2023–2025 гг.

В 2023–2025 гг. на территории 14 областей Республики Казахстан проведён комплексный эпизоотологический и молекулярный мониторинг лихорадки Западного Нила (ЛЗН) с целью оценки циркуляции вируса в природных очагах и выявления потенциальных рисков формирования устойчивых эпидемиологических зон. Исследование охватывало основные предполагаемые резервуары и переносчики возбудителя, включая диких перелётных птиц, комаров, иксодовых клещей и летучих мышей, отобранных в природных биотопах и вблизи населённых пунктов. Всего было исследовано 362 образца биологического материала от диких птиц, 84 образца от летучих мышей, 679 клещей и 1554 комара. Лабораторную диагностику проводили методом полимеразной цепной реакции с использованием праймеров, специфичных к вирусу лихорадки Западного Нила. По результатам исследований РНК вируса ЛЗН была выявлена исключительно у диких птиц — в 5 из 362 образцов, что соответствует общей распространённости 1,38 % (95 % ДИ: 0,45–3,19 %). В образцах, полученных от комаров, клещей и летучих мышей, РНК вируса ЛЗН обнаружена не была. Положительные пробы зарегистрированы в

Павлодарской и Карагандинской областях, что подтверждает ведущую роль мигрирующих птиц в заносе вируса на территорию Казахстана. Полученные данные указывают на необходимость продолжения систематического эпизоотологического и молекулярного мониторинга для своевременной оценки рисков формирования и поддержания природных очагов инфекции.

Ключевые слова: мониторинг, ПЦР, лихорадка Западного Нила, флавивирусы, дикие птицы, комары, клещи, летучие мыши, эпизоотологический мониторинг.

References

- 1 Nash, D., Mostashari, F., Fine, A., et al. (2001). The outbreak of West Nile virus infection in the New York City area in 1999. *New England Journal of Medicine*, 344(24), 1807–1814.
- 2 Chancey, C., Grinev, A., Volkova, E., & Rios, M. (2015). The global ecology and epidemiology of West Nile virus. *BioMed Research International*, 2015, Art. ID 376230. <https://doi.org/10.1155/2015/376230>
- 3 Balanca, G., Gaidet, N., Savini, G., et al. (2009). Low West Nile virus circulation in wild birds in an area of recurring outbreaks in Southern France. *Vector-Borne and Zoonotic Diseases*, 9(6), 737–741. <https://doi.org/10.1089/vbz.2008.0147>
- 4 Bernkopf, H., Levine, S., & Nerson, R. (1953). Isolation of West Nile virus in Israel. *Journal of Infectious Diseases*, 93(3), 207–218.
- 5 Jupp, P.G. (2001). The ecology of West Nile virus in South Africa and the occurrence of outbreaks in humans. *Annals of the New York Academy of Sciences*, 951, 143–152.
- 6 Murgue, B., Murri, S., Triki, H., Deubel, V., & Zeller, H.G. (2001). West Nile virus in the Mediterranean basin: 1950–2000. *Annals of the New York Academy of Sciences*, 951, 117–126.
- 7 Hayes, E.B., Komar, N., Nasci, R.S., Montgomery, S.P., O’Leary, D.R., & Campbell, G.L. (2005). Epidemiology and transmission dynamics of West Nile virus disease. *Emerging Infectious Diseases*, 11(8), 1167–1173.
- 8 Swetnam, D., Widen, S.G., Wood, T.G., et al. (2018). Terrestrial bird migration and West Nile virus circulation, United States. *Emerging Infectious Diseases*, 24(12), 2184–2194.
- 9 Campbell, G.L., Marfin, A.A., Lanciotti, R.S., & Gubler, D.J. (2002). West Nile virus. *The Lancet Infectious Diseases*, 2(9), 519–529.
- 10 Petersen, L.R., Brault, A.C., & Nasci, R.S. (2013). West Nile virus: Review of the literature. *JAMA*, 310(3), 308–315.
- 11 World Health Organization. (2017). West Nile virus: Fact sheet. www.who.int. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/west-nile-virus>
- 12 Ostapchuk, Y.O., Zhigailov, A.V., Perfilyeva, Y.V., Shumilina, A.G., Yeraliyeva, L.T., Nizkorodova, A.S., Kuznetsova, T.V., Iskakova, F.A., Berdygulova, Z.A., Neupokoeva, A.S., & Mamadaliyev, S.M. (2020). Two case reports of neuroinvasive West Nile virus infection in the Almaty region, Kazakhstan. *IDCases*, Art. e00872. <https://doi.org/10.1016/j.idcr.2020.e00872>
- 13 Egemberdieva, R.A., Shapieva, Zh.Zh., Dmitrovskii, A.M., Maikanov, N.S., Musralina, L.Z., & Ergalieva, A.A. (2019). Likhoradka Zapadnogo Nila: kliniko-epidemiologicheskie proiavleniia [West Nile fever: Clinical and epidemiological manifestations]. *Vestnik Kazakhskogo Natsionalnogo Meditsinskogo Universiteta — Bulletin of the National Medical University*, 2, 17–20 [in Russian].
- 14 Kerimbayev, A.A., Musaeva, G.K., Omarova, Z.D., Rystaeva, R.A., Kopeev, S.K., Rametov, N.M., & Orynbaev, M.B. (2015). Monitoring likhoradki Zapadnogo Nila sredi dikikh ptits na territorii RK [Monitoring of West Nile fever among wild birds in Kazakhstan]. *Vestnik Gosudarstvennogo universiteta imeni Shakarima goroda Semei — Bulletin of the Shakarim State University of Semey*, 4(72), 150–162 [in Russian].
- 15 Alibekova, D.A., Smith, G.J., Argimbayeva, T.U., Omarova, Z.D., Rystaeva, R.A., Yermekbay, T.T., Tulendibayev, A.B., Aubakir, N.A., & Orynbaev, M.B. (2023). Likhoradka Zapadnogo Nila sredi dikikh ptits v yuzhnykh regionakh Kazakhstana [West Nile fever among wild birds in southern Kazakhstan]. *Biotekhnologiya i biologicheskaya bezopasnost: dostizheniia i perspektivy razvitiia. Materialy Mezhdunarodnoi nauchno-prakticheskoi konferentsii, posviashchennoi 65-letiiu Nauchno-issledovatel'skogo instituta problem biologicheskoi bezopasnosti Ministerstva Zdravookhraneniia Respubliki Kazakhstan — Biotechnology and Biological Safety: Achievements and Development Prospects Proceedings of the International Scientific and Practical Conference dedicated to the 65th anniversary of the Research Institute for Biological Safety Problems of the Ministry of Health of the Republic of Kazakhstan* (pp. 170-171) [in Russian].
- 16 World Organisation for Animal Health (WOAH). (2024). Manual of diagnostic tests and vaccines for terrestrial animals (13th ed., Chapter 2.1.24: West Nile fever). Paris: WOAH.
- 17 Tamura, K., Stecher, G., Peterson, D., Filipski, A., & Kumar, S. (2013). MEGA6: Molecular evolutionary genetics analysis version 6.0. *Molecular Biology and Evolution*, 30(12), 2725–2729. <https://doi.org/10.1093/molbev/mst197>
- 18 Palmieri, C., Franca, M., Uzal, F., Anderson, M., Barr, B., Woods, L., Moore, J., Woolcock, P., & Shivaprasad, H. L. (2011). Pathology and immunohistochemical findings of West Nile virus infection in Psittaciformes. *Veterinary Pathology*, 48, 975–984.
- 19 Sultankulova, K.T., Melisbek, A.M., Kozhabergenov, N.S., Burashev, Y.D., Mukhami, N.N., Zakarya, K.D., & Orynbaev, M.B. (2021). Detection of West Nile fever among wild birds in Kazakhstan. *Eurasian Journal of Ecology*, 68(3), 64–71. <https://doi.org/10.26577/EJE.2021.v68.i3.07>

20 Hook, S.A., Nelson, C.A., & Mead, P.S. (2021). West Nile virus: Biology, transmission, and human infection. *Clinical Microbiology Reviews*, 35(1), e00103-21. <https://doi.org/10.1128/CMR.00103-21>

21 Anderson, J.F., Andreadis, T.G., Vossbrinck, C.R., Tirrell, S., Wakem, E.M., French, R.A., & Garmendia, A.E. (1999). Isolation of West Nile virus from mosquitoes, crows, and a Cooper's hawk in Connecticut. *Science*, 286, 2331–2333. <https://doi.org/10.1126/science.286.5448.233>

22 Grazhdanov, A.K., Ayazbayev, T.Z., Toporkov, A.V., Bidashko, F.G., Zakharov, A.V., Belonozhkina, L.B., Pak, M.V., & Andryushchenko, A.V. (2014). O vyivlenii novykh prirodnykh ochagov aktualnykh infektsionnykh boleznei na zapade Kazakhstana [Identification of new natural foci of infectious diseases in western Kazakhstan]. *Problemy osobo opasnykh infektsii — Problems of especially dangerous infections*, 3, 20–24 [in Russian].

23 Alibekova, D.A., Barakbayev, K.B., Omarova, Z.D., Rystaeva, R.A., Sultankulova, K.T., Burashev, Y.D., Argimbayeva, T.U., Tulendibayev, A.B., Aubakir, N.A., Yermekbay, T.T., Abeuov, K.B., Kerimbayev, A.A., & Orynbaev, M.B. (2025). Serological investigations on West Nile virus in horses in Kazakhstan. *Microorganisms*, 13, Art. 2541. <https://doi.org/10.3390/microorganisms13112541>

24 World Organisation for Animal Health (WOAH) (2023). West Nile fever. In *Manual of diagnostic tests and vaccines for terrestrial animals*. Paris: WOAH.

25 Metz, M.B.C., Olufemi, O.T., Daly, J.M., & Barba, M. (2021). Systematic review and meta-analysis of seroprevalence studies of West Nile virus in equids in Europe between 2001 and 2018. *Transboundary and Emerging Diseases*, 68(4), 1814–1823. <https://doi.org/10.1111/tbed.13866>

26 Centers for Disease Control and Prevention. (2022). West Nile virus: Veterinary impact. www.cdc.gov. Retrieved from <https://www.cdc.gov/westnile/veterinarians/index.html>

27 Platonov, A.E., Fedorova, M.V., Karan, L.S., Shopenkaya, T.A., Platonova, O.V., & Zhuravlev, V. I. (2008). Epidemiology of West Nile infection in Volgograd, Russia, in relation to climate change and mosquito bionomics. *Parasitology Research*, 103(Suppl. 1), S45–S53. <https://doi.org/10.1007/s00436-008-1050-0>

28 Platonov, A.E., Shipulin, G.A., Shipulina, O.Y., Tyutyunnik, E.N., Frolochkina, T.I., Lanciotti, R.S., Yazyshina, S., Platonova, O.V., Obukhov, I.L., Zhukov, A.N., Vengerov, Y.Y., & Pokrovskii, V.I. (2001). Outbreak of West Nile virus infection, Volgograd Region, Russia, 1999. *Emerging Infectious Diseases*, 7(1), 128–132. <https://doi.org/10.3201/eid0701.010118>

29 Nurmakanov, T., Sansyzbaev, Y., Atshabar, B., Berlin, V., Kobzhasarov, D., Yeskhojayeov, O., Vilkoova, A., Ayazbayev, T., Andryushchenko, A., Bidashko, F., Hay, J., & Shvetsov, A. (2021). Phylogenetic characteristics of West Nile virus isolated from *Culex modestus* mosquitoes in West Kazakhstan. *Frontiers in Public Health*, 8, Art. 575187. <https://doi.org/10.3389/fpubh.2020.575187>

30 Grazhdanov, A.K., Kozhanova, O.I., Toporkov, A.V., Ayazbayev, T.Z., Matveeva, N.I., Karnaukhov, I.G., Popov, N.V., Razdorskii, A.S., & Arkhipova, G.N. (2013). Sravnitelnyi analiz proiavlennii opasnykh infektsii v Saratovskoi i Zapadno-Kazakhstanskoi oblastiakh v tseliakh sovremennoi otsenki epidemiologicheskikh riskov [Comparative analysis of dangerous infections in Saratov and West Kazakhstan regions]. *Problemy osobo opasnykh infektsii — Problems of especially dangerous infections*, 4, 38–44 [in Russian].

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Invasive plant species in the flora of the Karaganda region

Studying the invasive flora of regions is an important task for preserving biological diversity and monitoring the potential spread of invasive taxa. The aim of this study was to compile a list of invasive vascular plant species in the Karaganda region and to characterize them according to their distribution, time and mode of introduction, and degree of naturalization. The study identified 112 invasive species belonging to 91 genera and 36 families in the region. In terms of the time of introduction, neophytes predominate in the Karaganda Region — 97 species, or 86.6 %. Archeophytes account for a smaller share — 15 taxa (13.4 %). According to the mode of introduction, the following were identified: ergasiophytes (53 species, or 47.3 %), xenophytes (54 species, or 48.2 %), and acoluthophytes (5 species, or 4.5 %). According to the degree of naturalization, the following were identified: epicophytes (47 species or 42.0 %), ephemeroxytes (26 species or 23.2 %), agriophytes (27 species or 24.1 %), and colonophytes (12 species or 10.7 %). In terms of distribution, invasive species were classified as follows: occasional — 34 taxa (30.35 %); common — 44 taxa (39.28 %); very rare — 14 taxa (12.50 %); rare — 19 taxa (16.96 %). The data obtained reflect active migration processes involving the dispersal of seeds of invasive species and their gradual integration into local plant communities. The active naturalization and prevalence of many taxa require constant monitoring and the development of programs to curb their further spread in the Karaganda region.

Keywords: invasive species, Karaganda region, dispersal method, degree of distribution, time of dispersal, degree of naturalization.

Introduction

The Convention on Biological Diversity (1992) calls for the conservation of ex situ habitats, that is, the conservation of habitats within ecosystems and natural habitats. At the 15th meeting of the Conference of the Parties to the Convention on Biological Diversity (Montreal, Canada, December 7–19, 2022), it was agreed in agenda item 21 that invasive species are one of the main factors contributing to the loss of natural biodiversity on a global scale. Noting the increase in international shipments of living organisms and the potential for their introduction into new territories, it is proposed that invasive species be monitored at the national level, measures be taken to mitigate any harmful effects on local populations, and population sizes be controlled and regulated. Conference participants noted the need to study the pathways of invasion of flora and fauna species, assess the damage caused, and take measures to prevent their spread, further introduction, or mitigate the consequences [1].

According to the definition of <https://www.gisp.org/>, invasive alien species are animals, plants, fungi, and microorganisms that have entered an environment that is not their natural habitat and have established themselves there [2].

Many countries around the world have developed strategies to combat invasive species. For example, the European Strategy on Invasive Alien Species (2003) [3] states that invasive species have long been introduced into Europe, but this process has accelerated over the past century, posing threats to biodiversity. The guiding principles of the strategy for combating invasive species establish a three-stage approach: 1) preventing introduction into other countries and within countries; 2) if introduction has occurred, take early warning measures to prevent establishment; 3) in the event of establishment, take measures for the long-term management of invasive species. In the United States, there is a plan for managing invasive species that involves federal agencies, state agencies, local authorities, and the private sector. Specifically, the transport of invasive species between states is completely prohibited; measures are in place for their on-site eradication; and grants are regularly allocated for the control and eradication of invasive weed species.

In Russia, a large-scale study was conducted on the most dangerous invasions [4], of which about 62 % were introduced accidentally, 33 % intentionally, and 5 % spread on their own. Many alien species currently occupy a small range but tend to spread rapidly.

Kazakhstan has not yet adopted a strategy to combat invasive species, and there is no comprehensive list of species, particularly at the regional level, which justifies the relevance and novelty of this study. The study of invasive species must begin at the regional level.

The aim of this study is to compile a list of invasive plant species in the Karaganda Region and to characterize them by time and mode of introduction, as well as their degree of naturalization.

Experimental

The subject of the study was alien species of vascular plants in the flora of the Karaganda Region. Field collections and data analysis were conducted in 2025. A preliminary inventory of alien plants was compiled based on an analysis of field journals, herbarium materials (herbarium funds: AA, QAR, TASH, LE, MW, SVER, NS, NSK, KUZ, ALTB), and data from the GBIF and iNaturalist platforms. Field studies covered various parts of the Karaganda Region; based on these collections, the species composition of the flora was analyzed and invasive species were identified.

Taxonomic characterization was based on an analysis of the species, genus, and family composition of invasive species. The names of the accepted plant genera and species are taken from the Plants of the World Online (POWO) website [5].

The occurrence of species was assessed using the following gradations: common—species are found everywhere in suitable habitats; occasional—plants occur sporadically but not in all regions of the study area; rare—plants found only sporadically in individual regions of the study area; very rare—no more than 5 locations are known throughout the entire study area [6].

Based on the mode of introduction, the following groups are distinguished: ergasiophytes, alucophytes, and xenophytes [7]; based on the time of introduction: neophytes and archaeophytes [8]; and based on the degree of naturalization: epecophytes, ephemeroxytes, agriophytes, and colonophytes [9].

Results and Discussion

Analysis of the invasive flora of the Karaganda Region has allowed for the preliminary identification of 112 species of adventive (introduced) plants belonging to 36 families and 91 genera (Table 1). The greatest species diversity is exhibited by the families Asteraceae (24 species, 21.4 %), Brassicaceae (10 species, 8.9 %), Poaceae (9 species, 8.0 %), and Rosaceae (5 species, 4.5 %), which is characteristic of the flora of temperate regions with actively cultivated agricultural lands. They account for more than 40 % of all introduced species in the region.

Table 1

List of invasive plant species in the Karaganda Region

| No. | Species | Family | Period of introduction | Mode of introduction | Degree of naturalization | Occurrence |
|-----|---------------------------------------|---------------|------------------------|----------------------|--------------------------|--------------|
| 1 | <i>Amaranthus albus</i> L. | Amaranthaceae | neophyte | xenophyte | epiphyte | occasionally |
| 2 | <i>Amaranthus blitoides</i> S. Wats. | Amaranthaceae | neophyte | xenophyte | epiphyte | rare |
| 3 | <i>Amaranthus retroflexus</i> L. | Amaranthaceae | neophyte | xenophyte | epiphyte | common |
| 4 | <i>Atriplex hortensis</i> L. | Amaranthaceae | neophyte | ergasiophyte | ephemeroxyte | occasionally |
| 5 | <i>Bassia scoparia</i> (L.) Beck | Amaranthaceae | neophyte | xenophyte | epiphyte | common |
| 6 | <i>Anethum graveolens</i> L. | Apiaceae | neophyte | ergasiophyte | ephemeroxyte | common |
| 7 | <i>Carum carvi</i> L. | Apiaceae | neophyte | xenophyte | agriophyte | occasionally |
| 8 | <i>Conium maculatum</i> L. | Apiaceae | archaeophyte | xenophyte | epiphyte | very rare |
| 9 | <i>Pastinaca sativa</i> L. | Apiaceae | archaeophyte | ergasiophyte | agriophyte | occasionally |
| 10 | <i>Turgenia latifolia</i> (L.) Hoffm. | Apiaceae | neophyte | acolyutophyte | ephemeroxyte | rare |
| 11 | <i>Artemisia sieversiana</i> Ehrh. ex | Asteraceae | neophyte | xenophyte | epiphyte | common |
| 12 | <i>Artemisia tournefortiana</i> | Asteraceae | neophyte | acolyutophyte | ephemeroxyte | occasional |

| No. | Species | Family | Period of introduction | Mode of introduction | Degree of naturalization | Occurrence |
|-----|--------------------------------------|-----------------|------------------------|----------------------|--------------------------|--------------|
| 13 | <i>Carduus acanthoides</i> L. | Asteraceae | neophyte | xenophyte | ephemerophyte | common |
| 14 | <i>Centaurea cyanus</i> L. | Asteraceae | neophyte | xenophyte | epicophyte | occasional |
| 15 | <i>Centaurea diffusa</i> Lam. | Asteraceae | neophyte | xenophyte | epicophyte | occasional |
| 16 | <i>Centaurea pseudomaculosa</i> | Asteraceae | neophyte | xenophyte | epicophyte | rare |
| 17 | <i>Cichorium intybus</i> L. | Asteraceae | neophyte | ergasiophyte | agriophyte | common |
| 18 | <i>Cota tinctoria</i> (L.) G. Gay | Asteraceae | neophyte | acolyutophyte | epicophyte | occasional |
| 19 | <i>Cyclachaena xanthiifolia</i> | Asteraceae | neophyte | xenophyte | epiphyte | rare |
| 20 | <i>Echinops sphaerocephalus</i> L. | Asteraceae | neophyte | xenophyte | epicophyte | rare |
| 21 | <i>Erigeron canadensis</i> L. | Asteraceae | neophyte | xenophyte | epiphyte | common |
| 22 | <i>Grindelia squarrosa</i> (Pursh) | Asteraceae | neophyte | xenophyte | epicophyte | rare |
| 23 | <i>Helianthus annuus</i> L. | Asteraceae | neophyte | ergasiophyte | ephemerophyte | occasionally |
| 24 | <i>Helianthus tuberosus</i> L. | Asteraceae | neophyte | ergasiophyte | epiphyte | occasionally |
| 25 | <i>Matricaria chamomilla</i> L. | Asteraceae | neophyte | xenophyte | ephemerophyte | common |
| 26 | <i>Matricaria discoidea</i> DC. | Asteraceae | neophyte | xenophyte | agriophyte | rare |
| 27 | <i>Rhaponticum repens</i> (L.) | Asteraceae | neophyte | xenophyte | epiphyte | common |
| 28 | <i>Senecio viscosus</i> L. | Asteraceae | neophyte | xenophyte | agriophyte | rare |
| 29 | <i>Sonchus oleraceus</i> L. | Asteraceae | archaeophyte | xenophyte | agriophyte | usually |
| 30 | <i>Tragopogon dubius</i> Scop. | Asteraceae | neophyte | xenophyte | epicophyte | common |
| 31 | <i>Tripleurospermum inodorum</i> | Asteraceae | archaeophyte | xenophyte | epiphyte | common |
| 32 | <i>Xanthium orientale</i> L. | Asteraceae | neophyte | xenophyte | epiphyte | rare |
| 33 | <i>Xanthium strumarium</i> L. | Asteraceae | neophyte | xenophyte | agriophyte | common |
| 34 | <i>Armoracia rusticana</i> | Brassicaceae | neophyte | ergasiophyte | colonophyte | common |
| 35 | <i>Brassica juncea</i> (L.) Czern. | Brassicaceae | neophyte | xenophyte | ephemerophyte | common |
| 36 | <i>Brassica rapa</i> L. | Brassicaceae | archaeophyte | xenophyte | epiphyte | occasionally |
| 37 | <i>Bunias orientalis</i> L. | Brassicaceae | neophyte | xenophyte | epiphyte | occasionally |
| 38 | <i>Camelina sativa</i> (L.) Crantz | Brassicaceae | neophyte | ergasiophyte | ephemerophyte | common |
| 39 | <i>Capsella bursa-pastoris</i> (L.) | Brassicaceae | archaeophyte | xenophyte | agriophyte | usually |
| 40 | <i>Hesperis matronalis</i> L. | Brassicaceae | neophyte | ergasiophyte | ephemerophyte | rare |
| 41 | <i>Isatis tinctoria</i> L. | Brassicaceae | archaeophyte | xenophyte | agriophyte | common |
| 42 | <i>Lepidium densiflorum</i> Schrad. | Brassicaceae | neophyte | xenophyte | epiphyte | occasional |
| 43 | <i>Rhamphospermum arvense</i> | Brassicaceae | archaeophyte | xenophyte | epiphyte | occasional |
| 44 | <i>Cannabis sativa</i> L. | Cannabaceae | archaeophyte | ergasiophyte | epiphyte | occasionally |
| 45 | <i>Impatiens glandulifera</i> Royle | Balsaminaceae | neophyte | ergasiophyte | agriophyte | very rare |
| 46 | <i>Berberis vulgaris</i> L. | Berberidaceae | neophyte | ergasiophyte | colonophyte | very common |
| 47 | <i>Cerinth minor</i> L. | Boraginaceae | neophyte | xenophyte | ephemerophyte | very rare |
| 48 | <i>Echium vulgare</i> L. | Boraginaceae | neophyte | ergasiophyte | epicophyte | common |
| 49 | <i>Symphytum officinale</i> L. | Boraginaceae | neophyte | ergasiophyte | epicophyte | rare |
| 50 | <i>Cerastium holosteoides</i> Fries. | Caryophyllaceae | neophyte | xenophyte | agriophyte | occasionally |
| 51 | <i>Gypsophila vaccaria</i> (L.) Sm. | Caryophyllaceae | neophyte | xenophyte | epiphyte | common |
| 52 | <i>Saponaria officinalis</i> L. | Caryophyllaceae | neophyte | ergasiophyte | epiphyte | occasionally |
| 53 | <i>Silene csererii</i> Baumg. | Caryophyllaceae | neophyte | xenophyte | epicophyte | occasional |
| 54 | <i>Stellaria media</i> (L.) Vill. | Caryophyllaceae | neophyte | xenophyte | epiphyte | common |
| 55 | <i>Euonymus europaeus</i> L. | Celastraceae | neophyte | ergasiophyte | agriophyte | rare |
| 56 | <i>Cornus alba</i> L. | Cornaceae | neophyte | ergasiophyte | colonophyte | very rare |
| 57 | <i>Echinocystis lobata</i> (Michx.) | Cucurbitaceae | neophyte | ergasiophyte | ephemerophyte | rare |
| 58 | <i>Cuscuta approximata</i> Bab. | Convolvulaceae | neophyte | xenophyte | epiphyte | occasional |

