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On the anniversary date from the scientific heritage of professor N.G. Skopin

50 years have passed since the publication of the work of Nikolay Georgievich Skopin, Professor of the Department of Zoology, Karaganda State University "Darkling beetles (Coleoptera, Tenebrionidae). Questions of comparative morphology and system. A review of the fauna of Kazakhstan". This is a sufficient period of time to understand, overestimate or forget the scientific works of the scientist. In this article, we have made a modest attempt to highlight the scientific heritage of our senior mentor and scientist, the teacher of our teachers. The first rector of the Karaganda State University, Evney Buketov, highly appreciated the entomological research of N.G. Skopin and initiated the preparation of the mentioned final work. Skopin's research focused on the systematics of a very complex group, and as a tenebrionidologist, he was both talented and authoritative in his field. His name is forever associated with the history of the study and classification of darkling beetles. The effectiveness of his system of identification by larval characteristics and male genitalia has been demonstrated in the distinction between separate genera and species. N.G. Skopin described 32 superspecies taxa and even more species. It is important to note that a number of these taxa while remaining valid, retain the surname Skopin in their nomenclature. Foreign specialists turned to him for his expert opinion on the identification of Tenebrionidae species and other coleopterological material. The world's most prominent entomological museums boast a plethora of specimens amassed and identified by Skopin.

Keywords: entomology, Coleoptera, Tenebrionidae, fauna, taxonomy, Kazakhstan, Faculty of Biology of Karaganda State University, Department of Zoology.

The study of darkling beetles (family Tenebrionidae) in Kazakhstan has its origins in the research conducted by academician P.S. Pallas. Further studies of the beetles belonging to this family in Central Asia and Kazakhstan were conducted by numerous entomologists during the first half and middle of the last century. A brief historical review is given in the dissertation of A.V. Bogachev [1]. Recent research findings pertaining to the group, collection material, and regional faunistic works of tenebrionidologists can be consulted on the websites of the Institute of Zoology of the Republic of Kazakhstan and the Zoological Institute of the Russian Academy of Sciences [2-3].

In Central Asia and Kazakhstan, darkling beetles are among the most widespread and conspicuous insects. The appearance of these beetles is so diverse that it is difficult to assign them to one family. Among them there are forms with wide-oval and elongated, strongly convex and strongly flattened bodies. The eliters have ribs and are punctate or smooth. Being cosmopolitans, these beetles prefer tropical and arid regions. According to trophic preference the majority of members of the family are phytophagous, but there are also saprophagous, necrophagous, xylophagous and others. Professor of Karaganda State University Nikolay Georgievich Skopin, one of the prominent tenebrionidologists of the USSR, devoted a lot of time to the study of this group in Kazakhstan. The study of the morphology and ecology of members of this family was the focus of N.G. Skopin's life's work, as the identification of many species is challenging and presents a substantial scientific enigma. The surname Skopin can be seen in many scientific articles published over the last 60 years and devoted to the problems of taxonomy, phylogeny and ecology of darkling beetles. In addition to being referenced in the bibliography, it is also found in the nomenclature of genera and species. For example, Skopin is mentioned 116 times in a recent article "Review of genus group names in the family Tenebrionidae (Insecta, Coleoptera)" [4]. N.G. Skopin's works are often referred to when writing reviews on darkling beetles, describing new species, revising tribes, etc. [5–8]. These examples demonstrate the recognition of N.G. Skopin's works in the international scientific community and their importance for faunistics, the most important branch of entomology.

N.G. Skopin was born on December 17, 1913 in the family of a tailor in Kuibyshev (Samara). After his father died, the family moved to Tashkent, where Nikolai went to secondary school. In 1930 he entered the Technical School of Plant Protection. After graduating, he was sent to work in Kazakhstan, in the Kyzylorda region. A year later, having passed external exams, Nikolai Skopin entered the second biology course at the Central Asian State University (CASU) in Tashkent, founded with the participation of the greatest scientists of the century — zoologist D.N. Kashkarov, zoologist-geographer L.S. Berg, soil scientist N.A. Dimo and others.

He graduated with honours in 1938. He was sent to work in the Plant Quarantine Inspectorate of the People's Commissariat of Agriculture of the USSR. In 1940 N.G. Skopin came to Kazakhstan at the invitation of the Republican