Continuation of Table 1

| No. | Species | Family | Period of introduction | Mode of introduction | Degree of naturalization | Occurrence |
|-----|--------------------------------------|-----------------|------------------------|----------------------|--------------------------|--------------|
| 59 | <i>Cuscuta europaea</i> L. | Convolvulaceae | neophyte | xenophyte | epiphyte | common |
| 60 | <i>Thuja occidentalis</i> L. | Cupressaceae | neophyte | ergasiophyte | ephemerophyte | Rare |
| 61 | <i>Elaeagnus angustifolia</i> L. | Elaeagnaceae | neophyte | ergasiophyte | agriophyte | usually |
| 62 | <i>Elaeagnus commutata</i> Bernh. | Elaeagnaceae | neophyte | ergasiophyte | agriophyte | rare |
| 63 | <i>Hippophae rhamnoides</i> L. | Elaeagnaceae | neophyte | ergasiophyte | agriophyte | occasionally |
| 64 | <i>Caragana arborescens</i> Lam. | Fabaceae | neophyte | ergasiophyte | agriophyte | common |
| 65 | <i>Medicago sativa</i> L. | Fabaceae | neophyte | ergasiophyte | agriophyte | usually |
| 66 | <i>Trifolium pratense</i> L. | Fabaceae | neophyte | ergasiophyte | epiphyte | common |
| 67 | <i>Trifolium repens</i> L. | Fabaceae | neophyte | xenophyte | ephemerophyte | common |
| 68 | <i>Fumaria officinalis</i> L. | Papaveraceae | neophyte | xenophyte | ephemerophyte | common |
| 69 | <i>Ribes aureum</i> Pursh. | Grossulariaceae | neophyte | ergasiophyte | colonophyte | common |
| 70 | <i>Phacelia tanacetifolia</i> Benth. | Hydrophyllacea | neophyte | ergasiophyte | ephemerophyte | rare |
| 71 | <i>Clinopodium acinos</i> (L.) | Lamiaceae | neophyte | xenophyte | ephemerophyte | very rare |
| 72 | <i>Galeopsis bifida</i> Boenn. | Lamiaceae | neophyte | xenophyte | epiphyte | occasional |
| 73 | <i>Galeopsis ladanum</i> L. | Lamiaceae | neophyte | xenophyte | epiphyte | occasional |
| 74 | <i>Leonurus quinquelobatus</i> | Lamiaceae | neophyte | xenophyte | ephemerophyte | occasional |
| 75 | <i>Alcea rosea</i> L. | Malvaceae | neophyte | ergasiophyte | ephemerophyte | common |
| 76 | <i>Malva pusilla</i> Smith. | Malvaceae | neophyte | xenophyte | epiphyte | common |
| 77 | <i>Tilia cordata</i> Mill. | Malvaceae | neophyte | ergasiophyte | colonophyte | very rare |
| 78 | <i>Fraxinus pennsylvanica</i> | Oleaceae | neophyte | ergasiophyte | agriophyte | occasionally |
| 79 | <i>Syringa vulgaris</i> L. | Oleaceae | neophyte | ergasiophyte | colonophyte | occasionally |
| 80 | <i>Roemeria refracta</i> DC. | Papaveraceae | neophyte | acolyutophyte | ephemerophyte | rare |
| 81 | <i>Agropyron cristatum</i> (L.) | Poaceae | neophyte | ergasiophyte | agriophyte | common |
| 82 | <i>Avena fatua</i> L. | Poaceae | archaeophyte | xenophyte | epiphyte | usually |
| 83 | <i>Avena sativa</i> L. | Poaceae | archaeophyte | ergasiophyte | ephemerophyte | usually |
| 84 | <i>Bromus tectorum</i> L. | Poaceae | neophyte | xenophyte | epiphyte | common |
| 85 | <i>Digitaria sanguinalis</i> (L.) | Poaceae | neophyte | acolyutophyte | ephemerophyte | rare |
| 86 | <i>Echinochloa crus-galli</i> (L.) | Poaceae | archaeophyte | xenophyte | epiphyte | common |
| 87 | <i>Elymus violaceus</i> (Hornem.) | Poaceae | neophyte | xenophyte | epiphyte | occasional |
| 88 | <i>Hordeum jubatum</i> L. | Poaceae | neophyte | xenophyte | agriophyte | common |
| 89 | <i>Hordeum vulgare</i> L. | Poaceae | archaeophyte | ergasiophyte | ephemerophyte | usually |
| 90 | <i>Panicum miliaceum</i> L. | Poaceae | archaeophyte | ergasiophyte | agriophyte | occasionally |
| 91 | <i>Fagopyrum esculentum</i> | Polygonaceae | neophyte | ergasiophyte | ephemerophyte | rare |
| 92 | <i>Clematis mandshurica</i> Rupr. | Ranunculaceae | neophyte | ergasiophyte | ephemerophyte | very rare |
| 93 | <i>Amelanchier spicata</i> (Lam.) | Rosaceae | neophyte | ergasiophyte | colonophyte | very rare |
| 94 | <i>Malus baccata</i> (L.) Borkh. | Rosaceae | neophyte | ergasiophyte | agriophyte | common |
| 95 | <i>Malus domestica</i> Borkh. | Rosaceae | neophyte | ergasiophyte | colonophyte | usually |
| 96 | <i>Prunus tomentosa</i> Thunb. | Rosaceae | neophyte | ergasiophyte | agriophyte | common |
| 97 | × <i>Sorbaronia fallax</i> | Rosaceae | neophyte | ergasiophyte | colonophyte | occasional |
| 98 | <i>Populus alba</i> L. | Salicaceae | neophyte | ergasiophyte | agriophyte | occasionally |
| 99 | <i>Populus</i> × <i>sibirica</i> | Salicaceae | neophyte | ergasiophyte | colonophyte | occasional |
| 100 | <i>Salix acutifolia</i> Willd. | Salicaceae | neophyte | ergasiophyte | agriophyte | common |
| 101 | <i>Salix alba</i> L. | Salicaceae | neophyte | ergasiophyte | agriophyte | common |
| 102 | <i>Acer campestre</i> L. | Sapindaceae | neophyte | ergasiophyte | colonophyte | very rare |
| 103 | <i>Acer negundo</i> L. | Sapindaceae | neophyte | ergasiophyte | agriophyte | occasionally |
| 104 | <i>Acer tataricum</i> L. | Sapindaceae | neophyte | ergasiophyte | colonophyte | occasionally |

| No. | Species | Family | Period of introduction | Mode of introduction | Degree of naturalization | Occurrence |
|-----|------------------------------------|---------------|------------------------|----------------------|--------------------------|--------------|
| 105 | <i>Solanum nigrum</i> L. | Solanaceae | archaeophyte | xenophyte | epiphyte | occasionally |
| 106 | <i>Portulaca oleracea</i> L. | Portulacaceae | neophyte | xenophyte | epiphyte | |
| 107 | <i>Reseda lutea</i> L. | Resedaceae | neophyte | xenophyte | epiphyte | very rare |
| 108 | <i>Myricaria bracteata</i> Royle | Tamaricaceae | neophyte | ergasiophyte | ephemerophyte | very rare |
| 109 | <i>Viola arvensis</i> Murr. | Violaceae | neophyte | xenophyte | epiphyte | very rare |
| 110 | <i>Parthenocissus quinquefolia</i> | Vitaceae | neophyte | ergasiophyte | epiphyte | very rare |
| 111 | <i>Ulmus laevis</i> Pall. | Ulmaceae | neophyte | ergasiophyte | epiphyte | occasionally |
| 112 | <i>Ulmus pumila</i> L. | Ulmaceae | neophyte | ergasiophyte | epiphyte | usually |

In terms of the time of introduction to the Karaganda region, neophytes—species introduced after 1700—dominate. There are 97 taxa (86.6 %) of these, indicating an active influx of alien plants in the most recent period, associated with the development of agriculture, urbanization, and the expansion of horticulture. The remaining species are classified as archaeophytes, that is, species that arrived before 1700. This group consists of 15 species (13.4 %). They are predominantly associated with ancient agriculture and long-term anthropogenic impact (e.g., *Sonchus oleraceus*, *Avena fatua*, *Capsella bursa-pastoris*, and others).

Based on their mode of introduction, the largest number of species fall into three main categories:

- Ergasiophytes — 53 species (47.3 %), plants originally introduced by humans into cultivation (ornamental, forage, medicinal, etc.) and subsequently naturalized in the wild flora (*Helianthus tuberosus*, *Medicago sativa*, *Acer negundo*);
- Xenophytes — 54 species (48.2 %), introduced accidentally via crop seeds, transportation, or other means (*Erigeron canadensis*, *Bromus tectorum*, *Xanthium orientale*);
- Acclimatized species — 5 species (4.5 %) that spread independently without direct human involvement, for example, *Turgenia latifolia* and *Roemeria refracta*.
- Invasive species are classified by degree of naturalization as follows:
- Epicofytes — 47 species (42.0 %), fully established and actively reproducing in natural habitats (e.g., *Erigeron canadensis*, *Rhaponiticum repens*, *Lepidium densiflorum*).
- Ephemerophytes — 26 species (23.2 %), which take root temporarily but do not form stable populations (*Helianthus annuus*, *Digitaria sanguinalis*).
- Agrophytes — 27 species (24.1 %), having colonized agrocenoses and disturbed biotopes (*Capsella bursa-pastoris*, *Panicum miliaceum*).
- Colonophytes — 12 species (10.7 %), restricted to artificial or semi-natural habitats (*Berberis vulgaris*, *Tilia cordata*, *Populus × sibirica*).

In terms of prevalence, invasive species were distributed as follows: occasionally — 34 taxa (30.35 %); commonly — 44 taxa (39.28 %); very rarely — 14 taxa (12.50 %); rarely — 19 taxa (16.96 %). We can observe a trend whereby more than one-third of the identified invasive species fall into the “common” category, and about 30 % into the “occasional” category, which indicates their widespread distribution. This situation points to existing threats to the native flora.

Conclusion

Thus, the structure of the adventive flora of the Karaganda Region indicates the dominance of modern introductions (neophytes) and the significant role of xeno- and ergasiophytes, reflecting both unintentional seed dispersal and the results of human economic activity. The predominance of epecophytes indicates the active naturalization of some alien plants and their gradual incorporation into local plant communities, which requires constant monitoring to prevent potential invasive processes. These same data are confirmed by the classification of more than half of the invasive species into the “common” and “occasional” categories based on their prevalence in the study area.

The data obtained can serve as a basis for compiling a reference guide on alien plant species in the Karaganda Region and for developing measures to monitor them and prevent their further spread.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Kali A.** — conceptualization, drafting, and data analysis; **Sailau A.S.** — data curation and data collection.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Bradley, B.A., Blumenthal, D.M., Wilcove, D.S., & Ziska, L.H. (2010). Predicting plant invasions in an era of global change. *Trends in Ecology and Evolution*, 25, 310–318. <https://doi.org/10.1016/j.tree.2009.12.003>
- 2 Cowl, T.A., Crist, T.O., Parmenter, R.R., Belovsky, G., & Lugo, A.E. (2008). The spread of invasive species and infectious disease as drivers of ecosystem change. *Frontiers in Ecology and the Environment*, 6, 238–246. <https://doi.org/10.1890/070151>
- 3 Callaway, R.M., & Ridenour, W.M. (2004). Novel weapons: invasive success and the evolution of increased competitive ability. *Frontiers in Ecology*, 2(8), 436–443. [https://doi.org/10.1890/1540-9295\(2004\)002\[0436: NWISAT\]2.0.CO;2](https://doi.org/10.1890/1540-9295(2004)002[0436: NWISAT]2.0.CO;2)
- 4 Chytrý, M., Schaminée, J.H.J., & Schwabe, A. (2011). Vegetation survey: a new focus for Applied Vegetation Science. *Applied Vegetation Science*, 14(4), 435–439. <https://doi.org/10.1111/j.1654-109X.2011.01154.x>
- 5 (2026). Plants of the World Online (POWO). Retrieved from <https://powo.science.kew.org/>
- 6 Gnatyuk, E.P., & Kryshen, A.M. (2005). *Methods for investigating coenofloras (example of plant communities in harvested forest areas in Karelia)*. Petrozavodsk: Karelian Research Centre of the Russian Academy of Sciences.
- 7 Dai, Z.C., Wan, L.Y., Qi, S.S. et al. (2020). Synergy among hypotheses in the invasion process of alien plants: a road map within a timeline. *Perspectives in Plant Ecology, Evolution and Systematics*, 10, 125575. <https://doi.org/10.1016/j.ppees.2020.125575>
- 8 Dufrene, M., & Legendre, P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs*, 67(3), 345–366.
- 9 Gaertner, M., Biggs, R., Te Beest, M., Hui, C., Molofsky, J., & Richardson, D.M. (2014). Invasive plants as drivers of regime shifts: identifying high priority invaders that alter feedback relationships. *Diversity and Distributions*, 20, 733–744. <https://doi.org/10.1111/ddi.12182>

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Қарағанды облысы флорасының инвазивті түрлері

Аймақтың инвазивті флорасын зерделеу биологиялық әртүрлілікті сақтау және осы таксондардың одан әрі таралуының мониторингі үшін маңызды міндет. Зерттеудің мақсаты Қарағанды облысының тамырлы өсімдіктер флорасының инвазивті түрлерінің конспектісін жасау және олардың таралу, әкеліну үрдісі мен тәсілін осы аймақтағы табиғиландыру дәрежесі бойынша сипаттау. Зерттеу нәтижелері көрсеткендей, аймақта 91 тұқымдас пен 36 тұқымның 112 инвазивті түрі анықталған. Әкелу уақыты бойынша Қарағанды облысында неофиттердің 97 түрі немесе 86,6 % басым. Ең аз үлесті археофиттер — 15 таксон (13,4 %) алады. Енгізу тәсілі бойынша мынадай: эргасиофиттер (53 түр немесе 47,3 %), ксенофиттер (54 түр немесе 48,2 %), аколотофиттер (5 түр немесе 4,5 %). Жаратылыстану тәсілі бойынша: эпикофиттер (47 түр немесе 42,0 %), эфемерофиттер (26 түр немесе 23,2 %), агрофиттер (27 түр немесе 24,1 %), колонофиттер (12 түр немесе 10,7 %) бөлінді. Инвазивтік түрлердің таралу дәрежесі бойынша былайша бөлінеді: сирек — 34 таксон (30,35 %); жай — 44 таксон (39,28 %); өте сирек — 14 таксон (12,50 %); сирек — 19 таксон (16,96 %). Алынған деректер инвазивті түрлердің тұқымдарын енгізудің белсенді көші-қон процестерін және олардың жергілікті өсімдік қоғамдастықтарына біртіндеп енгізілуін көрсетеді. Көптеген таксондардың белсенді түрде табиғатқа

айналуы мен таралуы тұрақты мониторингті және Қарағанды облысында одан әрі таралуын тежеу бағдарламаларын әзірлеуді талап етеді.

Кілт сөздер: инвазивті түрлері, Қарағанды облысының аймағы, әкелу тәсілі, таралу дәрежесі, әкелу уақыты, жаратылу дәрежесі.

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Инвазивные виды флоры Карагандинской области

Изучение инвазивной флоры регионов является важной задачей для сохранения биологического разнообразия и мониторинга возможного дальнейшего распространения данных таксонов. Целью настоящего исследования являлось составление конспекта инвазивных видов флоры сосудистых растений Карагандинской области и их характеристика по степени распространенности, степени и способу заноса, степени натурализации в данном регионе. Результаты исследований показали, что в регионе выявлены 112 инвазивных видов из 91 рода и 36 семейств. По времени заноса в Карагандинской области преобладают неофиты — 97 видов, или 86,6 %. Меньшую долю занимают археофиты — 15 таксонов (13,4 %). По способу заноса выделены: эргасиофиты (53 вида, или 47,3 %), ксенофиты (54 вида, или 48,2 %), аколотофиты (5 видов, или 4,5 %). По способу натурализации были выделены: эпикофиты (47 видов, или 42,0 %), эфемерофиты (26 видов, или 23,2 %), агриофиты (27 видов, или 24,1 %), колонофиты (12 видов, или 10,7 %). По степени распространенности инвазивные виды распределились следующим образом: изредка — 34 таксона (30,35 %); обычно — 44 таксона (39,28 %); очень редко — 14 таксонов (12,50 %); редко — 19 таксонов (16,96 %). Полученные данные отражают активные миграционные процессы заноса семян инвазивных видов и их постепенное включение в местные растительные сообщества. Активная натурализация и распространенность многих таксонов требует постоянного мониторинга и разработки программ сдерживания дальнейшего распространения в Карагандинской области.

Ключевые слова: инвазивные виды, Карагандинская область, способ заноса, степень распространенности, время заноса, степень натурализации.

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Cryopreservation of *Filipendula ulmaria* Seed Material

Cryopreservation of plant seeds is of great practical importance for biodiversity conservation and practical application. The aim of this study was to evaluate the factors determining the success of cryopreservation of *Filipendula ulmaria* seeds, including the freezing method, thawing conditions, storage containers, and light sensitivity. Seed material was collected in the wild in the Karkaraly Mountains. Cryopreservation was carried out using cryotubes and aluminum foil bags while seeds stored using traditional methods in a refrigerator served as controls. The results showed no significant differences in germination between light and dark conditions, which does not dictate the method of germination in open ground or laboratory conditions. Comparison of thawing regimes revealed the advantage of slow thawing at room temperature (20–22 °C), during which germination reached 75 %, which was significantly higher than the control values. Analysis of freezing regimes allowed us to establish the highest germination rates with rapid freezing in foil bags. The proposed approach can be used for long-term cryopreservation of the *Filipendula ulmaria* gene pool.

Keywords: *Filipendula ulmaria*, seed material, cryopreservation, seed germination, germination energy, freezing-thawing regimen.

Introduction

The conservation of biological diversity and the establishment of seed banks for economically valuable plants are of significant scientific and practical importance [1]. This need arises from land degradation caused by human activity, as well as global climate change [2]. Among various storage methods, cryopreservation stands out as one of the most effective [3, 4]. Seed preservation creates potential for plant breeding [5, 6]. Storing plant material at -196 °C temperature stops all metabolic and physiological processes [5]. Storage at extremely low temperatures allows genetic material to be preserved indefinitely, with minimal financial costs and maintenance, without requiring large areas of space. Literature data [3–8] demonstrate the effectiveness of cryopreservation for medicinal plant seeds.

An interesting subject for research is *Filipendula ulmaria* (L.) Maxim (family Rosaceae), whose herb is used in folk medicine as an anti-inflammatory, diuretic, antirheumatic, antibacterial, antioxidant, and analgesic agent, as well as for digestive problems, respiratory diseases, and skin conditions [9–11].

To introduce medicinal plant seed material into a cryobank, studies were conducted to optimize the cryopreservation conditions for *Filipendula ulmaria* seeds.

Experimental

The subject of the laboratory studies was *F. ulmaria* seeds. The plant is frost-tolerant, drought-tolerant, and a facultative heliophyte, preferring xeromesophilic habitat conditions and moderately moist loamy or humus-rich sandy loam soils (Fig. 1). Under the conditions of Central Kazakhstan, the species is successfully introduced and can be cultivated on an industrial scale, which creates a need for the establishment of a seed bank, including storage at subcritical low temperatures.



Figure 1. Flowering shoot of *Filipendula ulmaria*

The research material was collected in the Karkaraly Mountains (Karkaraly District, Karaganda Region) during the third decade of August 2024.

Laboratory studies on optimizing cryopreservation conditions for *F. ulmaria* seed material were conducted at the Research Park for Biotechnology and Eco-Monitoring of the Faculty of Biology and Geography (Karaganda National Research University named after academician E.A. Buketov) in 2023–2025.

Prior to freezing, the initial moisture content of the seeds was determined using an Ohaus (China) moisture meter. *F. ulmaria* seeds were stored in an SDS-20 CryoMach (Russia) Dewar flask with liquid nitrogen ($-196\text{ }^{\circ}\text{C}$) for one month [12]. Aluminum foil bags and cryotubes (Deltalab, China) were used as freezing containers [13]. *F. ulmaria* seed material was not specifically selected prior to the start of the experiments; damaged, immature, and empty seeds were removed.

Seeds were thawed after cryopreservation using the following methods:

- 1) slow de-frosting at room temperature ($20\text{--}22\text{ }^{\circ}\text{C}$);
- 2) fast de-frosting in a water bath ($40\text{--}45\text{ }^{\circ}\text{C}$).

Stepwise freezing and rapid freezing (by immersing the seeds in a container in liquid nitrogen) were also investigated [14].

To assess the effectiveness of cryopreservation of *F. ulmaria*, seed viability was determined based on laboratory germination and germination energy [15] in Petri dishes. Before sowing the seeds, the Petri dishes are treated with 90 % alcohol and placed in laminar flow cabinets for 20 minutes for additional disinfection. After this time, filtered discs moistened with distilled water are placed in the Petri dishes. Before sowing in Petri dishes, the seeds were treated with a 0.5 % potassium permanganate solution for 5 minutes, then rinsed with distilled water [16].

The Petri dishes were placed in a climate chamber for the entire duration of the study, at a temperature of $+24\text{ }^{\circ}\text{C}$ and under constant illumination. Seeds were watered with distilled water as needed, if the Petri dish substrate dried out. The lids of the Petri dishes had to be opened for 5–10 seconds daily to allow the gas composition inside the dishes to change. During germination observation, the emergence of seedlings was recorded daily; germination rate was assessed on day 15, and germination energy on day 7. Seeds stored using the traditional method (refrigerator, $0\text{--}2\text{ }^{\circ}\text{C}$) served as the control.

All experiments were conducted in four independent replicates ($n=4$) by 100 seeds. Data are presented as mean \pm standard deviation (SD). Differences between treatments were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's honestly significant difference (HSD) test at a significance level of $p < 0.05$. All statistical analyses were performed using R software (R Foundation for Statistical Computing, Vienna, Austria).

Results and Discussion

In the initial stages of the study, the germination of seeds stored without cryopreservation was analyzed. Seed germination was conducted in light and in the dark. It was found that for *F. ulmaria* seed material, no significant difference was detected between the light and dark germination treatments. Seed germination was $71.0 \pm 5.4\%$ in light and $70.0 \pm 3.54\%$ in darkness (Tab. 1).

Seed germination of *Filipendula ulmaria* under various lighting conditions

| Germination rates, % | Germination conditions | |
|----------------------|------------------------|-------------|
| | In light | In the dark |
| Germination energy | 65.6±1.25 | 68.4±2.25 |
| Seed germination | 71.0±5.4 | 70.0±3.54 |

The data obtained indicate that there are no requirements for deep sowing for this species.

When seeds are stored in liquid nitrogen, the container [5] in which freezing takes place affects the germination of the plant material. The seed material was packaged in foil envelopes and plastic cryotubes. The results showed that the seeds retain their germination capacity after storage in liquid nitrogen vapors with complete physiological ripening (Fig. 2).

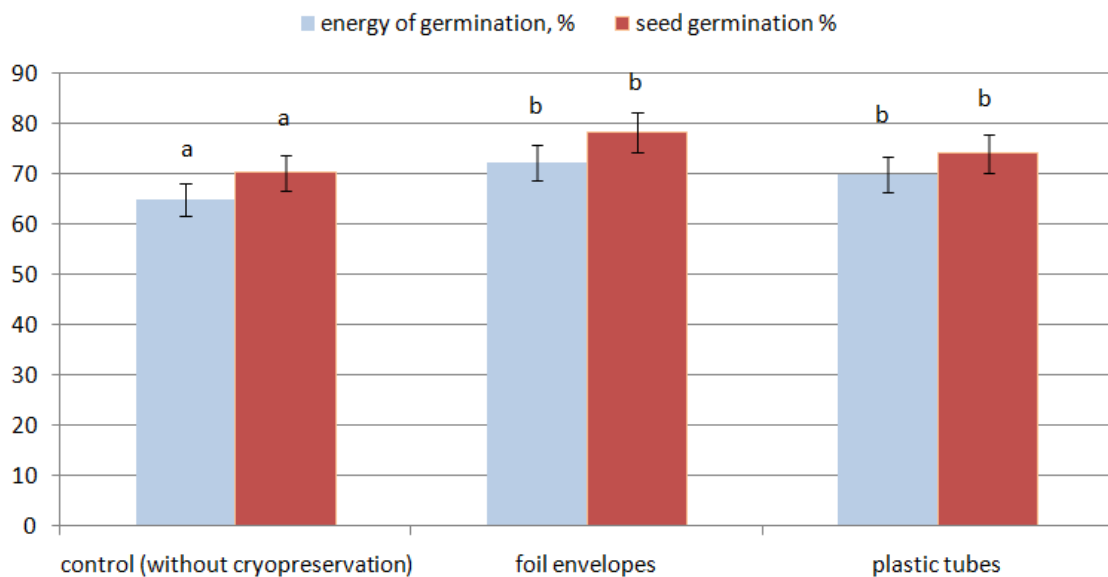


Figure 2. Germination of *Filipendula ulmaria* seeds in various containers. Different letters indicate significant differences between treatment groups at $P \leq 0.05$

The highest germination energy and seed germination were observed in *F. ulmaria* seeds stored at liquid nitrogen temperature in foil envelopes — 78.25 ± 8.41 %. The germination of seed material frozen in cryotubes were 75.0 ± 7.45 %, which is significantly higher than the control and does not differ significantly from the results obtained in foil containers. Thus, the germination rate of seed material in the cryotube experiments was 5.0 % higher than the control, and in the foil envelope variant, it was 8.25 % higher.

Thus, when storing *F. ulmaria* seed material in liquid nitrogen, both foil envelopes and cryotubes are recommended containers.

The next factor influencing the success of seed preservation during cryopreservation is the thawing conditions. An analysis of the literature [5–11] showed that thawing conditions may vary for different plant species, depending on genetic characteristics, seed coat thickness, physiology, and the accumulation of reserve nutrients.

During laboratory studies, two thawing regimes were initially used: slow thawing at room temperature (+20–22°C) and fast thawing in a water bath (+40°C).

Slow thawing at a temperature of +22–24 °C following cryogenic storage proved to be the significantly better option for *F. ulmaria* seeds (75.0 ± 7.45 %). This method exceeded the control values by 5.0 %. With rapid thawing, the germination rate of the seeds of the studied species was 67.5 ± 5.53 %, which was 2.5 % lower than the control values; however, no statistically significant differences from the control were detected (Fig. 3).

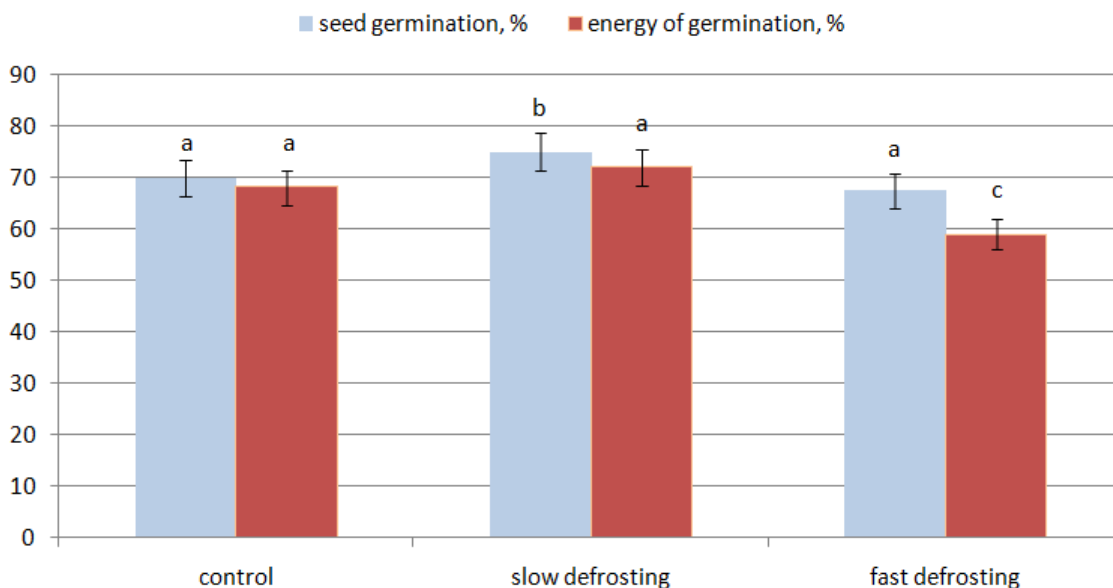


Figure 3. Germination rates of *Filipendula ulmaria* seeds depending on the thawing regime. Different letters indicate differences between experimental variants at $P \leq 0.05$

Thus, to achieve the best germination rates and germination energy of *F. ulmaria* seeds, slow thawing at room temperature (+22–24 °C) is recommended.

In the next stage, experiments were conducted to compare stepwise and rapid freezing. Rapid freezing was performed by quickly immersing plant samples in cryotubes and foil envelopes in liquid nitrogen for three days. Two-stage freezing was also performed in foil envelopes and cryotubes.

First, the test samples were placed in a refrigerator at +4 °C for 60 minutes, and then transferred to a freezer at -20 °C for one hour. Next, the test seeds in their containers were immersed in the vapor of liquid nitrogen contained in a Dewar flask for three days. After the seed material of the test species had been in liquid nitrogen, a slow thawing mode was used.

Based on the results of the experimental studies, it was determined that when seed material is rapidly placed in liquid nitrogen vapor, foil envelopes are the best container for achieving the highest germination rate (Fig. 4). Seed germination in this experimental treatment was 78.25 ± 8.41 %. For seeds frozen in plastic containers, germination energy did not differ significantly from the control, while germination was significantly higher than the control but lower than the values obtained for the foil container treatment.

In the two-stage freezing of *F. ulmaria* seeds, the germination energy values for plastic containers were significantly lower than the control, whereas for foil containers, they did not differ significantly from the control. However, seed germination for both container variants was significantly higher than the control.

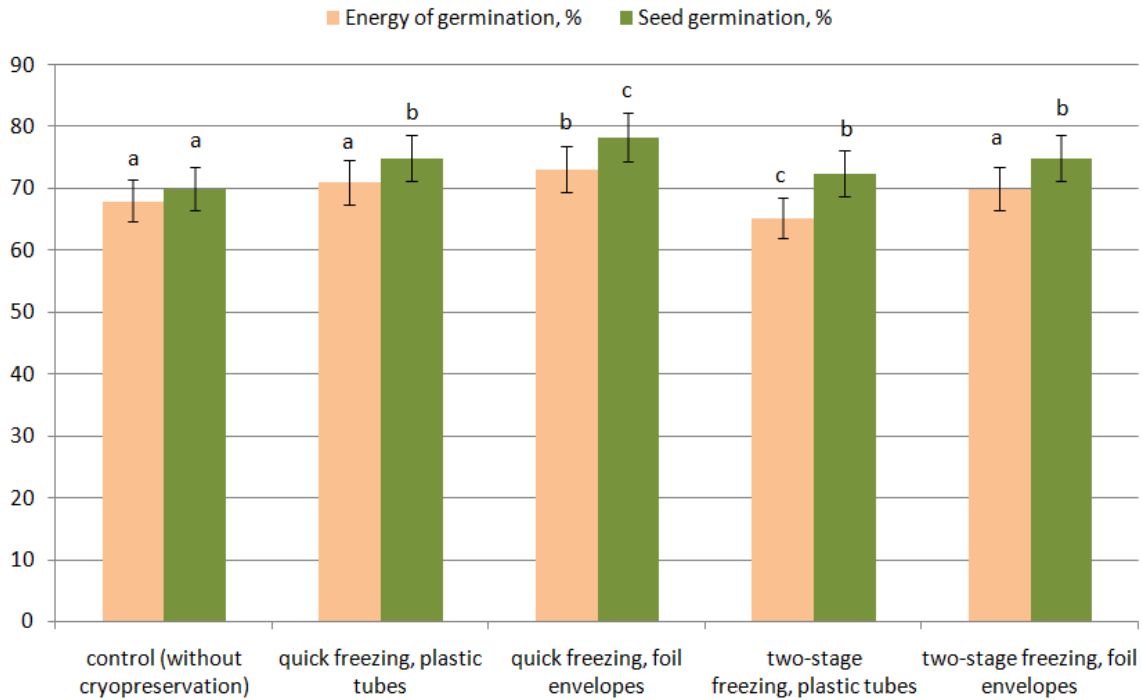


Figure 4. Germination of *Filipendula ulmaria* seeds depending on the freezing regime. Different letters indicate significant differences between experimental variants at $P \leq 0.05$

A comparative analysis of the two freezing methods used revealed that the highest germination rates were observed for the variant involving freezing in foil containers and the use of the rapid method. This result can be explained by the fact that foil provides faster and more uniform cooling, and the rapid method prevents the formation of ice crystals in the tissues.

Conclusion

Thus, for long-term cryopreservation, it is recommended to freeze *F. ulmaria* seeds in foil envelopes by rapid immersion in a Dewar flask and to use a slow thawing regimen. The results demonstrated the effectiveness of this storage method, as *F. ulmaria* seeds successfully survived storage at supercritical low temperatures, not only maintaining but also increasing germination rates and germination energy.

The data obtained can be used to develop a cryopreservation protocol and introduce *F. ulmaria* into a seed cryobank.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Gavrilkova E.A.** — conceptualization, laboratory experiments, investigation; **Tyrzhanova S.S.** — seed collection, draft writing; **Tleukenova S.S.** — data analysis; **Mussina R.T.** — data curation, data collection, draft writing.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Nakum, P., Singh, B., & Solanki, H. (2025). The significance of seed banks: A review of techniques and technologies. *World Journal of Advanced Research and Reviews*, 25(02), 2401–2407. <https://doi.org/10.30574/wjarr.2025.25.2.0573>
- 2 Wambugu, P.W., Nyamongo, D.O., & Kirwa, E.C. (2023). Role of Seed Banks in Supporting Ecosystem and Biodiversity Conservation and Restoration. *Diversity*, 15(8), 896. <https://doi.org/10.3390/d15080896>
- 3 Zeng, L., Sun, Z., Fu, L., Gu, Y., Li, R., He, M., & Wei, J. (2024). Cryopreservation of Medicinal Plant Seeds: Strategies for Genetic Diversity Conservation and Sustainability. *Plants*, 13(18), 2577. <https://doi.org/10.3390/plants13182577>
- 4 Pavlov, A.V., Porokhovina, E.A., Pavlov, A.V., Kiseleva, I.V., & Brutch, N.B. (2026). The Influence of Cryopreservation and Low-Temperature Seed Storage on the Morphological and Agronomical Characteristics of Fiber Flax. *Plants*, 15(4), 602. <https://doi.org/10.3390/plants15040602>
- 5 Ishmuratova, M., Tleukenova, S., Ramazanov, A., Gavrilkova, E., & Ageev, D. (2021). Study of cryopreservation conditions for seed materials of *Chartolepis intermedia* Boiss. *Bio Web of Conferences — Northern Asia Plant Diversity*, 38, 00046. <https://doi.org/10.1051/bioconf/20213800046>
- 6 Ren, R., Zhe, J., Guo, J., & Yang, X. (2023). Cryopreservation of herbaceous Asteraceae seeds: effects of seed reserves on seed germination and seedling regrowth. *Cryobiology*, 112, 104562. <https://doi.org/10.1016/j.cryobiol.2023.104562>
- 7 Kholina, A.B., & Voronkova, N.M. (2012). Seed cryopreservation of some medicinal legumes. *Journal of Botany*, 2012(1), 186891. <https://doi.org/10.1155/2012/186891>
- 8 Ghaffarzadeh-Namazi, L., Babaeian, N., Ghamari-zare, A., & Nematzadeh, G.H. (2015). Cryopreservation of the seeds of the medicinal plant *Satureja bachtiarica* Bunge. *Int J Biosci.*, 6(2), 24–29. <https://dx.doi.org/10.12692/ijb/6.2.24-29>
- 9 Farzaneh, A., Hadjiakhoondi, A., Khanavi, M., Manayi, A., Bahram Soltani, R., & Kalkhorani, M. (2021). *Filipendula ulmaria* (L.) Maxim. (meadowsweet): a review of traditional uses, phytochemistry and pharmacology. *Research J Pharmacognosy*, 9(3), 85–106. <https://doi.org/10.22127/rjp.2021.302028.1781>
- 10 Andonova, T., Muhovski, Y., Apostolova, E., Naimov, S., Mladenova, S., Slavov, I., Dincheva, I., Georgiev, V., Pavlov, A., & Dimitrova-Dyulgerova, I. (2024). DNA-Protective, Antioxidant, and Anti-Carcinogenic Potential of Meadowsweet (*Filipendula ulmaria*) Dry Tincture. *Antioxidants*, 13(10), 1200. <https://doi.org/10.3390/antiox13101200>
- 11 Samardzic, S., Arsenijevic, J., Bozic, D., Milenkovic, M., Tesevic, V., & Maksimovic, Z. (2017). Antioxidant, anti-inflammatory, and gastroprotective activity of *Filipendula ulmaria* (L.) Maxim. and *Filipendula vulgaris* Moench. *Journal of Ethnopharm.*, 213, 132–137. <https://doi.org/10.1026/j.jep.2017.11.013>
- 12 Sharma, M., Kumar, P., & Dwivedi, P. (2023). Artificial seed production and cryopreservation technology for conservation of plant germplasm with special reference to medicinal plants. *Medicinal Plants: Biodiversity, Biotechnology and Conservation*, 33, 581–593. Springer.
- 13 Reed B.M. (2008). *Plant cryopreservation: a practical guide*. Springer Science and Business Media, USA.
- 14 Shri, K.K., Pavithra A., Pazhamalai, V., Meenambiga, S.S., & Romauld, S.I. (2025). Plant genetic resources conservation by cryopreservation. In *Biotechnology in Plant Conservation*. Springer.
- 15 Hegde, R.B., Kudva, V., & Nayak, S. (2025). Advanced techniques for seed quality assessment and germination monitoring. *Discov Appl Sci.*, 690 (2025). <https://doi.org/10.1007/s42452-025-07284-8>
- 16 Prasad, S.R. (2023). Testing seed for quality. In *the book Seed Science and Technology, 2023*, 299–334. https://doi.org/10.1007/978-981-19-5888-5_13

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***Filipendula ulmaria* тұқымдық материалын криоконсервациялау**

Өсімдік тұқымдарын криоконсервациялау биоәртүрлілікті сақтауда практикалық маңызға ие. Зерттеудің мақсаты *Filipendula ulmaria* тұқымдарын криоконсервациялаудың факторларына, соның ішінде мұздату әдісіне, жібіту режиміне және ыдыстар түрлеріне, сонымен қатар жарыққа байланысты баға беру. Тұқымдық материалы Қарқаралы тауларында табиғи жағдайда жиналды. Тұқымдар криодыстарда және алюминий фольга пакеттерінде криоконсервацияланды, ал бақылау ретінде тоңазытқыш камерада дәстүрлі тәсілмен сақталған тұқымдар алынды. Зерттеу нәтижелері жарықта және қараңғыда өсу кезінде айтарлықтай дәлелді айырмашылықтардың болмауын көрсетті, бұл ашық топырақ пен зертханалық жағдайларда өсіруді шектемейді. Жібіту режимдерін салыстыру бөлме температурасында (20–22 °C) баяу жібітудің артықшылығын көрсетті, онда өнгіштік 75 % құрады, бұл бақылау мәндерінен айтарлықтай жоғары болып шықты. Мұздату режимдерін талдауда фольга пакеттерінде жылдам мұздату кезінде ең жоғары көрсеткіштерді анықтауға мүмкіндік берді. Ұсынылған тәсіл *Filipendula ulmaria* генофондын ұзақ мерзімді криосақтау үшін пайдаланылуы мүмкін.

Кілт сөздер: *Filipendula ulmaria*, тұқымдық материал, криоконсервациялау, тұқымның өнгіштігі, өну энергиясы, мұздату-жібіту режимі.

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Криоконсервация семенного материала *Filipendula ulmaria*

Криоконсервация семян растений имеет важное практическое значение для сохранения биоразнообразия и их использования. Целью настоящего исследования являлась оценка факторов, определяющих успешность криоконсервации семян *Filipendula ulmaria*, включая способ замораживания, режим оттаивания, тару и отношение к свету. Семенной материал был собран в природных условиях в горах Каркаралы. Семена криоконсервировали в криопробирках и в пакетах из алюминиевой фольги, контролем служили семена, хранившиеся традиционным способом в холодильной камере. Результаты показали отсутствие достоверных отличий между проращиванием на свету и в темноте, что не регламентирует способ проращивания в открытом грунте и лабораторных условиях. Сравнение режимов оттаивания выявило преимущество медленного размораживания при комнатной температуре (20–22°C), при котором всхожесть составила 75 %, что оказалось достоверно выше контрольных показателей. Анализ режимов замораживания позволил установить максимальные показатели при быстром замораживании в пакетах из фольги. Предлагаемый подход может быть использован для долгосрочного криохранения генофонда *Filipendula ulmaria*.

Ключевые слова: *Filipendula ulmaria*, семенной материал, криоконсервация, всхожесть семян, энергия прорастания, режим замораживания — оттаивания.

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Morphological and anatomical analysis of *Hedysarum gmelinii*, growing in the Karaganda region (Central Kazakhstan)

The study of the structure of medicinal plant raw materials is part of pharmacognostic analysis. In this work, anatomical and morphological studies were conducted on the promising plant *Hedysarum gmelinii*, whose herb and roots have potential for use in human and veterinary medicine. The raw materials were collected during the flowering phase, rehydrated, and analyzed at both macroscopic and microscopic levels. The following diagnostic macroscopic features were identified: shape and color of the stem, type of leaf pubescence, and characteristics of the inflorescence and flowers. At the microscopic level, diagnostic features included the structure of stem vascular tissues, fine ribbing of the stem, leaf anatomy (isobilateral type, if applicable), stomatal type and distribution, and the structure and arrangement of secondary xylem elements in the root. The results obtained can be used to verify the authenticity of plant raw materials and to prepare draft regulatory documentation for raw materials of this species.

Keywords: *Hedysarum gmelinii*, morphological and anatomical structure, aboveground and underground organs, diagnostic signs.

Introduction

The study of the useful flora of Kazakhstan has great potential, as it allows for the identification of promising sources of biologically active substances suitable for the production of new medicinal and veterinary preparations [1].

One of the most promising taxonomic groups is the genus *Hedysarum* L. (family Fabaceae), for certain species of which the Republic of Kazakhstan possesses a sufficient raw material base. In the natural flora, the genus *Hedysarum* L. comprises more than 200 species, of which 37 grow in the flora of Kazakhstan, including 12 endemic species [2].

From plants of the genus *Hedysarum* L., 115 biologically active compounds have been isolated, including flavonoids, triterpenes and triterpenoid saponins, coumarins, lignanoids, alkaloids, and sterols, which possess antioxidant, antitumor, anti-aging, antidiabetic, and antihypertensive effects [3–7].

Among the Kazakhstani representatives of the genus *Hedysarum* L., four species are known (*H. alpinum* L., *H. flavescens* Regel et Schmalh., *H. theinum* Krasnob., and *H. neglectum* Ledeb.), which possess expectorant, restorative, stimulant, antiviral, and antiprotozoal properties [8] and are used as antioxidants, immunostimulants, rejuvenating agents, restoratives, and tonics [9, 10].

In Central and Northern Kazakhstan, *Hedysarum gmelinii* Ledeb. is of interest, as it has significant raw material reserves and is a potential source of xanthenes, phenolic compounds, tannins, and alkaloids.

To facilitate the use of this species for medical purposes, we conducted an anatomical and morphological study of *H. gmelinii* to identify diagnostic features necessary for assessing the authenticity of the raw material.

Experimental

H. gmelinii was collected in the vicinity of the village of Karagaily (Karkaraly District, Karaganda Region, GPS-coordinates: N 49.42714; E 75.75434) during the flowering and fruiting phase, in the first ten days of August 2025.

The raw material in the form of herbaceous parts was collected in the morning, and the roots were dug up in the evening. Drying was carried out in a room protected from sunlight until the moisture content reached 10–12 %. The species was identified by staff of the Department of Botany, Faculty of Biology and Geography, Karaganda National Research University named after academician E.A. Buketov. The herbarium specimen is stored in the herbarium collection (acronym QAR, barcode QAR00013920).

Air-dried raw material (shoot, leaf, root) was softened in a mixture of distilled water: glycerin: 96 % ethanol (in a 1:1:1 ratio), then boiled in a 5 % sodium hydroxide solution [11]. Surface preparations were prepared on a manual microtome using disposable blades.

During microscopy, the preparations were examined under a BIOLAM 06-12 microscope (Russia) using magnifications of 16×20, 16×10, and 16×4 [12]. Microscopic photographs were captured on a tablet using Altamy Studio software and processed in Paint 10.1.

Classic methodological guidelines were applied when describing the specimens and identifying diagnostic features [13–15].

Results and Discussion

External characteristics of the plant. It belongs to the ancient Mediterranean-steppe type of distribution. It inhabits mountainous gravelly and rocky slopes, scree, and chalk deposits. In terms of ecological group, it is a xeromesophyte, which is reflected in its internal structure.

H. gmelinii is a perennial herbaceous plant, 15 to 40 cm tall (Fig. 1). The root is short and taproot-like. The shoots are ascending or rising, ribbed, with a rough surface, and range in color from light green to greenish-yellow.



Figure 1. *H. gmelinii* in the flowering stage

The leaves are imparipinnate, with 4 to 8 pairs of leaflets on a compound leaf. The leaflets are elliptical or narrowly ovate, with the upper surface green and glabrous, and the lower surface silvery-green, pubescent with appressed hairs. The venation is pinnate, faintly visible on the upper side of the leaf. The flowers are arranged in terminal racemes, containing 10–25 flowers. The flowers are zygomorphic, with a pink-purple corolla.

The following diagnostic features can be identified at the macroscopic level: the shape, color, and type of leaf pubescence, the shape of the inflorescence, and the color of the flowers.

Microscopy. The stem in cross-section (Fig. 2) is rounded and slightly lobed, hollow in the central part, and non-fasciculate in structure. The stem's perimeter is covered by a thin layer of bark, or periderm, consisting of small, dark-colored cells. Beneath the periderm, in the corners, lie areas of angular collenchyma, whose cells are oval-shaped with partially thickened walls.

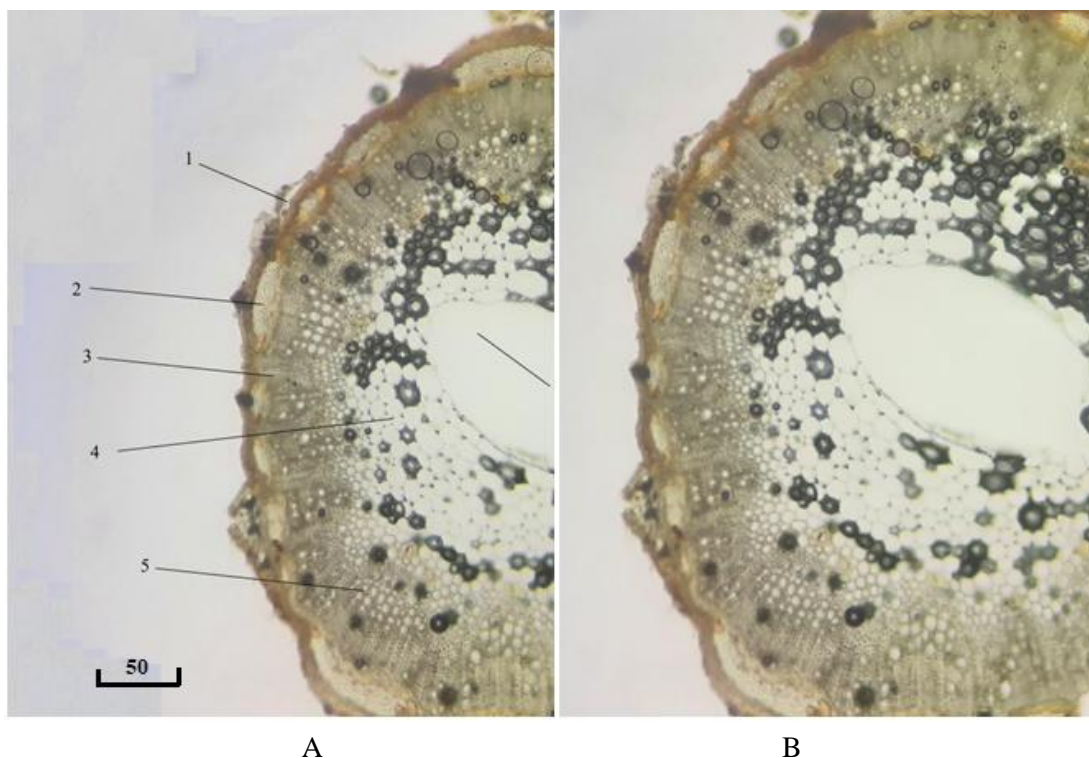


Figure 2. Cross-section of a *Hedysarum gmelinii* stem, fragment:
 A — stem fragment, B — fragment with remnants of medullary parenchyma;
 1 — bark, 2 — collenchyma, 3 — phloem, 4 — medullary parenchyma, 5 — xylem, 6 — stem cavity.
 Dimensions are given in μm

The vascular system consists of phloem regions corresponding to former vascular bundles, as well as xylem chains. The annular vascular zone is interrupted by rays of medullary parenchyma. The remnants of medullary parenchyma consist of large, thin-walled cells.

In cross-section, the leaf is flat, isolateral in shape, with an indistinct division into columnar and spongy tissues (Fig. 3). This characteristic is described for this species growing in more arid conditions, whereas in mesophytic habitats a dorsoventral structure is formed [16]. Veins protrude from the underside of the leaf. On both sides, the leaf is covered by a single-layered epidermis consisting of rounded cells that fit tightly together and are covered by a layer of cuticle on the outer side. The mesophyll is undifferentiated. Within its thickness lie the central and lateral vascular bundles, of the collateral type, closed. The phloem is oriented toward the upper side, the xylem toward the lower.

On the adaxial side of the leaf, the cells are more elongated in shape compared to the abaxial side. The stomata are not embedded in the epidermis and are of the anomocytic type. In terms of number, there is a predominance of stomata on the upper side—the epistomatic type. The stomatal index is 1.5–1.6.

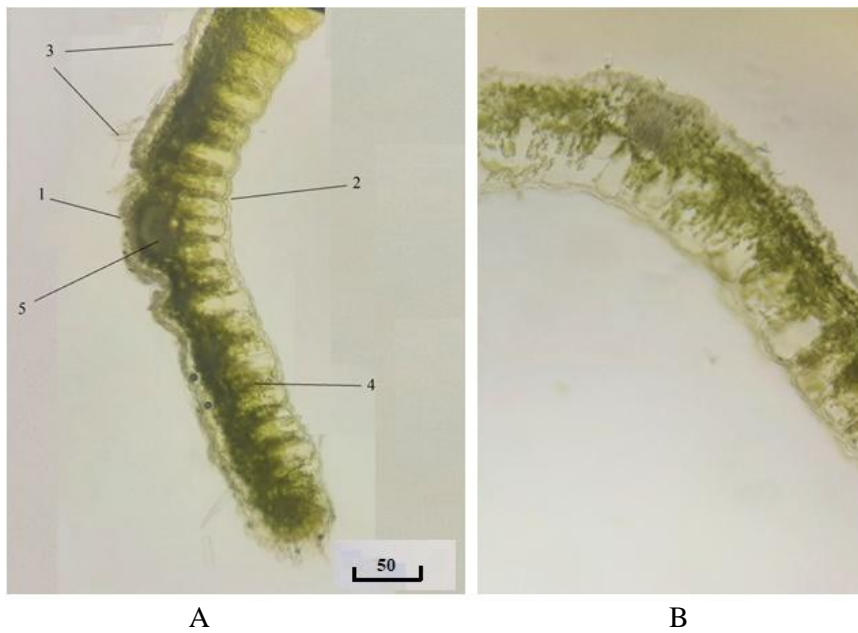


Figure 3. Cross-section of a *Hedysarum gmelinii* leaf, section through the midrib:
 A — section through the midrib, B — lateral section;
 1 — lower epidermis, 2 — upper epidermis, 3 — trichome remnants, 4 — mesophyll,
 5 — vascular bundle. Magnification is given in μm

The root of *H. gmelinii* (Fig. 4) is rounded with a well-defined cortex and has a secondary anatomical structure.

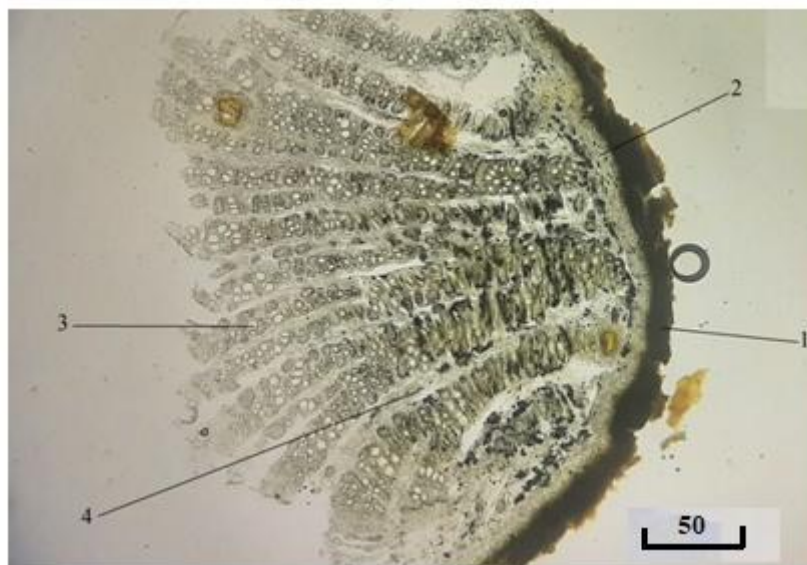


Figure 4. Cross-section of the root of *Hedysarum gmelinii*, fragment:
 1 — cortex, 2 — cortical parenchyma, 3 — xylem, 4 — parenchymatous rays.
 Magnification is given in μm

The covering tissue of the cork layer (periderm) accounts for about 5–7 % of the root's structure and consists of 4–5 layers of cells. Periderm cells are rectangular, strongly compressed from the surface, and dark brown in color. The cortex is slightly thinner than the periderm and consists of parenchyma cells that are tangentially flattened. Xylem elements, both primary and secondary, are present in the form of chains of vessels radiating from the center of the root—remnants of a polyarchic vascular bundle. Between the xylem chains lie sections of phloem and parenchyma rays.

The following diagnostic features have been identified at the microscopic level: a non-fascicular stem structure, fine ribbing, an isolateral leaf type, the type and arrangement of stomata, and the shape and arrangement of secondary xylem elements in the root.

Conclusion

Thus, anatomical and morphological studies of the above-ground and underground organs of *H. gmelinii* have been conducted. The structural characteristics of the shoot, root, and leaf at the macro- and microscopic levels have been identified. Diagnostic features of the raw material have been determined. Specifically, at the microscopic level: the shape, color, and type of leaflet pubescence; the shape of the inflorescence and the color of the flowers; at the microscopic level: the structure of the stem's vascular elements, the fine ribbing of the stem, the isolateral leaf type, the type and arrangement of stomata, and the shape and arrangement of the root's secondary xylem elements.

The data obtained can be used to identify the species and verify the authenticity of plant raw materials.

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Author Contribution

Suleimen Y.M. — research, field study, raw material collection, anatomical and morphological study, draft writing.

References

- 1 Грудзинская Л.М. Аннотированный список лекарственных растений Казахстана: Справочное издание / Л.М. Грудзинская, Н.Г. Гемеджиева, Н.В. Нелина, Ж.Ж. Каржаубекова. — Алматы, 2014. — 200 с.
- 2 Флора Казахстана. ТТ. 1–9. — Алма-Ата: Наука, 1956–1966.
- 3 Патент RU(11) 2 490 022(13) С1. Федорова Ю.С., Кузнецов П.В., Сухих А.С. Способ получения фитопрепаратов из растений рода *Hedysarum* (Копеечник чайный *Hedysarum theinum*, копеечник забытый *Hedysarum neglectum*). Опубликовано: 20.08.2013. — Бюл. № 23.
- 4 Pat. CN113768822 (A) Liu X., Wang S., Liu J., Wang H. Application of radix hedysari polysaccharide in preparation of cosmetics with moisture absorption, moisture retention or relieving effects. Pub. 2021-12-10.
- 5 Патент RU2713194 (C1) Федорова Ю.С., Кульпин П.В., Шапошников К.В., Сулов Н.И. Нейролептическое средство. — Оpubл. 2020-02-04.
- 6 Фитопрепараты ВИЛАР. Научно-справочное издание. — Москва: БОРУС-Пресс, 2009. — 256 с.
- 7 Федорова Ю.С. Сравнительное фитохимическое исследование некоторых видов растений рода *Hedysarum*: автореф. дисс. ... канд. фарм. наук / Ю.С. Федорова. — Самара, 2011. — 24 с.
- 8 Kukushkina T.A. Content of mangiferin and total amount of xanthones in plants of some wild-growing and introduced *Hedysarum* (Fabaceae) species / T.A. Kukushkina, G.I. Vysochina, N.A. Karnaukhova, I.Y. Selyutina // *Rastitelnye Resursy*. — 2011. — Vol. 47. — P. 99–106.
- 9 Li Y.Z. Chemical constituents from *Hedysarum polybotrys* and their antitumor activities / Y.Z. Li, J. Huang, H.C. Guo, B. Ren // *Chin Trad Herb Drugs*. — 2009. — Vol. 40. — P. 1195–1198.
- 10 Аксенова В.Н. Биоактивные производные ксантоновых С-гликозидов — QSAR-подход / В.Н. Аксенова, М.А. Морозова, А.В. Сыроешкин // *Разработка и регистрация лекарственных средств*. — 2023. — Т. 12, № 2. — С. 21–33.
- 11 Андреева В.Ю. Основы морфологии и систематики растений в фармакогнозии: учебное пособие для студентов фармацевтического факультета / В.Ю. Андреева, Н.В. Исайкина, Н.С. Зиннер. — Томск: Издательство Сибирского государственного медицинского университета, 2021. — 176 с.
- 12 Барыкина Р.П. Справочник по ботанической микротехнике. Основы и методы / Р.П. Барыкина, Т.Д. Веселова, А.Г. Девятков, Х.Х. Джалилова, Г.М. Ильина, Н.В. Чубатова. — Москва: Изд-во МГУ, 2004. — 312 p.
- 13 Rudall P.J. *Anatomy of flowering plants* / P.J. Rudall. — Cambridge: Cambridge University Press, 2007. — 159 p.
- 14 Лотова Л.И. Морфология и анатомия высших растений / Л.И. Лотова. — М.: Эдиториал, 2004. — 528 с.
- 15 Crang R. *Plant anatomy: a concept-based approach to the structure of seed plants* / R. Crang, Sh. Lyons-Sobaski, R. Wise. — Springer, 2018. — 507 p.
- 16 Карнаухова Н.А. Анатомическое строение листа *Hedysarum gmelini* (Fabaceae) / Н.А. Карнаухова // *Растительный микро Азиатской России*. — 2016. — № 4(24). — С. 3–9. DOI: 10.21782/RMAR1995-2449-2016-4(3-9)

Е.М. Сулеймен

Қарағанды облысында (Орталық Қазақстан) өсетін *Hedysarum gmelinii* морфологиялық және анатомиялық талдау

Дәрілік өсімдіктер шикізатының құрылымын зерттеу фармакогностикалық талдаудың бір бөлігі. Жұмыста шөбі мен тамыры медицина мен ветеринарияда қолдану әлеуетіне ие *Hedysarum gmelinii* перспективасы өсімдіктеріне анатомиялық-морфологиялық зерттеулер жүргізілді. Шикізат гүлдену фазасында жиналды, жібітілді, макро және микроскопиялық деңгейде жекелеген мүшелердің құрылымы сипатталды. Шикізаттың диагностикалық белгілері анықталды. Сыртқы белгілері бойынша келесі сипатты белгілерді бөліп көрсетуге болады: пішіні, сабағының түсі, жапырақтарының түгі, гүлінің пішіні және гүлдерінің түсі. Микроскопиялық деңгейде мынадай диагностикалық белгілер анықталған: сабақтың өткізгіш элементтерінің құрылысы, сабақтың ұсақ қырлы болуы, жапырақтың оқшауланған типі, сағаның типі мен орналасу ерекшеліктері, тамырдың қайталама ксилемдік элементтерінің нысаны мен орналасу типі. Алынған нәтижелер өсімдік шикізатының түпнұсқалығын растау және осы түрдегі шикізатқа нормативтік құжаттама жобасын дайындау үшін пайдаланылуы мүмкін.

Кілт сөздер: *Hedysarum gmelinii*, морфологиялық және анатомиялық құрылымы, жерүсті және жерасты органдары, диагностикалық белгілері.

Е.М. Сулеймен

Морфологический и анатомический анализ *Hedysarum gmelinii*, произрастающего в Карагандинской области (Центральный Казахстан)

Изучение строения сырья лекарственных растений является частью фармакогностического анализа. В нашей работе выполнены анатомо-морфологические исследования перспективного растения *Hedysarum gmelinii*, трава и корни которого имеют потенциал применения в медицине и ветеринарии. Сырье собирали в фазе цветения, размачивали, описывали строение отдельных органов на макро- и микроскопическом уровне. Определены диагностические признаки сырья. По внешним признакам можно выделить следующие характерные черты: форма, окраска стебля, тип опушения листочков, форма соцветия и окраску цветков. На микроскопическом уровне установлены следующие диагностические признаки: строение проводящих элементов стебля, мелкая ребристость стебля, изолатеральный тип листа, тип и особенности размещения устьиц, форма и тип размещения вторичных ксилемных элементов корня. Полученные результаты могут использоваться для подтверждения подлинности растительного сырья и подготовки проекта нормативной документации на сырье данного вида.

Ключевые слова: *Hedysarum gmelinii*, морфологическая и анатомическая структура, надземные и подземные органы, диагностические признаки.

References

- 1 Grudzinskaya, L.M., Gemedzhieva, N.G., Nelina, N.V., & Karzhaubekova, Zh.Zh. (2014). *Annotirovannyi spisok lekarstvennykh rastenii Kazakhstana: Spravochnoe izdanie* [An Annotated List of Medicinal Plants of Kazakhstan: Reference Publication]. Almaty [in Russian].
- 2 (1956–1966). *Flora Kazakhstana* [Flora of Kazakhstan]. Vols. 1–9. Almaty: Nauka [in Russian].
- 3 (2013). *Patent RU(11) 2 490 022(13) C1. Fedorova Ju.S., Kuznecov P.V., Suhii A.S. Sposob polucheniia fitopreparatov iz rastenii roda Hedysarum (Kopechnik chainyi Hedysarum theinum, kopechnik zabytyi Hedysarum neglectum). Opublikovano: 20.08.2013. Biul. № 23* [Patent RU(11) 2 490 022(13) C1. Method for producing herbal preparations from plants of the genus Hedysarum (Tea Hedysarum Hedysarum theinum, Forgotten Hedysarum Hedysarum neglectum)]. Published: August 20, 2013. Bulletin No. 23] [in Russian].
- 4 (2021). Pat. CN113768822 (A) Liu X., Wang S., Liu J., Wang H. *Application of radix hedysari polysaccharide in preparation of cosmetics with moisture absorption, moisture retention or relieving effects*. Published: 2021-12-10.
- 5 (2020). *Patent RU2713194 (C1) Fedorova Ju.S., Kulpin P.V., Shaposhnikov K.V., Suslov N.I. Neurolepticheskoe sredstvo. Opubl. 2020-02-04* [Patent RU2713194 (C1). Neuroleptic preparation. Published: 2020-02-04] [in Russian].
- 6 (2009). *Fitopreparaty VILAR. Nauchno-spravochnoe izdanie* [Phytopreparation of VILAR. Scientific-reference work]. Moscow: Borus-Press [in Russian].
- 7 Fedorova, Y.S. (2011). *Sravnitel'noe fitokhimicheskoe issledovanie nekotorykh vidov rastenii roda Hedysarum* [A Comparative Phytochemical Study of Several Species of the Genus Hedysarum]. *Extended abstract of candidate's thesis*. Samara [in Russian].

- 8 Kukushkina, T.A., Vysochina, G.I., Karnaukhova, N.A., & Selyutina, I.Y. (2011). Content of mangiferin and total amount of xanthenes in plants of some wild-growing and introduced *Hedysarum* (Fabaceae) species. *Rastitelnye Resursy*, 47, 99–106.
- 9 Li, Y.Z., Huang, J., Guo, H.C., & Ren, B. (2009). Chemical constituents from *Hedysarum polybotrys* and their antitumor activities. *Chin Trad Herb Drugs*, 40, 1195–1198.
- 10 Aksenova, V.N., Morozova, M.A., & Syroeshkin, A.V. (2023). Bioaktivnye proizvodnye ksantonovykh S-glikozidov — QSAR-podkhod [Bioactive derivatives of xanthone C-glycosides — the QSAR approach]. *Razrabotka i registratsia lekarstvennykh sredstv — Development and registration of medicines*, 12(2), 21–33 [in Russian].
- 11 Andreeva, V.Yu., Isajkina, N.V., & Zinner, N.S. (2021). *Osnovy morfologii i sistematiki rastenii v farmakognozii: uchebnoe posobie dlia studentov farmatsevticheskogo fakulteta* [Fundamentals of Plant Morphology and Systematics in Pharmacognosy: A Textbook for Pharmacy Students]. Tomsk: Izdatelstvo Sibirskogo gosudarstvennogo meditsinskogo universiteta [in Russian].
- 12 Barykina, R.P., Veselova, T.D., Devyatov, A.G., Dzhaililova, H.H., Ilyina, G.M., & Chubatova, N.V. (2004). *Spravochnik po botanicheskoi mikrotekhnike. Osbovy i metody* [Handbook of Botanical Microtechnology. Fundamentals and Methods]. Moscow: Moscow State University Press [in Russian].
- 13 Rudall, P.J. (2007). *Anatomy of flowering plants*. Cambridge: Cambridge University Press.
- 14 Lotova, L.I. (2004). *Morfologiya i anatomia vischikh rastenii* [Higher plant morphology and anatomy]. Moscow: Editorial [in Russian].
- 15 Crag, R., Lyons-Sobaski, Sh., & Wise, R. (2018). *Plant anatomy: a concept-based approach to the structure of seed plants*. Springer.
- 16 Karnaukhova, N.A. (2016). Anatomicheskoe stroenie lista *Hedysarum gmelini* (Fabaceae) [Anatomical structure of leaf of *Hedysarum gmelini* (Fabaceae)]. *Rastitelnyi mir Aziatskoi Rossii — Vegetative world of Asian Russia*, 4(24), 3–9. DOI: 10.21782/RMAR1995-2449-2016-4(3-9) [in Russian].

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Phytocenotic Characteristics and Resources of *Ferula songarica* in Central Kazakhstan (within the Ulytau and Karaganda Regions)

The study of the biological characteristics and resource potential of medicinal plants is an important task in modern botany and pharmacognosy. One of the promising medicinal species in the flora of Kazakhstan is *Ferula songarica*, which is characterized by a high content of biologically active compounds and valuable pharmacological properties. The aim of this study was to identify populations of *F. songarica* in natural conditions in Central Kazakhstan and to assess plant raw material resources. Field studies were conducted in 2024–2025 using a route-reconnaissance method at eight key sites located in the Ulytau and Karaganda regions. During the study, plant density, morphometric parameters, yield, exploitable raw material reserves, and potential harvest volume were determined. It was established that natural populations containing *F. songarica* are characterized by a sparse spatial distribution of individuals. The density of reproductive plants ranges from 0.36 to 6.05 plants/10 m², and plant height is 83.06–133.2 cm. The yield of roots, calculated on an air-dry weight basis, was 3,580–7,010 kg/ha, and that of aboveground parts was 234–315 kg/ha. The total area of plots suitable for raw material harvesting was 281.5 ha. The exploitable stock of roots is estimated at 1,874.85 tons, and that of the herbaceous parts at 79.22 tons. The potential harvest volume of roots is estimated at 183.8 tons, and that of aboveground parts at 55.43 tons. The results obtained demonstrate the feasibility of harvesting *F. songarica* raw materials in natural conditions for the production of medicinal and parapharmaceutical products.

Keywords: *Ferula songarica*, population, yield, Central Kazakhstan, exploitable stock, potential harvest volume, roots, aboveground biomass, medicinal plant raw materials.

Introduction

The vegetation of Kazakhstan is characterized by a high level of biodiversity and significant resource potential for medicinal plants. According to current estimates, the flora of Kazakhstan includes more than 5,500 species of vascular plants [1], of which about 270 species are used in traditional and official medicine [2]. Many of them possess valuable pharmacological properties and are considered promising sources of biologically active compounds for the pharmaceutical industry [3–5].

A special place among medicinal plants is occupied by representatives of the genus *Ferula* L. (Apiaceae), which is one of the largest genera in the family and includes more than 180 species [6], distributed primarily in the arid and subarid regions of Central Asia, Iran, Afghanistan, and western China. The main centers of species diversity for the genus are also concentrated in Kazakhstan, where about 48 species of *Ferula* grow, many of which have medicinal, forage, and economic value [7].

Plants of the genus *Ferula* have long been widely used in practice, primarily in three capacities: as forage, medicinal, and essential oil plants [2, 6]. In recent years, interest in the pharmacological properties of ferulas has increased significantly, due to their high content of biologically active compounds, primarily terpenoid coumarins, terpene alcohols and their esters with aromatic acids, as well as sesquiterpene lactones [8–11]. These compounds are considered promising targets for further pharmacological research and the search for new drugs.

One of the promising representatives of the genus is *Ferula songarica* Pall. ex Spreng. The species inhabits the steppe and foothill regions of Kazakhstan [12]. The species is of economic interest as a medicinal plant possessing anti-inflammatory, antitumor, and antispasmodic properties, used in traditional medicine for the treatment of diseases of the joints, cardiovascular and digestive systems, as well as an antioxidant and immune stimulant [13, 14].

To understand the potential for practical use of *F. songarica*, research is needed to study natural populations and assess raw material reserves.

In light of the above, the aim of this study was to investigate the population characteristics and assess the raw material reserves of *F. songarica* under various ecological and phytocenotic conditions in Central Kazakhstan.

Experimental

Field studies were conducted in the first ten days of June 2024-2025, when *F. songarica* plants were in the mass flowering phase. A preliminary analysis of the species' distribution was performed based on an analysis of herbarium collections (QAR and NUR herbaria).

Field surveys to determine the resources of the studied species were conducted using a route-reconnaissance method. In natural stands, we determined yield, stand density, and raw material reserves of aboveground and underground organs, and described the floristic composition of the sites [15, 16]. The studies were conducted in warm and dry weather; raw material collection for yield assessment was carried out in the morning, after the dew had dried.

The assessment of raw material reserves in the communities was conducted using the key plot method [17]. At each plot, the area, density of marketable specimens, yield, and reserves of underground and aboveground parts were assessed in terms of air-dry weight. The area of the stands was determined by mapping their configuration to geometric shapes. Control points were recorded using GPS, after which the dimensions and area of the stands were calculated. To assess yield, raw material was harvested from at least 8–10 plots, and underground organs from 4 plots. Young and middle-aged generative individuals served as marketable specimens.

The aboveground biomass was cut with pruning shears at a height of 10–12 cm from the soil surface to maximize the collection of leaves and inflorescences. *F. songarica* roots were dug up at a depth of 50–60 cm. The harvested biomass was dried in a room protected from sunlight [18]. The grass intended for drying was cut into smaller pieces (8–12 cm), the roots were washed to remove soil and also cut into smaller pieces (5–6 cm long and up to 2–3 cm wide). During drying, the raw material was regularly turned to prevent spoilage.

The air-dried raw material was weighed separately for each site. When selecting sites suitable for harvesting, the standards of Good Agricultural and Collection Practices (GACP) were taken into account [19].

The exploitable stock of raw material was calculated by multiplying the yield per unit area by the total area of the stands. The volume of the potential annual harvest of roots was set at 10 % of the exploitable stock, and that of aboveground parts at 70 % [20].

Species identification was performed based on the Flora of Kazakhstan [21], and Latin names were cited according to the Plants of the World Online (POWO) system.

Statistical analysis of the results was performed using the method of N.L. Udolskaya [22].

Results and Discussion

Field studies have shown that *F. songarica* is characterized by a sparse spatial distribution of individuals. The plants are found primarily as solitary specimens, in small groups of 6–8 individuals, or in thickets ranging in size from 10×20 to 20×70 m. This type of distribution is characteristic of many species of the genus *Ferula* growing in the steppe and semi-arid ecosystems of Central Asia, where the spatial structure of populations is determined by soil moisture conditions, microtopography, and competitive interactions with other plant species [21].

In the Karaganda and Ulytau regions (Central Kazakhstan), we surveyed sites containing natural stands of *F. songarica*, which cover the slopes of gentle, low hills and inter-hill depressions at elevations ranging from 250 to 540 m above sea level (Fig. 1). The flora of the surveyed areas consists of flowering plants of *Ferula songarica* and associated species: *Festuca valesiaca*, *Agropyron cristatum*, *Artemisia austriaca*, *Artemisia frigida*, *Artemisia dracunculus*, *Artemisia nitrosa*, *Artemisia pauciflora*, *Galatella villosa*, *Galatella tatarica*, *Astragalus danicus*, *Thymus marschallianus*, *Potentilla bifurca*, *Potentilla humifusa*, *Jurinea multiflora*, *Centaurea scabiosa*, *Phlomis tuberosa*, *Atraphaxis spinosa*, *Androsace turkestanica*, *Carex* sp., *Ranunculus* sp., *Caragana frutex*, *Erysimum diffusum*, *Rosa spinosissima*, *Descurainia sophia*, *Spiraea hypericifolia*, *Achillea nobilis*, *Elytrigia repens*, and others. Vegetation aspect: yellow-green.



Figure 1. Typical habitats of *Ferula songarica* in Central Kazakhstan

Key site No. 1 is located in the vicinity of the village of Baikonyr, Ulytau District, Ulytau Region (N 47.83524, E 65.50149, elevation 250 m above sea level). The site covers an area of 225 ha. The soils consist of clayey saline meadows. The plant community belongs to the wormwood-grass-ferula type of phytocenoses. The dominant species is *F. songarica* (cop1, coverage about 80 %), the subdominants are species of the genus *Artemisia* (cop2, coverage about 80 %), and the herbaceous layer is arranged in two tiers. The density of generative individuals is 6.05 ± 0.52 individuals/10 m². The average height of reproductive plants is 133.2 ± 6.65 cm. The diameter of the aboveground part varies from 24 to 46 cm, and the length of the root system is 20–35 cm. The average plant density is 0.82 ± 0.06 plants/m². The raw material yield was 7,010 kg/ha on a dry weight basis (Tab. 1). The exploitable stock of root raw material is estimated at 1,577.25 tons; that of grass at 64.13 tons (Tab. 2). The potential harvest volume is estimated at 157.0 and 44.89 tons, respectively.

Table 1

**Yield and raw material reserves of *Ferula songarica* roots in Central Kazakhstan
(on an air-dry weight basis)**

| Region | Key site | Area of thickets, ha | Yield, kg/ha | Operational reserves, tons | Potential raw material harvest, tons |
|---------------|----------|----------------------|--------------|----------------------------|--------------------------------------|
| Ulytau | 1 | 225.0 | 7,010±212 | 1,577.25 | 157.0 |
| | 2 | 25.0 | 6970±340 | 174.25 | 14.4 |
| | 3 | 7.1 | 3688±256 | 26.18 | 2.6 |
| | 4 | 5.0 | 5152±302 | 25.76 | 2.6 |
| Karaganda | 5 | 5.3 | 5020±340 | 26.61 | 2.7 |
| | 6 | 4.8 | 4250±180 | 2.0 | 0.2 |
| | 7 | 3.2 | 3,580±190 | 11.45 | 1.2 |
| | 8 | 6.1 | 5,140±260 | 31.35 | 3.1 |
| Total: | | 281.5 | | 1,874.85 | 183.8 |

Table 2

**Yield and raw material reserves of *Ferula songarica* aboveground part in Central Kazakhstan
(in terms of air-dry weight)**

| Region | Key site | Area of the stand, ha | Yield, kg/ha | Operational reserves, tons | Potential raw material harvest, tons |
|--------|----------|-----------------------|--------------|----------------------------|--------------------------------------|
| Ulytau | 1 | 225.0 | 285±18 | 64.13 | 44.89 |
| | 2 | 25.0 | 260±31 | 6.5 | 4.55 |
| | 3 | 7.1 | 315±22 | 2.24 | 1.56 |
| | 4 | 5.0 | 220±30 | 1.1 | 0.77 |

| Region | Key site | Area of the stand, ha | Yield, kg/ha | Operational reserves, tons | Potential raw material harvest, tons |
|-----------|----------|-----------------------|--------------|----------------------------|--------------------------------------|
| Karaganda | 5 | 5.3 | 312±25 | 1.65 | 1.15 |
| | 6 | 4.8 | 250±19 | 1.2 | 0.84 |
| | 7 | 3.2 | 234±21 | 0.75 | 0.52 |
| | 8 | 6.1 | 270±34 | 1.65 | 1.15 |
| Total: | | 281.5 | | 79.22 | 55.43 |

Key site No. 2 is also located in the Ulytau Region, Ulytau District, 15 km north of the village of Baikonur (N 47.83442, E 65.93964, elevation 347 m above sea level). The area of the vegetation cover is 25 ha. The soils are clayey-saline. The phytocenosis belongs to the grass-wormwood-ferula type. The vegetation is two-tiered. The main dominants are *F. songarica* (cop1, coverage about 65 %), *Calamagrostis epigeios*, and *Poa bulbosa* (cop2, 10–15 %). The height of generative plants is 125.2±6.57 cm. The number of vegetative individuals is 18.3±1.52 individuals/100 m². The average height of generative plants is 125.2±6.65 cm. The density of generative plants is 0.82±0.06 plants/m². The number of vegetative plants reaches 18.3±1.52 plants/100 m². The diameter of the above-ground plant mass is 20–37 cm, and the root length is 15–25 cm. The raw material yield was 6,970 kg/ha on a dry weight basis (Tab. 1). The exploitable root stock is estimated at 174.25 tons on a dry weight basis, and the potential raw material harvest volume is 14.4 tons. For the aboveground parts, these figures are estimated at 6.5 and 4.55 tons, respectively.

Key site No. 3 is located in the Zhanaarkinsky District of the Ulytau Region, near the village of Aktubek (N 48.56255; E 70.90449, elevation 462 m above sea level). The site covers an area of 7.1 hectares. The plant community is a ferula-reed type. The main dominant species are: *F. songarica* (cop2), *Calamagrostis epigeios* (soc). The total projective cover reaches 70 %. The herbaceous layer is two-tiered and species-poor. The density of generative individuals is 0.36± 0.02 individuals/10 m², which is the lowest value among the studied plots. Plants are found singly or in small groups of 5–8 individuals. The average height of generative plants is 93.06±7.39 cm. Root yield is 3,688 kg/ha. The exploitable stock is estimated at 26.18 tons, and the potential harvest volume is 2.6 tons (Tab. 1). The exploitable stock of aboveground parts, with a yield of 315 kg/ha, amounted to 2.24 tons, and the potential harvest volume was 1.56 tons (Tab. 2).

Key site No. 4 is located in the Ulytau District, near the Krasnaya Zaimka wintering grounds, on a rocky, gravelly hill (N 48.73330; E 66.89036, elevation 539 m above sea level). The area covers 5 ha. The phytocenosis also belongs to the ferula-calamagrostis type. Main dominants: *F. songarica* (cop2), *Calamagrostis epigeios* (soc). Total cover is up to 65–75 %. The herbaceous layer is three-tiered, with a species composition of up to 15 taxa. The density of generative individuals is 0.41± 0.01 individuals/10 m², and the number of vegetative individuals is 21.3±1.92 individuals/100 m². The average height of generative plants is 135.1±6.52 cm. Root yield amounted to 5,152 kg/ha on a dry weight basis. The exploitable stock is estimated at 25.76 tons, and the potential harvest volume of underground organs is 2.6 tons (Tab. 1). For aboveground parts, the raw material yield was 220 kg/ha, the exploitable stock is estimated at 1.1 tons, and the potential harvest volume at 0.77 tons.

Key site No. 5 is located in the Karaganda Region, Karkaraly District, near the village of Matak (N 49.68053; E 74.70494, elevation 540 m above sea level). The study plot covers an area of 5 hectares. The community belongs to the ferula-calamagrostis type. The dominant species are *F. songarica* (cop2) and *Calamagrostis epigeios* (soc), with a total projective cover reaching 65 %. The herbaceous layer is two-tiered, and the species composition of the community consists of approximately 10–11 taxa. The density of generative individuals is 0.83± 0.05 individuals/10 m², and the number of vegetative individuals is 20.2±1.72 individuals/100 m². The average height of generative plants is 121.2±6.65 cm. Root yield was 5,020 kg/ha, and herb yield was 312 kg/ha. The exploitable root stock is estimated at 26.61 tons, with a potential harvest of 2.7 tons; for grass, these figures are estimated at 1.65 and 1.15 tons, respectively (Tab. 1, 2).

Key site No. 6 is located in the Karaganda Region, Karkaralinsky District, near the village of Koktas (N 49.61813; E 75.00541, elevation 522 m above sea level). The area of the study plot is 4.8 ha. The community belongs to the ferula-caragana type. The dominant species are *F. songarica* (cop2) and *Caragana frutex* (cop1); the species composition of the community comprises about 15 taxa. The total projective cover is estimated at 80–85 %. The herbaceous layer is three-tiered. The density of generative individuals is 0.54± 0.04 individuals/10 m², and the number of vegetative individuals is 5.9±0.07 individuals/100 m². The average height of generative plants is 126.8±8.2 cm. Root yield was 4,250 kg/ha, and grass yield was

250 kg/ha (Tab. 1, 2). The exploitable root stock is estimated at 2.0 tons, and the grass stock at 1.2 tons. The potential harvest volume of roots and grass was 0.2 and 0.84 tons, respectively.

Key site No. 7 is located in the Abai District of the Karaganda Region, on the slopes of the Spassky Hills (N 49.50934; E 73.25108, elevation 605 m above sea level). The site covers an area of 3.2 ha and is dominated by a rose-spirea-ferula community, with a total projective cover of 90 %. The dominant species is *Rosa spinosissima* (cop2), with *Spiraea hypericifolia* (cop1) and *F. songarica* (cop — sp) as co-dominants. The overall species composition is quite rich—up to 18–20 taxa. The herbaceous layer is three-tiered. The density of generative individuals is 0.81 ± 0.06 individuals/10 m², and the number of vegetative individuals is 10.5 ± 0.04 individuals/100 m². The average height of generative plants is 112.6 ± 8.3 cm. Root yield was 3,580 kg/ha, and above-ground yield was 234 kg/ha (Tab. 1, 2). The exploitable root stock is estimated at 11.45 tons, and the potential root harvest at 1.2 tons. For aboveground parts, these figures are estimated at 0.75 and 0.52 tons, respectively.

Key site No. 8 is located in the Bukhar-Zhyrau District of the Karaganda Region, in the floodplain of the Nura River near the village of Rostovka (N 50.07045; E 72.73544, elevation 385 m above sea level). The area is 6.1 ha, with a community of *Calamagrostis*, *Ferula*, and *Spiraea*. The dominant species is *Calamagrostis epigeios* (cop2); co-dominants are *F. songarica* and *Spiraea hypericifolia*—both with cop1. The total number of species in the community is 18–19. The herbaceous layer is three-tiered. The density of generative individuals is 0.71 ± 0.05 individuals/10 m², and the number of vegetative individuals is 9.4 ± 0.03 individuals/100 m². The average height of generative plants is 126.4 ± 9.4 cm. Root yield was 5,140 kg/ha, and above-ground yield was 270 kg/ha (Tab. 1, 2). The exploitable root stock is estimated at 31.35 tons, with a potential raw material harvest of 3.1 tons. For aboveground parts, these figures are estimated at 1.65 and 1.15 tons, respectively.

Analysis of the data revealed significant variability in the population parameters of *F. songarica* across different habitats. The highest density of reproductive individuals was observed in Plot 1, where it reached 6.05 individuals/10 m², while the lowest was recorded in Key site No. 3. The highest root yield indices were recorded for key site No. 1 — 7,010 kg/ha, and the lowest for plot No. 7 (3,580 kg/ha). However, the highest grass yield was recorded in key site No. 3 — 315 kg/ha — while the lowest was in site No. 7 — 234 kg/ha. Differences in the yield and growth density of *F. songarica* are likely related to soil and climatic conditions.

Conclusion

The study of natural populations of *F. songarica* in Central Kazakhstan within the Karaganda and Ulytau regions revealed their widespread distribution and the presence of stands suitable for harvesting raw materials, including both above-ground and underground parts.

Eight key sites were identified, with a total stand area of 281.5 ha. Root yields ranged from 3,688 to 7,010 kg/ha on an air-dry weight basis, while above-ground organ yields ranged from 234 to 315 kg/ha. The potential harvest volumes of roots and grass amounted to 183.8 and 55.43 tons, respectively.

The results obtained expand our understanding of the population structure and resource potential of *F. songarica*. The practical significance of the study lies in the possibility of using the obtained data to develop scientifically sound recommendations for the rational use of the species' natural resources and its conservation.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Mukhtubayeva S.K.** — research, field study, species identification; **Ramazanov A.K.** — raw material collection, draft writing; **Ageev D.V.** — data analysis; **Takirova M.B.** — data curation, data collection, draft writing; **Myrzagaliyeva A.B.** — statistical analysis.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Паршина Г.Н. Сохранение и управление биоразнообразием в Республике Казахстан / Г.Н. Паршина, У. Мукиянова, Л.В. Шабанова // Вестник КазНУ, серия биологическая. — 2012. — № 2(54). — С. 16–20.
- 2 Грудзинская Л.М. Аннотированный список лекарственных растений Казахстана: Справочное издание / Л.М. Грудзинская, Н.Г. Гемеджиева, Н.В. Нелина, Ж.Ж. Каржаубекова. — Алматы, 2014. — 200 с.
- 3 Мухтубаева С.К. О современных тенденциях использования ферулы воюющей (*Ferula foetida* L.) в Южном Казахстане / С.К. Мухтубаева // Вестник Павлодарского государственного университета. Химико-биологическая серия. — 2010. — № 1. — С. 87–90.
- 4 Majid Mohammadhosseini M. The genus *Ferula*: Ethnobotany, phytochemistry and bioactivities — A review / M. Majid Mohammadhosseini, A. Venditti, S.D. Sarker, L. Nahar, A. Akbarzadeh // *Industrial Crops and Products*. — 2019. — Vol. 129. — P. 350–394. <https://doi.org/10.1016/j.indcrop.2018.12.012>
- 5 Alruways M.W. Antimicrobial effects of *Ferula* species — an herbal tactic for management of infectious diseases / M.W. Alruways // *Journal of King Saud University, Science series*. — 2023. — Vol. 10. — Article ID 102806. <https://doi.org/10.1016/j.jksus.2023.102806>
- 6 Mahendra P. *Ferula asafoetida*: Traditional uses and pharmacological activity / P. Mahendra, S. Bisht // *Pharmacognosy reviews*. — 2012. — Vol. 6(12). — P. 141–146. <https://doi.org/10.4103/0973-7847.99948>
- 7 Сафина Л.К. Ферулы Казахстана / Л.К. Сафина, М.Г. Пименов. — Алма-Ата: Наука, 1984. — 109 с.
- 8 Зубайдова Т.М. О фармакологическом исследовании разных видов рода *Ferula* L. в медицине XX века / Т.М. Зубайдова, Дж.Н. Джамшедов, С.Дж. Исупов, И.А. Загребельный, С.М. Давлаткадамов, Дж. Содиков, П.Ш. Сухробов // Вестник Таджикского национального университета. Серия естественных наук. — 2014. — № 1/3(134). — С. 225–229.
- 9 Khosnutdinova T.S. Coumarins of genus *Ferula* L. (Apiaceae Lindl.) / T.S. Khosnutdinova, N.G. Gemejiyeva, Zh.Zh. Karzhaubekova, N.A. Sultanova // *Eurasian Chem.-Technol. J.* — 2023. — Vol. 25(1). — P. 39–56. <https://doi.org/10.18321/ectj1494>
- 10 Boghrati Z. *Ferula* species: A rich source of antimicrobial compounds / Z. Boghrati, M. Iranshahi // *Journal of Herbal Medicine*. — 2019. — Vol. 16. — Article ID 100244. <https://doi.org/10.1016/j.hermed.2018.10.009>
- 11 Chen Z. Research Progress of *Ferula ferulaeoides*: A Review / Z. Chen, G. Zhou, S. Ma // *Molecules*. — 2023. — Vol. 28(8). — Article ID 3579. <https://doi.org/10.3390/molecules28083579>
- 12 Коровин Е.П. Ферула — *Ferula* L. / Е.П. Коровин // В кн.: Флора Казахстана. — Алма-Ата, 1962. — Т. 6. — С. 385–416.
- 13 Turdiyeva Zh.A. Development of Composition and Technology of Anti-Fungal Gel with *Ferula songarica* Essential Oil Growing In The Territory Of Central Kazakhstan / Zh.A. Turdiyeva, G.A. Atazhanova, M.Y. Ishmuratova, A.V. Samorodov, S.B. Akhmetova, A.T. Medeshova, S.N. Shaikina, A. Ramazonova, A.B. Abdikalik, M.E. Zholdasbayev, Zh. T. Amirkhanova // *Research Journal of Pharmacy and Technology*. — 2026. — Vol. 19(1). — P. 131–136. <https://doi.org/10.52711/0974-360X.2026.00020>
- 14 Turdiyeva Zh. A. Histochemical Analysis of The Aerial part of *Ferula songarica* growing in the Territory of the Karaganda Region (Central Kazakhstan) / Zh. A. Turdiyeva, M.Y. Ishmuratova, G.A. Atazhanova, A. Ramazonova // *Research Journal of Pharmacy and Technology*. — 2023. — Vol. 16(11). — P. 5079–5074. <https://doi.org/10.52711/0974-360X.2023.00823>
- 15 Верник Р.С. Некоторые методы изучения популяций сырьевых растений при маршрутных обследованиях // Рациональное использование растительных ресурсов Казахстана / Р.С. Верник. — Алма-Ата: Наука, 1986. — С. 24–27.
- 16 Понятовская В.М. Учет обилия и характера размещения растений в сообществах / В.М. Понятовская // Тр. БИН, Сер. III Геоботаника. — М. -Л.: Наука, 1964. — Вып. 3. — С. 209–299.
- 17 Крылова И.Л. Методика ориентировочной оценки величины запасов лекарственного растительного сырья / И.Л. Крылова, В.И. Капорова, Л.С. Соболева, Т.М. Киселева // *Раст. ресурсы*. — 1989. — Т. 25, № 3. — С. 426–432.
- 18 Куваев В.Б. Направления и принципы ведения ресурсных работ (на примере лекарственных растений) / В.Б. Куваев // *Принципы и методы рационального использования дикорастущих полезных растений*. — Петрозаводск, 1989. — С. 18–33.
- 19 Guideline on Good Agricultural and Collection Practice (GACP) for starting materials of herbal origin. — Committee on Herbal Medicinal Products (HMPC), 2025. — 18 p.
- 20 Ивашин Д.С. Справочник по заготовкам лекарственных растений / Д.С. Ивашин, З.Ф. Катина, И.З. Рыбачук и др. — Киев: Урожай, 1983. — 295 с.
- 21 Флора Казахстана. ТТ. 1–9. — Алма-Ата: Наука, 1956–1966.
- 22 Удольская Н.Л. Методика биометрических расчетов / Н.Л. Удольская. — Алма-Ата: Наука, 1976. — 45 с.

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Орталық Қазақстандағы *Ferula songarica* фитоценодикалық сипаттамасы мен ресурстары (Ұлытау және Қарағанды облыстары шегінде)

Дәрілік өсімдіктердің биологиялық ерекшеліктері мен ресурстық әлеуетін зерттеу қазіргі заманғы ботаника мен фармакогнозияның маңызды міндеті. Қазақстан флорасының перспективалы дәрілік түрлерінің бірі құрамында биологиялық белсенді қосылыстардың жоғары болуымен және бағалы фармакологиялық қасиеттерімен сипатталатын *Ferula songarica*. Осы зерттеудің мақсаты Орталық Қазақстанның табиғи жағдайларында *F. songarica* популяциясын және өсімдік шикізатының ресурстарын анықтау. Далалық зерттеулер 2024-2025 жылдары маршруттық-барлау әдісімен Ұлытау және Қарағанды облыстарының аумағында орналасқан сегіз негізгі учаскеде жүргізілді. Жұмыс барысында өсімдіктердің өсу тығыздығы, морфометриялық көрсеткіштері, өнімділігі, шикізаттың пайдалану қорлары және ықтимал жинау көлемі айқындалды. *F. songarica* қатысатын табиғи популяциялар дарактардың сирек кеңістікте орналасуымен сипатталатыны айқындалды. Генеративтік өсімдіктердің тығыздығы 0,36-дан 6,05 данадан /10 м², ал өсімдіктердің биіктігі 83,06-133,2 см құрайды, Тамыр өнімділігі ауа-құрғақ салмаққа есептегенде 3580-7010 кг/га, жерүсті органдары — 234-315 кг/га құрады. Шикізат дайындау үшін жарамды учаскелердің жиынтық ауданы 281,5 га болды. Түбірлердің пайдалану қоры 1874,85 тоннаға, шөптер 79,22 тоннаға бағаланды. Ықтимал тамыр жинау көлемі 183,8 тонна, жерүсті органдары — 55,43 тонна деңгейінде есептелген. Алынған нәтижелер дәрілік және парафармацевтикалық заттарды өндіру үшін табиғи жағдайларда *F. songarica* шикізатын жинау мүмкіндігін көрсетеді.

Кілт сөздер: *Ferula songarica*, популяциясы, өнімділігі, Орталық Қазақстан, пайдалану қоры, ықтимал жинау көлемі, тамыры, биомассасы, дәрілік өсімдік шикізаты.

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Фитоценодикалық характеристика и ресурсы *Ferula songarica* в Центральном Казахстане (в пределах Улытауской и Карагандинской областей)

Изучение биологических особенностей и ресурсного потенциала лекарственных растений является важной задачей современной ботаники и фармакогнозии. Одним из перспективных лекарственных видов флоры Казахстана является *Ferula songarica*, характеризующаяся высоким содержанием биологически активных соединений и ценными фармакологическими свойствами. Целью настоящего исследования являлось выявление популяций *F. songarica* в природных условиях Центрального Казахстана и оценка ресурсов растительного сырья. Полевые исследования проводились в 2024-2025 гг. маршрутно-рекогносцировочным методом на восьми ключевых участках, расположенных на территории Улытауской и Карагандинской областей. В ходе работы определялись плотность произрастания, морфометрические показатели растений, урожайность, эксплуатационные запасы сырья и объем возможного сбора. Установлено, что природные популяции с участием *F. songarica* характеризуются разреженным пространственным размещением особей. Плотность генеративных растений варьирует от 0,36 до 6,05 экз./10 м², а высота растений составляет 83,06–133,2 см. Урожайность корней в пересчете на воздушно-сухой вес составила 3580–7010 кг/га, надземных органов — 234–315 кг/га. Совокупная площадь участков, пригодных для заготовки сырья, составила 281,5 га. Эксплуатационный запас корней оценен в 1874,85 тонн, травы — 79,22 тонн. Объем возможного сбора корней рассчитан на уровне 183,8 тонн, надземных органов — 55,43 тонн. Полученные результаты показывают возможность сбора сырья *F. songarica* в природных условиях для производства лекарственных и парафармацевтических средств.

Ключевые слова: *Ferula songarica*, популяция, урожайность, Центральный Казахстан, эксплуатационный запас, объем возможного сбора, корни, надземная биомасса, лекарственное растительное сырье.

References

- 1 Parshina, G.N., Mukiyanova, U., & Shabanova, L.V. (2012). Sokhranenie i upravlenie bioraznoobraziem v Respublike Kazakhstan [Conservation and Management of Biodiversity in the Republic of Kazakhstan]. *Vestnik Kazakhskogo Natsionalnogo Universiteta. Seriya Biologicheskaya — Bulletin of the Kazakh National University. Biological Series*, 2(54), 16–20 [in Russian].
- 2 Grudzinskaya, L.M., Gemedzhieva, N.G., Nelina, N.V., & Karzhaubekova, Zh.Zh. (2014). *Annotirovannyi spisok lekarstvennykh rastenii Kazakhstana: Spravochnoe izdanie* [An Annotated List of Medicinal Plants of Kazakhstan: Reference Publication]. Almaty [in Russian].

- 3 Mukhtubayeva, S.K. (2010). O sovremennykh tendentsiakh ispolzovaniia feruly voniuchei (*Ferula foetida* L.) v Yuzhnom Kazakhstane [On current trends in the use of *Ferula foetida* L. in Southern Kazakhstan]. *Vestnik Pavlodarskogo gosudarstvennogo universiteta. Khimiko-biologicheskaya seriya — Bulletin of Pavlodar State University. Chemical and Biological Series*, 1, 87–90 [in Russian].
- 4 Majid Mohammadhosseini, M., Venditti, A., Sarker, S.D., Nahar, L., & Akbarzadeh, A. (2019). The genus *Ferula*: Ethnobotany, phytochemistry and bioactivities — A review. *Industrial Crops and Products*, 129, 350–394. <https://doi.org/10.1016/j.indcrop.2018.12.012>
- 5 Alruways, M.W. (2023). Antimicrobial effects of *Ferula* species — an herbal tactic for management of infectious diseases. *Journal of King Saud University, Science series*, 10, 102806. <https://doi.org/10.1016/j.jksus.2023.102806>
- 6 Mahendra, P., & Bisht, S. (2012). *Ferula asafoetida*: Traditional uses and pharmacological activity. *Pharmacognosy reviews*, 6(12), 141–146. <https://doi.org/10.4103/0973-7847.99948>
- 7 Safina, L.K., & Pimenov, M.G. (1984). *Feruly Kazakhstana* [Ferula of Kazakhstan]. Almaty: Nauka [in Russian].
- 8 Zubaydova, T.M., Jamshedov, J.N., Isupov, S.J., Zagrebely, I.A., Davlatkadamov, S.M., Sodikov, J., & Sukhrovov, P.Sh. (2014). O farmakologicheskom issledovanii raznykh vidov roda *Ferula* L. v meditsine XX veka [On the pharmacological study of various species of the genus *Ferula* L. in 20th-century medicine]. *Vestnik Tadzhikskogo natsionalnogo universiteta. Seriya estestvennykh nauk — Bulletin of Tajik National University. Natural Sciences Series*, 1/3(134), 225–229 [in Russian].
- 9 Khosnutdinova, T.S., Gemejiyeva, N.G., Karzhaubekova, Zh.Zh., & Sultanova, N.A. (2023). Coumarins of the genus *Ferula* L. (Apiaceae Lindl.). *Eurasian Chem.-Technol. J.*, 25(1), 39–56. <https://doi.org/10.18321/ectj1494>
- 10 Boghrati, Z., & Iranshahi, M. (2019). *Ferula* species: A rich source of antimicrobial compounds. *Journal of Herbal Medicine*, 16, 00244. <https://doi.org/10.1016/j.hermed.2018.10.009>
- 11 Chen, Z., Zhou, G., & Ma, S. (2023). Research Progress of *Ferula ferulaeoides*: A Review. *Molecules*, 28(8), 3579. <https://doi.org/10.3390/molecules28083579>
- 12 Korovin, E.P. (1962). *Ferula* — *Ferula* L. [Ferula — *Ferula* L.]. *V knige: Flora Kazakhstana — In Book: Flora of Kazakhstan*, 6, 385–413. Almaty [in Russian].
- 13 Turdiyeva, Zh.A., Atazhanova, G.A., Ishmuratova, M.Y., Samorodov, A.V., Akhmetova, S.B., Medeshova, A.T., Shaikina, S.N., Ramazanova, A., Abdikalik, A.B., Zholdasbayev, M.E., & Amirhanova, Zh.T. (2026). Development of the Composition and Technology of an Antifungal Gel with *Ferula songarica* Essential Oil Grown in the Territory of Central Kazakhstan. *Research Journal of Pharmacy and Technology*, 19(1), 131–136. <https://doi.org/10.52711/0974-360X.2026.00020>
- 14 Turdiyeva, Zh. A., Ishmuratova, M. Y., Atazhanova, G. A., & Ramazanova, A. (2023). Histochemical Analysis of the Aerial Parts of *Ferula songarica* Growing in the Karaganda Region (Central Kazakhstan). *Research Journal of Pharmacy and Technology*, 16(11), 5079–5074. <https://doi.org/10.52711/0974-360X.2023.00823>
- 15 Vernik, R.S. (1986). Nekotorye metody izucheniia populiatsii syrevykh rastenii pri marshrutnykh obsledovaniiah [Some methods for studying populations of medicinal plants during route surveys]. *Ratsionalnoe ispolzovanie rastitelnykh resursov Kazakhstana — Rational use of plant resources of Kazakhstan* (pp. 24–27). Almaty: Nauka [in Russian].
- 16 Ponyatovskaya, V.M. (1964). Uchet obilii i kharaktera razmeshcheniia rastenii v soobshhestvakh [Accounting for the Abundance and Distribution of Plants in Communities]. *Trudy Botanicheskogo instituta, Seriya III Geobotanika — Proceedings of the Botanical Institute, Series III: Geobotany*, 3, 209–299. Moscow-Leningrad: Nauka [in Russian].
- 17 Krylova, I.L., Kaporova, V.I., Soboleva, L.S., & Kiseleva, T.M. (1989). Metodika orientirovochnoi otsenki velichiny zapasov lekarstvennogo rastitelnogo syria [Methodology for the preliminary assessment of medicinal plant raw material reserves]. *Rastitelnye Resursy — Vegetation Resources*, 25(3), 426–432 [in Russian].
- 18 Kuvaev, V.B. (1989). Napravleniia i printsipy vedeniia resursnykh rabot (na primere lekarstvennykh rastenii) [Directions and principles of resource management (using medicinal plants as an example)]. *Printsipy i metody ratsionalnogo ispolzovaniia dikorastushchikh poleznykh rastenii — Principles and methods of rational use of wild useful plants* (pp. 18–33). Petrozavodsk [in Russian].
- 19 (2025). *Guideline on Good Agricultural and Collection Practice (GACP) for starting materials of herbal origin*. Committee on Herbal Medicinal Products (HMPC).
- 20 Ivashin, D.S., Katina, Z.F., Rybachuk, I.Z., et al. (1983). *Spravochnik po zagotovkam lekarstvennykh rastenii* [Handbook on the Harvesting of Medicinal Plants]. Kyiv: Urozhai [in Russian].
- 21 (1956–1966). *Flora Kazakhstana* [Flora of Kazakhstan]. Vols. 1–9. Almaty: Nauka [in Russian].
- 22 Udolskaya, N.L. (1976). *Metodika biometricheskikh raschetov* [Methods of Biometric Calculations]. Alma-Ata: Nauka [in Russian].

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Anatomical structure of the leaves and shoots of *Sophora japonica* grown under cultivation in Aktau (Mangistau Region)

Selecting an adaptive plant assortment under conditions of global climate change and increasing aridification is a critical task for modern botanical science. This study focuses on the anatomical structure of young shoots and leaves of *Sophora japonica* to assess its adaptability to the arid conditions in the city of Aktau. Plant samples grown in the Mangyshlak Experimental Botanical Garden were collected for the study. Leaves and shoots were fixed, examined using a freezing microtome, and subsequently described in terms of their anatomical structure, with measurements taken of individual tissues. The results revealed that the leaf of *Sophora japonica* is of the light-type, with a clear division of the mesophyll into palisade and spongy tissues, the presence of a cuticle, and single- and multicellular trichomes on the epidermis; the stomata are of the anomocytic type, and based on their arrangement, the leaf is of the amphistomatic type. The mesophyll contains numerous calcium oxalate druses, localized primarily along the leaf veins. One-year-old shoots have a secondary anatomical structure, featuring a wide zone of chlorenchyma and a narrow zone of parenchyma. Xylem elements are small. The shoot epidermis exhibits a significant cuticle layer and soft trichome pubescence. This set of microscopic characteristics confirms the species' adaptation to the arid conditions of the city of Aktau.

Keywords: *Sophora japonica*, shoot, leaf, subtropical plant, anatomical study, diagnostic signs, adaptation to arid climate.

Introduction

Kazakhstan, especially its arid regions such as Mangistau, is facing accelerated aridification of the climate [1]. This poses challenges for biodiversity and agriculture, particularly due to the loss of plant species capable of adapting to extreme climatic conditions [2, 3].

Climate change projections indicate increased drought and rising average annual temperatures [4], which necessitate the development of sustainable strategies for the conservation and use of drought-tolerant plants. One promising direction is the introduction of subtropical woody xerophytes, which are well adapted to conditions of water scarcity and high temperatures [5].

Globally, subtropical plants are widely studied in countries with warm climates, such as Greece, Turkey, Spain, and others [6–8]. These studies aim to conserve and utilize subtropical plants under climate change conditions; however, they focus on areas with milder climates compared to the arid regions of Kazakhstan.

In the Republic of Kazakhstan, research related to the introduction of subtropical plants into arid regions is still in its early stages. To date, the mechanisms by which subtropical plants adapt to conditions of extreme drought have not been sufficiently studied, which limits the possibility of their widespread use for landscaping and land restoration. The lack of knowledge regarding the physiological, phenological, morphological, and genetic mechanisms by which these plants adapt to conditions in Mangistau necessitates in-depth research.

Therefore, a promising area of research at this time is the assessment of the degree of adaptation of subtropical plants to the extra-arid climate of Kazakhstan, including the evaluation of physiological, phenological, and anatomical-morphological indicators.

The aim of this study is to assess the characteristics of the anatomical structure of the leaves and shoots of the subtropical plant *Sophora japonica* growing in the conditions of Aktau.

Experimental

The study subjects were shoots and leaves of *Sophora japonica* (Fig. 1), collected from the dendrological section of the Mangyshlak Experimental Botanical Garden in May and August 2026.



Figure 1. Flowering (A) and fruiting (B) *Sophora japonica* plants in the Mangyshlak Experimental Botanical Garden

The structural study included microscopic analysis of tissues to identify anatomical changes associated with drought adaptation. This will help us understand how changes in cell and tissue structure contribute to water conservation and ensure plant survival under water-deficient conditions. Anatomical analysis will also be used to assess the condition of generative organs, which is important for understanding the mechanisms of drought tolerance.

Shoots and leaf samples were fixed in Fleming's solution [9], consisting of distilled water, 96 % ethyl alcohol, and glycerin in a 40:40:40 ratio (1:1:1). Transverse sections were prepared on an OMT-2802E freezing microtome, MZP-01 "TEKHNOM" (Russia). The resulting sections were examined and photographed using a Stemi 2000 MA151/35/20 microscope (China) at magnifications of $\times 60$, $\times 150$, and $\times 240$. Photo processing and measurements were performed using the HistoLab software. Specimens were cleared using glycerin [10]. Blue and green light filters were used to ensure image clarity.

Microscopic preparations were described according to methodological guidelines [11, 12].

All measurements were performed in 10 replicates. Data are presented as mean \pm standard deviation (SD). Differences between treatments were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's honestly significant difference (HSD) test at a significance level of $p < 0.05$.

Results and Discussion

The leaf of *Sophora japonica* is compound, imparipinnate, consisting of 6–15 pairs of leaflets. The leaves are dark green, almost smooth, and glossy on the adaxial side; on the abaxial side, they are light green and sparsely pubescent.

Microscopically, the leaf is of the light-type, flat, and dorsoventral in structure (Figs. 2, 3). The surface on both sides is covered by a single-layered epidermis; the thickness on the upper side is 1.46 μm , and on the lower side, 1.23 μm (Tab. 1). On the lower side, long, sparse, simple trichomes are noted, the length of which may exceed the thickness of the mesophyll. On the upper side of the leaf, the trichomes are small, unicellular, and pressed against the surface. The trichomes are unicellular and multicellular, with thin walls, straight or sickle-shaped. The cells on the adaxial side are larger and oval-shaped; the cuticle layer is thicker. On the abaxial side, the cells are clearly defined, and the cuticle layer is thin.

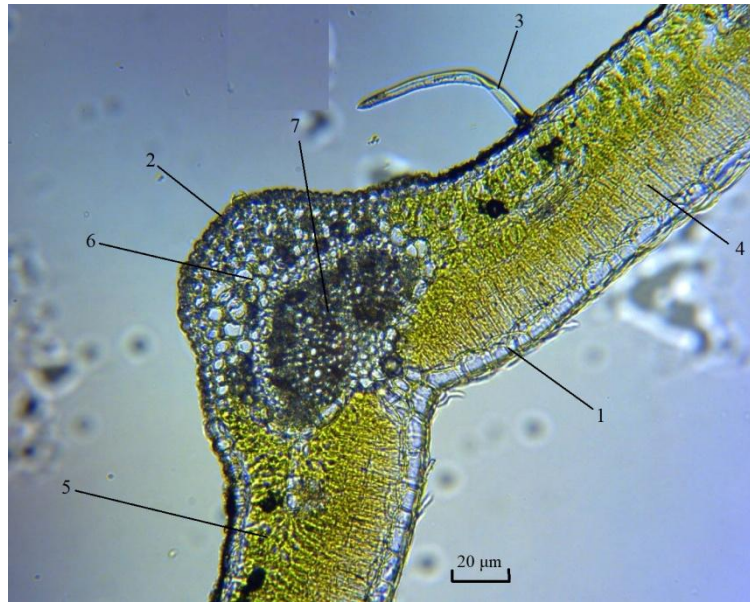


Figure 2. Cross-section of a *Sophora japonica* leaf, fragment in the region of the midrib
 1 — upper epidermis, 2 — lower epidermis, 3 — trichome, 4 — palisade mesophyll,
 5 — spongy mesophyll, 6 — loose collenchyma, 7 — vascular bundle



Figure 3. Cross-section of a *Sophora japonica* leaf, lateral fragment
 1 — upper epidermis, 2 — lower epidermis, 3 — trichome, 4 — palisade mesophyll, 5 — spongy mesophyll

Table 1

Dimensions of certain leaf tissues of *Sophora japonica*

| No. | Tissues | Parameters |
|-----|-------------------------|------------|
| 1 | Epidermal cell size, μm | |
| 1.1 | Upper side | 1.46±0.008 |
| 1.2 | Lower side | 1.23±0.10 |

Continuation of Table 1

| No. | Tissues | Parameters |
|-----|------------------------------------|------------------|
| 2 | Mesophyll thickness, μm | 18.69 ± 0.43 |
| 3 | Columnar mesophyll | |
| 3.1 | Number of rows, pieces | 1–2 |
| 3.2 | Row thickness, μm | 7.78 ± 0.29 |
| 4 | Spongy mesophyll | |
| 4.1 | Number of rows, pieces | 3 |
| 4.2 | Row thickness, μm | 8.94 ± 0.13 |

The mesophyll has a thickness of $18.69 \mu\text{m}$ in the lateral part of the leaf and is well divided into palisade and spongy tissues. The palisade tissues are 1-layered, rarely 2-layered, with a thickness of $7.78 \mu\text{m}$. The spongy tissues form up to 3 layers, and the thickness of this zone is $8.94 \mu\text{m}$. The central bundle is oval, slightly curved, collateral, of the closed type, surrounded by areas of loose collenchyma, the zones of which are thicker on the lower side. The phloem occupies an extremely small area, whereas the xylem occupies the main part. Under the epidermis, rare calcium oxalate crystals are noted, located primarily along the leaf veins (Fig. 4).

The leaf epidermis on both sides consists of cells with slightly curved lateral walls (Fig. 4); the walls are thickened. Stomata are numerous, of the anomocytic type, and located on both sides (amphistomatic type). Above the leaf veins, the epidermis consists of prosenchyma cells with straight walls. Numerous druses are visible through the epidermis.

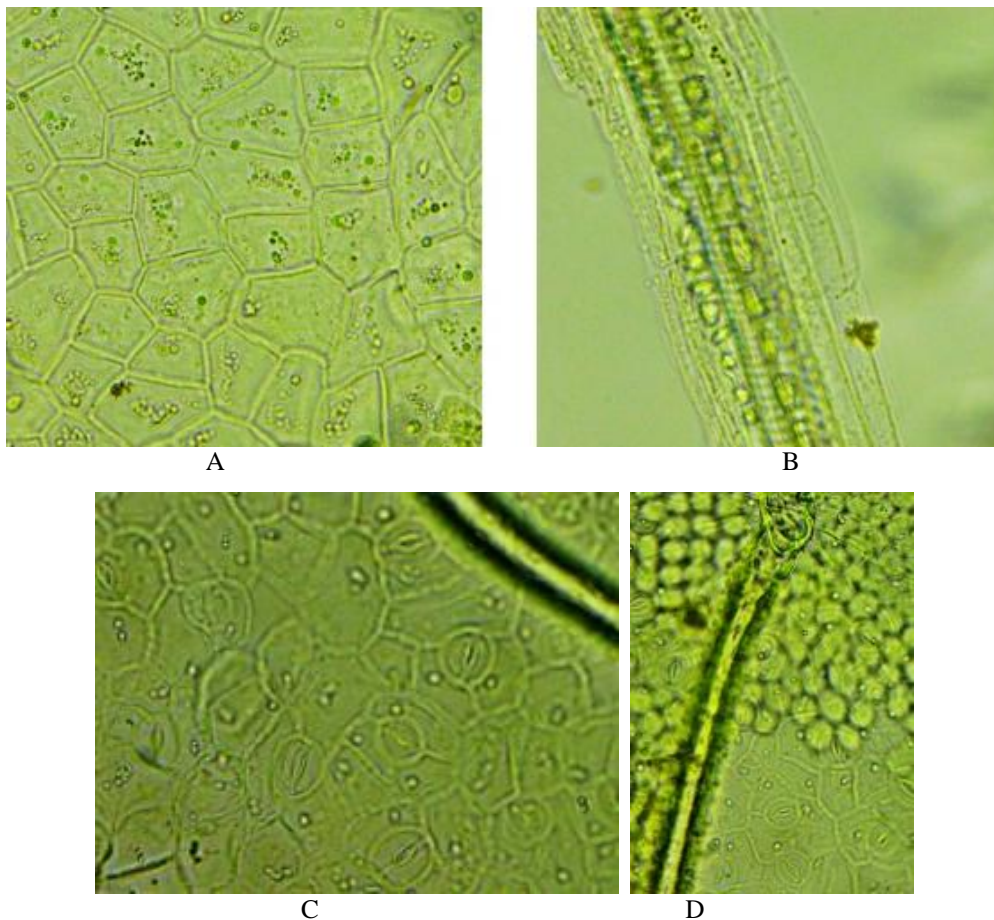


Figure 4. Surface preparation of *Sophora japonica*:

A — epidermis, B — crystalline inclusions along the leaf vein; C — anomocytic stomata, D — trichome

Trichomes are simple multicellular hairs consisting of a short base and long cells with a thick cuticle layer and warty walls.

Leaf tissues are characterized by large-celled structures, a well-developed cuticle on the upper surface, and pubescence on the lower surface, which is an adaptive trait for solar activity. The differentiated mesophyll indicates a light-demanding leaf type, and the presence of calcium oxalate druses indicates tolerance to growth on saline soils.

Young shoots of *Sophora japonica* are green or greenish-gray in color, often sparsely pubescent with short, simple hairs, and less frequently glabrous. The one-year-old shoot is rounded-lobed and non-fasciculate in structure (Fig. 5). The general pattern of microscopic structure is characteristic of secondary thickening.

The epidermis forms the outermost layer, with a thickness of 1.89 μm (Tab. 2); it consists of small, nearly rectangular cells. A fairly thick layer of cuticle is visible on the surface. The epidermis is reinforced by a ring of collenchyma cells lying beneath it. The chlorenchyma is 16.8 μm thick. The cortical parenchyma is also thick, with cells of a sinuous shape.

The sclerenchyma ring occupies a significant portion of the internal tissues and consists of small cells with barely visible intercellular spaces. The vascular system itself is of the non-bundled type, although clusters of fused bundles can be observed. The sclerenchyma ring is separated from the parenchyma by a layer of endoderm consisting of oval cells with straight walls.

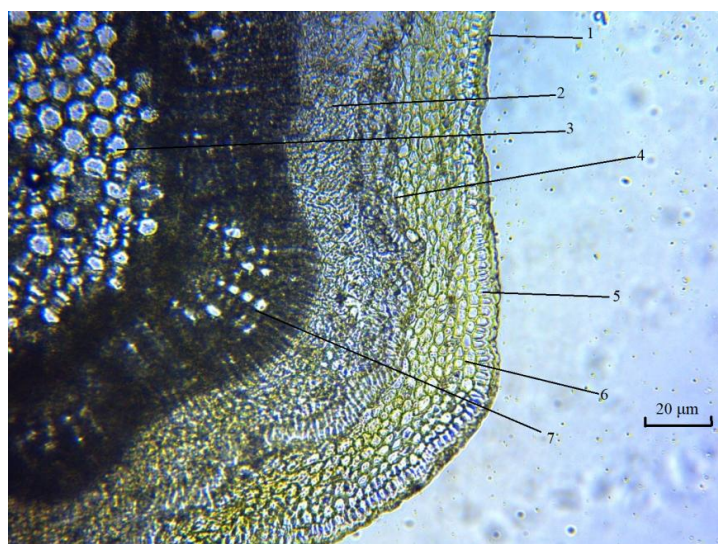


Figure 5. Cross-section of a one-year-old shoot of *Sophora japonica*, fragment 1 — epidermis, 2 — cork parenchyma, 3 — pith, 4 — endodermis, 5 — collenchyma, 6 — chlorenchyma, 7 — xylem

Table 2

Dimensions of some tissues of a one-year-old shoot of *Sophora japonica*

| No. | Tissues | Parameters |
|-----|--|--------------|
| 1 | Epidermis thickness, μm | 1.89±0.04 |
| 2 | Thickness of the parenchyma layer, μm | 16.80 ± 0.72 |
| 3 | Diameter of xylem vessels, μm | 2.30±0.13 |
| 4 | Area of xylem vessels, ×10 ⁻³ mm ² | 4.76±0.11 |
| 5 | Diameter of heartwood parenchyma cells, μm | 4.28±0.53 |

The phloem layer is thin, while the xylem layer is substantial. The average diameter of xylem vessels is 2.3 μm, and their area is 4.76 μm². The central part is occupied by loose cells of the medullary parenchyma, with a cell diameter of 4.28 μm.

The formation of a wide zone of cortex and chlorenchyma, the absence of a thick cuticle layer on the stem epidermis, and the development of mechanical tissues on the young shoot confirm the species' adaptability to arid conditions. These changes help conserve moisture, provide rigidity to cells when turgor is lost, and the development of pubescence allows for the dissipation of excess sunlight.

Conclusion

Microscopic examination of *Sophora japonica* grown in the Mangistau region revealed diagnostic features such as amphistomatic leaf type, an epidermis consisting of isodiametric cells with slightly curved walls, the presence of long, multicellular, coarse, wart-like hairs, a thick cuticle layer, and the presence of calcium oxalate crystals in the leaf mesophyll; a secondary anatomical structure of the stem with a well-defined zone of chlorenchyma and medullary parenchyma, a single-layered collenchyma, pubescence, and a cuticle on the stem epidermis.

It has been determined that the anatomical structure of the leaf and shoot indicates the plant's adaptability to the extra-arid conditions of the city of Aktau, which confirms the possibility of its widespread use in the region's green construction.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Imanbayeva A.A.** — conceptualization, laboratory experiments, investigation; **Tuyakova A.T.** — anatomical study, data description, draft writing; **Duysenova N.I.** — data analysis, data collection, draft writing.

Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W., & Courchamp, F. (2012). Impacts of climate change on the future of biodiversity. *Ecology Letters*, *15*, 365–377. DOI: 10.1111/j.1461-0248.2011.01736x
- 2 Borisov, A.V., Alekseev, A.O., Demkina, T.S., Eltsov, M.V., Kalinin, P.I., Alekseeva, T.V., & Khomutova, T.E. (2010). Climate Dynamics and the History of Soil Formation in the Steppe Zone of Eastern Europe in the Holocene. *Paleontological Journal*, *54*(8), 862–871.
- 3 Zhong, L., Ma, Y.M., Salama, M.S., & So, Z. (2010). Assessment of vegetation dynamics and their response to variations in precipitation and temperature in the Tibetan Plateau. *Climatic Change*, *103*, 3–4, 519–535.
- 4 (2019). Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Global Assessment Report on Biodiversity and Ecosystem Services. Retrieved from https://files.ipbes.net/ipbes-web-prod-public-files/americas_assessment_en.pdf
- 5 (2022). World Wide Fund for Nature (WWF). Living Planet Report. Retrieved from https://wwfint.awsassets.panda.org/downloads/embargo_13_10_2022_lpr_2022_full_report_single_page_1.pdf
- 6 (2026). Climate Change in Asian Regions. www.unep.org. Retrieved from <https://www.unep.org/ru/novosti-i-istorii/press-reliz/izmenenie-klimata-privodit-k-povysheniyu-temperatury-i-silnoy-zasukhe>
- 7 Mishra, S., & Krska, B. (2009). Temperature as a basic factor influencing phenological stages in *Zizyphus jujuba* Mill. *Acta Univ. Agric. Silvicult. Mendeliane Brunensins*, *57*(1), 89–95.
- 8 Quero, J.L., Villar, R., Marañón, T., & Zamora, R. (2006). Interactions of drought and shade effects on seedlings of four *Quercus* species: physiological and structural leaf responses. *New Phytologist*, *170*(4), 19–34. DOI: 10.1111/J.1469-8137.2006.01713
- 9 (1998). Botanical Microtechnique: a Handbook of Methods of Preparation, Staining, and of Microscopical Investigation of Vegetable Structures. *Nature*, *57*, 340. DOI: 10.1038/057340c0
- 10 Land, W.J.G. (2016). Botanical Microtechnique. *Botanical Gazette*, *61*(5), 448.
- 11 Crang, R., Lyons-Sobaski, S., & Wise, R. (2018). *Plant Anatomy: A Concept-Based Approach to the Structure of Seed Plants. Textbook*. Springer.
- 12 Cutler, D.F., Botha, T., & Stevenson, D.W. (2008). *Plant Anatomy: An Applied Approach*. Wiley-Blackwell.

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Ақтау (Маңғыстау облысы) дақылдарында өсірілген *Sophora japonica* жапырағы мен өркендерінің анатомиялық құрылымы

Климаттың жаһандық өзгеруі және аридизацияны күшейту жағдайында өсімдіктердің бейімделген ассортиментін таңдау қазіргі заманғы ботаникалық ғылымның маңызды міндеті. Жұмыстың мақсаты — Ақтау қаласының құрғақ жағдайларына бейімделуді бағалау үшін *Sophora japonica* жас өскіні мен жапырағының анатомиялық құрылымын бағалау. Зерттеу үшін Маңғышлақ эксперименталды ботаникалық бағында өсірілген өсімдіктердің үлгілері алынды. Жапырақтары мен өркендері іріктеліп, мұздатқыш микротомды қолдана отырып, микроскопия жасалды және анатомиялық құрылымды әрі қарай сипаттап, жеке тіндердің параметрлері өлшенді. Нәтижесінде *Sophora japonica* жапырағының жарқырауық типте екендігі, мезофиллдің палисадты және кеуек тәрізді тіндерге анық бөлінуі, эпидермисте кутикуланың, бір және көп жасушалы трихомалардың болуы; саңылауы аномоцитарлы типке, ал орналасуына қарай жапырақ амфистоматикалық типке жатады. Мезофиллде кальций оксалатының көптеген друздері бар, олар негізінен жапырақ тамырлары бойымен оқшауланған. Жылдық өркендер қайталама анатомиялық құрылымға ие, хлоренхима мен қабық паренхимасының кең аймағына ие. Ксилема элементтері ұсақ. Өркеннің эпидермисінде кутикуланың едәуір қабаты және жұмсақ трихомалардың түкті болуы байқалады. Микроскопиялық белгілер кешені түрдің Ақтау қаласының құрғақ жағдайларына бейімделуін растайды.

Кілт сөздер: *Sophora japonica*, өркен, жапырақ, субтропикалық өсімдік, анатомиялық зерттеу, диагностикалық белгілер, аридті климатқа бейімделу.

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Анатомическое строение листа и побега *Sophora japonica* выращенного в культуры в Ақтау (Мангистауская область)

Подбор адаптивного ассортимента растений в условиях глобального изменения климата и усиления аридизации является важной задачей современной ботанической науки. Цель настоящей работы заключалась в оценке анатомического строения молодого побега и листа *Sophora japonica* для оценки адаптивности к аридным условиям города Ақтау. Для исследования были взяты образцы растений, выращенных в Мангышлакском экспериментальном ботаническом саду. Листья и побеги фиксировали, выполняли микроскопирование с использованием замораживающего микротомы и дальнейшим описанием анатомического строения и измерением параметров отдельных тканей. Результаты позволили выявить, что лист *Sophora japonica* светового типа, с четким делением мезофилла на палисадную и губчатую ткани, наличием кутикулы, одно- и многоклеточных трихом на эпидермисе; устьица аномоцитного типа, по их размещению — лист амфистоматического типа. В мезофилле присутствуют многочисленные друзы оксалата кальция, локализованные преимущественно вдоль жилок листа. Годичные побеги имеют вторичное анатомическое строение, обладают широкой зоной хлоренхимы и коровой паренхимы. Ксилемные элементы мелкие. На эпидермисе побега отмечен значительный слой кутикулы и присутствие опушения из мягких трихом. Комплекс микроскопических признаков подтверждает адаптацию вида к засушливым условиям города Ақтау.

Ключевые слова: *Sophora japonica*, побег, лист, субтропическое растение, анатомическое исследование, диагностические признаки, адаптация к аридному климату.

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Search for promising medicinal plants of the *Rosaceae* family in the flora of the Mangistau Region

The study of medicinal plants in the regions of Kazakhstan is of great importance for identifying new sources of medicinal raw materials. The Mangistau Region is one of the least studied areas in Kazakhstan in terms of the potential and raw material resources of medicinal plants. This study assessed the potential medicinal use of members of the *Rosaceae* family. Twelve species belonging to eight genera of the *Rosaceae* family were recorded in the Mangistau Region. Among life forms, trees (4), shrubs (6), annual (1), and perennial (1) herbs were identified. In terms of ecology, the species were classified as mesophytes (7), xeromesophytes (4), and xerophytes (1); in terms of substrate type, they were classified as psammophytes (1), petrophytes (3), lithophytes (4), and glycophytes (4). The distribution of representatives of this family is ranked as follows: common — 2 taxa, rare — 1, very rare — 6. This situation can be explained by historical reasons and the climatic characteristics of the region. The potential for the medical use of all 12 taxa in the prevention and treatment of various groups of diseases has been established. The introduction of all identified species of this family is recommended, as there are no natural reserves for harvesting raw materials. The data obtained allow for planning further research on their introduction and practical application in medicine and for the production of para-pharmaceutical products.

Keywords: *Rosaceae* family, medicinal plants, summary, life forms, ecological groups, distribution, potential for medical use.

Introduction

Medicinal plants are of great importance worldwide as a source of new drugs, cosmetic preparations, and raw materials for the food industry [1]. For example, in Europe, more than 1,300 medicinal plants are used, of which up to 90 % are considered non-traditional, including wild resources. In the U.S., up to 85 % of prescriptions are based on natural ingredients. When analyzing the situation in developing countries in South America, Africa, and Southeast Asia, more than 80 % of the population uses exclusively traditional medicine, that is, remedies derived from plant and animal sources [2]. In the healthcare systems of developed countries, up to 25 % of prescriptions are for plant-based remedies.

The use of medicinal raw materials varies by country. Traditional Chinese and Indian medicine utilize up to 11,000 plant species, whereas European countries use approximately 300 species (Fig. 1).

Herbal medicines have an advantage over synthetic ones, which lies in their low toxicity, generally mild action, rare induction of allergic reactions, and the possibility of repeated and long-term courses of treatment and prevention. Therefore, the study of plants and the development of highly effective medicines based on them is one of the pressing tasks of medical and pharmaceutical science.

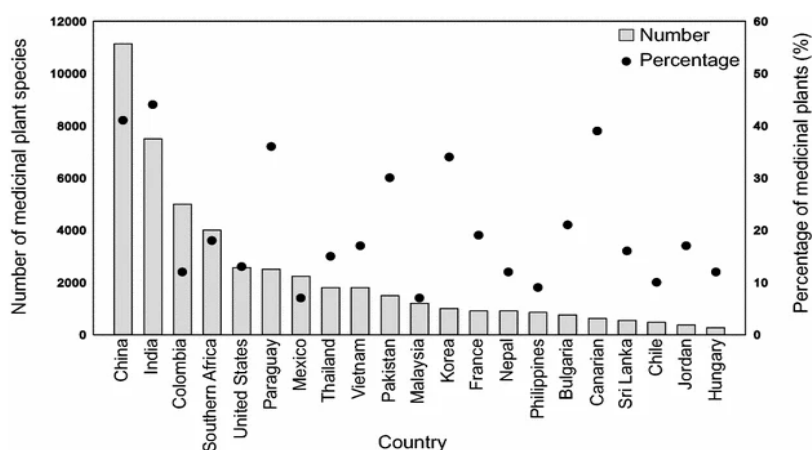


Figure 1. Number and percentage of medicinal plant use in different countries.

The bars in the histogram show the number of species, the dots show the percentage (according to Chen et al., 2016)

In recent decades, there has been a sharp increase in demand for herbal medicines, natural health products, and over-the-counter medications, leading to a rise in their use [3]. According to the IUCN, between 50,000 and 80,000 flowering plant species worldwide are used by people for medicinal purposes [4]. This raises the issue of preserving medicinal resources, as some authors estimate [5] that one medicinal species disappears every two years. Approximately 15,000 species are threatened with extinction, and 20 % of natural resources have been virtually depleted as a source of raw materials [6]. This problem is particularly acute in Africa, India, and China. The risk of extinction is linked to habitat destruction and intensive harvesting, which prevents plants from regenerating their populations.

Therefore, many countries around the world are developing regional programs to assess the status of natural resources, monitor their condition, evaluate genetic diversity, and implement in situ and ex situ conservation programs [6–8]. The most common measures include: conservation in natural habitats, shifting industrial production to cultivation, and conservation in the form of living collections at botanical institutions and seed banks (Fig. 2).

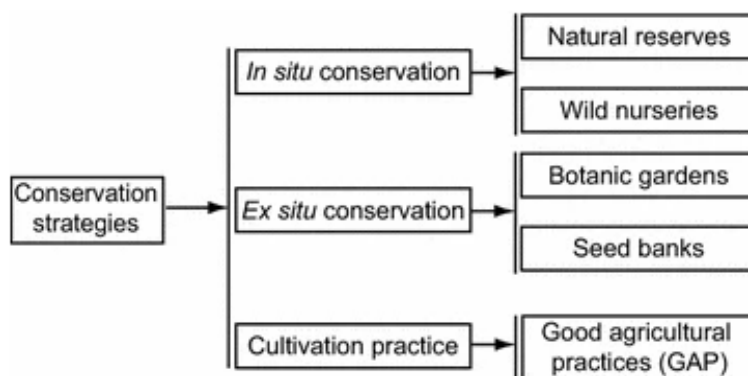


Figure 2. Schemes of methodological systems for the conservation of medicinal plants in global practice

Thus, an analysis of the global situation regarding medicinal plants reveals prospects for their comprehensive study, both in the wild and in cultivation, as well as the expansion of their practical applications. Among taxonomic groups, the Rosaceae family is of particular interest, as its species possess many useful properties: edible, ornamental, honey-producing, forage, medicinal, and decorative, among others.

The aim of this study is to assess the potential of medicinal plants of the Rosaceae family in the flora of the Mangistau Region for use in the treatment and prevention of various diseases.

Experimental

The subject of the study was species of the Rosaceae family in the flora of the Mangistau Region. Data analysis was conducted in 2025–2026. A summary of the species of this family was compiled based on an

analysis of field journals, MANG herbarium materials, data from the iNaturalist platform, and a summary of the region's flora [9].

The names of the accepted plant taxa are given according to data from the Plants of the World Online (POWO) platform [10].

To assess the potential for utilizing raw materials from natural habitats, the occurrence of this family's representatives in the wild was evaluated using the following categories: common, occasional, rare, and very rare [11].

Plants were ranked according to their medicinal properties based on literature data [12–18].

Results and Discussion

The territory of the Mangistau Region (Western Kazakhstan) is characterized by extremely arid conditions [19], which creates difficulties for the growth of many plant groups; however, the climatic conditions (moisture deficit and high solar insolation) are favorable for the accumulation of many groups of biologically active substances [20, 21].

An analysis of data on the region's flora showed that 770 species of vascular and higher spore-bearing plants, belonging to 333 genera and 73 families, grow in the region [9]. The largest families are Asteraceae, Boraginaceae, Brassicaceae, Caryophyllaceae, Chenopodiaceae, Fabaceae, Poaceae, and Polygonaceae, which account for up to 65 % of the total number of species.

The Rosaceae family in the flora of the Mangistau Region is not large in terms of species composition, comprising 12 species from 8 genera (Tab. 1).

Table 1

List of species of the Rosaceae family in the flora of the Mangistau Region, with brief descriptions

| No. | Species | Life form | Ecological group | Economic importance | Distribution |
|-----|--|------------------|---------------------------|--|--------------|
| 1 | <i>Armeniaca vulgaris</i> Lam. | Tree | Xeromesophyte, glycophyte | Medicinal, edible, ornamental, honey plant | Very rare |
| 2 | <i>Crataegus altaica</i> Lge. | Tree | Xeromesophyte, petrophyte | Ornamental, honey plant, medicinal, edible | Very rare |
| 3 | <i>Crataegus ambigua</i> C.A. Mey | Tree, shrub | Xeromesophyte, lithophyte | Ornamental, honey plant, medicinal, edible | Occasional |
| 4 | <i>Malus sieversii</i> (Ledeb.) M. Roem. | Tree | Mesophyte, lithophyte | Medicinal, edible, fodder, ornamental, honey plant | Very rare |
| 5 | <i>Potentilla pedata</i> Willd. ex Hornem. | Perennial | Xerophyte, psammophyte | Ornamental, medicinal | Common |
| 6 | <i>Potentilla supina</i> L. | Annual, biennial | Mesophyte, petrophyte | Medicinal, forage, ornamental, honey plant | Occasional |
| 7 | <i>Prunus spinosa</i> L. | Shrub | Mesophyte, glycophyte | Medicinal, edible, forage, ornamental, honey plant | Very rare |
| 8 | <i>Rosa canina</i> L. | Shrub | Mesophyte, glycophyte | Medicinal, edible, ornamental, honey plant | Very rare |
| 9 | <i>Rosa iliensis</i> Chrshan. | Shrub | Mesophyte, lithophyte | Medicinal, ornamental | Very rare |
| 10 | <i>Rosa laxa</i> Retz. | Shrub | Mesophyte, glycophyte | Medicinal, edible, ornamental | Occasional |
| 11 | <i>Rubus caesius</i> L. | Shrub | Mesophyte, lithophyte | Medicinal, edible, forage, ornamental, honey plant | Common |
| 12 | <i>Spiraea hypericifolia</i> L. | Shrub | Xeromesophyte, petrophyte | Medicinal, forage, ornamental, honey plant | Rare |

Despite the extremely arid conditions of the Mangistau Region, most of the identified species are mesophytes in terms of moisture requirements — 7 taxa, or 58.3 % — while 4 species are classified as xeromesophytes, accounting for 33.3 %. Only one species is classified as xerophytes — 8.2 %. This is due to the fact that members of this family primarily grow in gorges, along streams, springs, and seasonal water-courses — that is, in relatively more humid areas. The only xerophyte (*Potentilla pedata*) grows on mountain slopes, in desert zones, and on sandy soils.

In terms of life forms, 4 taxa (33.3 %) are trees, 6 species (50.0 %) are shrubs, and 1 species each (8.2 %) are classified as perennials and herbaceous perennials.

A pronounced ecological differentiation is also observed in relation to the substrate. Thus, the psammophyte (1 taxon — *Potentilla pedata*) grows on sandy soils and helps stabilize the sand. Petrophytes comprise 3 species: *Spiraea hypericifolia*, *Crataegus altaica*, and *Potentilla supina*, which are restricted to rocky slopes and plains, as well as gravelly scree. Lithophytes (4 species: *Rubus caesius*, *Crataegus ambigua*, *Rosa iliensis*, *Malus sieversii*) grow primarily in the cracks of rocky outcrops, especially along springs and streams, and are thus adapted to extreme arid conditions and a limited soil layer. Glycophytes are represented by 4 species (*Armeniaca vulgaris*, *Prunus spinosa*, *Rosa canina*, *Rosa laxa*) and prefer slightly saline soils.

This ratio of ecological groups indicates that the flora of this family formed at the junction of typically steppe, boreal, and desert elements. It is likely that in earlier periods, members of the Rosaceae family were more widely distributed; however, due to subsequent aridification of the climate, their range narrowed to limited mountainous areas where fresh water sources are present.

In terms of distribution within the study area, the species were distributed as follows: common — 2 taxa (16.5 %), including *Rubus caesius* and *Potentilla pedata*. Three taxa (25 %) are occasionally found, including *Rosa laxa*, *Potentilla supina*, and *Crataegus ambigua*. Only one taxon (8.2 %) falls into the “rare” category -*Spiraea hypericifolia*. The remaining 6 species (50.5 %) fall into the “very rare” category. This situation is linked to the region’s climatic conditions, where Rosaceae species grow in more humid areas associated with oases and mountainous regions with springs. This results in a limited number of suitable habitats. This situation indicates the limited availability of raw materials in natural conditions, meaning there is a need to introduce and subsequently cultivate species of the Rosaceae family for their practical use.

When considering their beneficial properties, it was noted that all members of this group possess medicinal, edible, honey-producing, and ornamental properties.

A separate analysis was conducted on the potential medicinal properties of species in the Rosaceae family. For example, **Armeniaca vulgaris** is a valuable source of minerals, pectin, free sugars, pigments, and flavonoids. In folk medicine, it is used for cardiovascular diseases, to boost immunity (Table 2), as a vitamin supplement, for diabetes prevention, and to improve digestion and vision [14].

Table 2

Medicinal properties of medicinal plants of the Rosaceae family growing in the Mangistau Region

| No. | Species | Medicinal properties | | | | | | |
|-----|--|---|---|-----------------------------------|-------------------------|-------------------|---|-------|
| | | For the treatment of the cardiovascular and nervous systems | For the treatment and prevention of gastrointestinal diseases | For allergies and as an antitoxic | As a vitamin supplement | To boost immunity | For the treatment and prevention of kidney diseases | Other |
| 1 | <i>Armeniaca vulgaris</i> Lam. | + | + | | + | + | | + |
| 2 | <i>Crataegus altaica</i> Lge. | + | + | + | + | | | + |
| 3 | <i>Crataegus ambigua</i> C.A. Mey | + | + | + | + | | | + |
| 4 | <i>Malus sieversii</i> (Ledeb.) M. Roem. | | + | + | + | + | + | + |
| 5 | <i>Potentilla pedata</i> Willd. ex Hornem. | + | | | | + | | + |
| 6 | <i>Potentilla supina</i> L. | + | | | | + | | + |
| 7 | <i>Prunus spinosa</i> L. | + | + | | + | | | + |
| 8 | <i>Rosa canina</i> L. | + | + | | + | + | | + |
| 9 | <i>Rosa iliensis</i> Chrshan. | + | + | | + | + | | + |
| 10 | <i>Rosa laxa</i> Retz. | + | + | | + | + | | + |
| 11 | <i>Rubus caesius</i> L. | + | + | + | + | | + | + |
| 12 | <i>Spiraea hypericifolia</i> L. | | | + | | | | + |

The flowers and fruits of *Crataegus altaica* and *Crataegus ambigua* are also a source of vitamins, carotenoids, sugars, and phenolic compounds. They are used in conventional and traditional medicine to treat cardiovascular diseases, as a sedative for the nervous system, as a vitamin supplement, to improve brain function, for hypertension, to improve gastrointestinal function, and as an anti-allergic and antioxidant agent [15].

Malus sieversii is a source of minerals, vitamins, pectins, sugars, and organic acids. The fruits have a beneficial effect on gastrointestinal function, possess mild diuretic and cholagogue properties, promote the elimination of heavy metal salts from the body, and have a general tonic effect [16].

The herbs *Potentilla pedata* and *Potentilla supina* have anti-inflammatory, general tonic, anti-burn, and antimicrobial effects and positively influence the functioning of the cardiovascular system [17].

The fruits of *Prunus spinosa* contain sugars, vitamins, pectins, flavonoids, and organic acids. They are used fresh or dried for constipation, as a carminative and vitamin supplement; they strengthen blood vessel walls, normalize blood pressure, and lower blood cholesterol levels [12, 13].

The fruits of *Rosa canina*, *Rosa iliensis*, and *Rosa laxa* are used as a vitamin supplement; they possess anti-inflammatory, antimicrobial, and cholagogue properties. A decoction is used for hypertension, to strengthen blood vessel walls, and as a sedative [12].

The fruits and leaves of *Rubus caesius* contain minerals, pectins, vitamins, coumarins, fatty oil, and essential oil. The plant is included in vitamin, cholagogue, and stomachic preparations. The roots possess homeostatic properties. In folk medicine, the leaves are used to normalize intestinal peristalsis and externally to wash wounds; decoctions and juice serve as sedatives and antipyretics [12, 13].

The shoots and flowers of *Spiraea hypericifolia* possess antioxidant and antiviral activity, and extracts exhibit antimicrobial and anti-inflammatory effects [18].

Thus, it has been established that all species of the Rosaceae family have potential for medical use in the prevention and treatment of diseases of various etiologies. 10 species are used to treat cardiovascular diseases, 9 taxa are used to treat the gastrointestinal tract, 5 taxa are used as antiallergic and antitoxic agents, 9 species are used as vitamin supplements, 7 species are used to boost immunity, 2 species for the prevention and treatment of urinary tract diseases, and 12 species possess other pharmacotherapeutic properties.

Conclusion

Thus, 12 species of the Rosaceae family have been identified growing in the Mangistau Region. Among the life forms, trees, shrubs, and annual and perennial herbs were identified. In terms of ecology, the species were classified as mesophytes, xeromesophytes, and xerophytes; in terms of substrate type, they were classified as psammophytes, petrophytes, lithophytes, and glycophytes. The distribution of representatives of this family ranges from common to very rare; most of the identified species occur only in limited areas within the region, which is due to the region's climatic characteristics. The potential for the medical use of all 12 taxa in the prevention and treatment of various groups of diseases has been established.

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Author Contributions

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Conflict of Interest

The authors declare no conflict of interest.

References

- 1 Bentley R. Medicinal plants / R. Bentley. — London: Domville-Fife Press, 2010. — P. 23–46.
- 2 Chen S. -L. Conservation and sustainable use of medicinal plants: problems, progress, and prospects / S.-L. Chen, H. Yu, H.-V. Luo, Q. Wu, C.-F. Li, A. Steinmetz // Chinese Medicine. — 2016. — Vol. 11. — Article ID 37. <https://doi.org/10.1186/s13020-016-0166-7>
- 3 Coley P.D. Using ecological criteria to design plant collection strategies for drug discovery / P.D. Coley, M.V. Heller, R. Aizprua, B. Arauz, N. Flores, M. Correa, M. Gupta, P.N. Solis, E. Ortega-Barría, L.I. Romero, B. Gómez, M. Ramos, L. Cubilla-Rios, T.L. Capson, T.A. Kursar // Front Ecol Environ. — 2003. — Vol. 1. — P. 421–428.
- 4 Монография ВОЗ о лекарственных растениях, широко используемых в новых независимых государствах. — Швейцария: ВОЗ, 2010. — 464 с.
- 5 Li D.Z. The science and economics of ex situ plant conservation / D.Z. Li, H.W. Pritchard // Trends Plant Sci. — 2009. — Vol. 14. — P. 614–621.
- 6 Panagos P. Towards estimates of future rainfall erosivity in Europe based on REDES and WorldClim datasets / P. Panagos, C. Ballabio, K. Meusburger et al. // Journal of Hydrology. — 2017. — Vol. 548. — P. 251–262. <https://doi.org/10.1016/j.jhydrol.2017.03.006>
- 7 Badahar B. Medicinal plants: an overview / B. Badahar, K.J. Reddy, M.L.B. Rao // In Book Advances in Medicinal plants. — Chennai, India, 2020. — P. 1–51.
- 8 Havens K. Ex situ plant conservation and beyond / K. Havens, P. Vitt, M. Maunder, E.O. Guerrant, K. Dixon // Bioscience. — 2006. — Vol. 56. — P. 525–531.
- 9 Иманбаева А.А. Сосудистые растения Мангистауской области (конспект флоры, анализ и ДНК-баркодирование): монография / А.А. Иманбаева, Н.И. Дуйсенова, Ш.А. Манабаева, А.А. Какимжанова, И.Ф. Белозеров, Ж.К. Мусаева, Г.Г. Гасанова, А.Б. Лукманов, Г.Т. Бпекбосын, Г.Ж. Бастаев, К.С. Бекесов, А.Б. Шевцов. — Астана: Центр Элит, 2024. — 420 с.
- 10 Plants of the World Online (POWO). — [Electronic resource]. — Access mode: <https://powo.science.kew.org/>
- 11 Куминова А.В. Растительный покров Алтая / А.В. Куминова. — Барнаул, 1960. — 451 с.
- 12 Грудзинская Л.М. Аннотированный список лекарственных растений Казахстана / Л.М. Грудзинская, Н.Г. Гемеджиева, Н.В. Нелина, Ж.Ж. Каржаубекова. — Алматы, 2014. — 220 с.
- 13 Растительные ресурсы России. Дикорастущие цветковые растения, их компонентный состав и биологическая активность. ТТ. 1–8. — Санкт-Петербург: БИН, 2008–2014.
- 14 Ишонкулова Д.У. Полезные свойства абрикоса / Д.У. Ишонкулова, А.Р. Равшанова // European Researcher. — 2019. — № 1. — С. 8–10.
- 15 Кароматов И.Д. Химический состав и лечебные свойства боярышника / И.Д. Кароматов, Н.А. Жалилов // Биология и интегративная медицина. — 2019. — № 1(29). — С. 109–141.
- 16 Муродова М.М. Яблоки — лечебное и профилактическое средство / М.М. Муродова, И.Д. Кароматов // Биология и интегративная медицина. — 2018. — № 1(18). — С. 119–129.
- 17 Сергалиева М.У. Фармакотерапевтический потенциал растений рода *Potentilla* / М.У. Сергалиева, В.Х. Мурталиева, М.А. Самотруева // Вопросы биологической, медицинской и фармацевтической химии. — 2024. — Т. 27, № 8. — С. 3–12. <https://doi.org/10.29296/25877313-2024-08-01>
- 18 Костикова В.А. Биологически активные вещества и антиоксидантная активность растений рода *Spiraea* L. Дальнего Востока России / В.А. Костикова, Т.М. Шалдаева // Химия растительного сырья. — 2016. — № 2. — С. 73–78. <https://doi.org/10.14258/jcprm.201602784>
- 19 Сафронова И.Н. Пустыни Мангышлака (очерк растительности) / И.Н. Сафронова // Труды БИН им. Л.В. Комарова. — 1996. — Т. 18. — 240 с.
- 20 Бименьиндавы Э. Влияние эколого-географических условий на содержание биологически активных веществ лекарственных растений: дисс. ... канд. биол. наук / Э. Бименьиндавы. — Казань, 2024. — 162 с.
- 21 Ендонова Г.Б. Динамика накопления суммы флавоноидов в скабиозе венечной и скабиозе бледно-желтой в зависимости от местообитания / Г.Б. Ендонова, Т.П. Анцупова // Пищевые продукты и здоровое питание: Сборник тезисов ежегодной аспирантско-студенческой конференции. — Кемерово, 2002. — С. 16.

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Маңғыстау облысының флорасындағы *Rosaceae* тұқымдасының перспективалы дәрілік өсімдіктерін іздеу

Қазақстанның өңірлеріндегі дәрілік өсімдіктерді зерттеу дәрілік шикізаттың жаңа көздерін іздеу үшін аса маңызды. Маңғыстау облысы дәрілік өсімдіктердің әлеуеті мен шикізат ресурстары тұрғысынан Қазақстанда ең аз зерттелген аймақ. Осы зерттеу аясында *Rosaceae* тұқымдасының өкілдерін дәрілік мақсатта қолдану әлеуетін бағалау бойынша зерттеу жүргізілді. Маңғыстау облысының аумағында

сегіз тұқымдасқа жататын *Rosaceae* тұқымдасының он екі түрі анықталды. Анықталған өмір сүру формаларына ағаштар (4), бұталар (6), біржылдықтар (1) және көпжылдықтар (1) жатады. Экологиялық тұрғыдан түрлер мезофиттерге (7), ксеромезофиттерге (4) және ксерофиттерге (1); субстрат түрі бойынша олар псаммофиттерге (1), петрофиттерге (3), литофиттерге (4) және гликофиттерге (4) жатқызылды. Осы тұқымдас өкілдерінің таралуы мынадай түрде жіктеледі: кең таралған — 2, сирек кездесетін — 1, өте сирек кездесетін — 6 таксон. Бұл жағдайды тарихи себептер мен өңірдің климаттық ерекшеліктерімен түсіндіруге болады. Барлық 12 таксонды әртүрлі ауру топтарын алдын алу және емдеу мақсатында медицинада қолдану әлеуеті анықталды. Осы тұқымдасының барлық анықталған түрлерін енгізу ұсынылған, себебі шикізат жинауға арналған табиғи қорықтар жоқ. Алынған мәліметтер оларды медицинада енгізу мен практикалық қолдану және парафармацевтикалық өнімдер өндіру бойынша әрі қарай зерттеулерді жоспарлауға мүмкіндік береді.

Кілт сөздер: *Rosaceae* тұқымдасы, дәрілік өсімдіктер, шолу, өмірлік формалар, экологиялық топтар, таралуы, медициналық қолдану әлеуеті.

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Поиск перспективных лекарственных растений семейства *Rosaceae* во флоре Мангистауской области

Изучение лекарственных растений в регионах Казахстана имеет важное значение для поиска новых источников лекарственного сырья. Мангистауская область является наименее изученной территорией в Казахстане в отношении потенциала и сырьевых ресурсов лекарственных растений. В рамках данной работы выполнены исследования по оценке потенциала применения представителей семейства *Rosaceae* в медицинских целях. На территории Мангистауской области выявлено произрастание 12 видов семейства *Rosaceae* из 8 родов. Среди жизненных форм выявлены деревья (4), кустарники (6), мало- (1) и многолетние (1) травы. По экологии виды были ранжированы на мезофиты (7), ксеромезофиты (4) и ксерофиты (1), по отношению к типу субстрата — на псаммофиты (1), петрофиты (3), литофиты (4) и гликофиты (4). Распространение представителей данного семейства ранжировано следующим образом: обычно — 2 таксона, редко — 1, очень редко — 6. Данная ситуация объясняется историческими причинами и климатическими особенностями региона. Установлен потенциал применения всех 12 таксонов в медицинских целях для профилактики и лечения различных групп заболеваний. Рекомендуется интродукция всех выявленных видов данного семейства, так как в природных условиях отсутствуют запасы для сбора сырья. Полученные данные позволяют планировать дальнейшие исследования по введению в интродукцию и практическому применению в медицине и для получения парафармацевтических средств.

Ключевые слова: семейство *Rosaceae*, лекарственные растения, конспект, жизненные формы, экологические группы, степень распространенности, потенциал применения в медицине.

References

- 1 Bentley, R. (2010). *Medicinal plants*. London: Domville-Fife Press.
- 2 Chen, S. -L., Yu, H., Luo, H. -V., Wu, Q., Li, C. -F., & Steinmetz, A. (2016). Conservation and sustainable use of medicinal plants: problems, progress, and prospects. *Chinese Medicine*, 11, 37. <https://doi.org/10.1186/s13020-016-0166-7>
- 3 Coley, P.D., Heller, M.V., Aizprua, R., Arauz, B., Flores, N., Correa, M., Gupta, M., Solis, P.N., Ortega-Barría, E., Romero, L.I., Gómez, B., Ramos, M., Cubilla-Rios, L., Capson, T.L., & Kursar, T.A. (2003). Using ecological criteria to design plant collection strategies for drug discovery. *Front Ecol Environ.*, 1, 421–428.
- 4 (2010). *Monografiia VOZ o lekarstvennykh rasteniiakh, shiroko ispolzuemykh v novykh nezavisimyykh gosudarstvakh* [WHO Monograph on Medicinal Plants Widely Used in the Newly Independent States]. Switzerland: WHO.
- 5 Li, D.Z., & Pritchard, H.W. (2009). The science and economics of ex situ plant conservation. *Trends Plant Sci.*, 14, 614–621.
- 6 Panagos, P., Ballabio, C., Meusburger, K. et al. (2017). Towards estimates of future rainfall erosivity in Europe based on REDES and WorldClim datasets. *Journal of Hydrology*, 548, 251–262. <https://doi.org/10.1016/j.jhydrol.2017.03.006>
- 7 Badahar, B., Reddy, K.J., & Rao, M.L.B. (2010). Medicinal plants: an overview. In *Book Advances in Medicinal plants*. Chennai, India.
- 8 Havens, K., Vitt, P., Maunder, M., Guarrant, E.O., & Dixon, K. (2006). Ex situ plant conservation and beyond. *Bioscience*, 56, 525–531.
- 9 Imanbaeva, A.A., Duissenova, N.I., Manabaeva, Sh.A., Kakimzhanova, A.A., Belozeroва, I.F., Musaeva, Zh. K., Gasanova, G.G., Lukmanov, A.B., Bekbosyn, G.T., Doschieva, G. Zh., Bastaev, V.V., Bekesov, K.S., & Shevtsov, A.B. (2024). *Sosudistye rasteniia Mangystauskoi oblasti (konspekt flory, analiz i DNK-barkodirovanie): monografiia* [Vascular plants of the Mangystau region (abstract, analysis, and DNA barcoding of the flora): Monograph]. Astana: Tsentr Elite [in Russian].

- 10 Plants of the World Online (POWO). *powo.science.kew.org*. Retrieved from <https://powo.science.kew.org/>
- 11 Kuminova, A.V. (1960). *Rastitelnyi pokrov Altaia* [Vegetation of Altai]. Barnaul [in Russian].
- 12 Grudzinskaya, L.M., Gemedzhieva, N.G., Nelina, N.V., & Karzhaubekova, Zh.Zh. (2014). *Annotirovannyi spisok lekarstvennykh rastenii Kazakhstana* [An Annotated List of Medicinal Plants of Kazakhstan]. Almaty [in Russian].
- 13 (2008–2014). *Rastitelnye resursy Rossii. Dikorastushchie tsvetkovye rasteniia, ikh komponentnyi sostav i biologicheskaia aktivnost* [Plant Resources of Russia. Wild-growing flowering plants, their chemical composition, and biological activity]. Saint Petersburg: BIN, 1–8 [in Russian].
- 14 Ishonkulova, D.U., & Ravshanova, A.R. (2019). Poleznye svoistva abrikosa [Beneficial Properties of Apricots]. *European Researcher*, 1, 8–10.
- 15 Karomatov, I.D., & Zhalilov, N.A. (2019). Khimicheskii sostav i lechebnye svoistva boiaryshnika [Chemical composition and medicinal properties of hawthorn]. *Biologiya i intergativnaia meditsina — Biology and Integrative Medicine*, 1(29), 109–141 [in Russian].
- 16 Murodova, M.M., & Karomatov, I.D. (2018). Yabloki — lechebnoie i profilakticheskoe sredstvo [Apples — a therapeutic and preventive agent]. *Biologiya i intergativnaia meditsina — Biology and Integrative Medicine*, 1(18), 119–129 [in Russian].
- 17 Sergaliev, M.U., Murtaliev, V.Kh., & Samotrueva, M.A. (2024). Farmakoterapevticheskii potentsial rastenii roda *Potentilla* [Pharmacotherapeutic potential of plants of the genus *Potentilla*]. *Voprosy biologicheskoi, meditsinskoi i farmatsevticheskoi khimii — Issues of Biological, Medical, and Pharmaceutical Chemistry*, 27(8), 3–12 [in Russian].
- 18 Kostikova, V.A., & Shaldaeva, T.M. (2016). Biologicheski aktivnye veshchestva i antioksidantnaia aktivnost rastenii roda *Spiraea* L. Dalnego Vostoka Rossii [Biologically Active Compounds and Antioxidant Activity of Plants of the Genus *Spiraea* L. from the Russian Far East]. *Khimiia rastitelnogo syria — Chemistry of Plant Raw Materials*, 2, 73–78. <https://doi.org/10.14258/jcprm.201602784> [in Russian].
- 19 Safronova, I. N. (1996). *Pustyni Mangyshlaka (ocherk rastitelnosti)* [Deserts of Mangyshlak: An essay on vegetation]. *Trudy Botanicheskogo Instituta imeni L.V. Komarova Rossiiskoi Akademii Nauk — Proceedings of the L.V. Komarov Botanical Institute of the Russian Academy of Sciences*, 18, 240 p. Saint Petersburg: RAS [in Russian].
- 20 Bimenindavi, E. (2024). Vliianie ekologo-geograficheskikh uslovii na sodержanie biologicheskii aktivnykh veshchestv lekarstvennykh rastenii [Influence of Ecological and Geographical Conditions on the Content of Biologically Active Substances in Medicinal Plants]. *Candidate's thesis*. Kazan [in Russian].
- 21 Endonova, G.B., & Antsupova, T.P. (2002). Dinamika nakopleniia summy flavonoidov v skabioze venechnoi i skabioze bledno-zheltoi v zavisimosti ot mestoobitaniia [Dynamics of the accumulation of total flavonoids in crown scabious and pale yellow scabious depending on habitat]. *Pishchevye produkty i zdorovoe pitanie: Sbornik tezisov ezhegodnoi aspirantsko-studencheskoi konferentsii — Food Products and Healthy Nutrition: Collection of abstracts from the annual graduate and undergraduate conference*, 16. Kemerovo [in Russian].

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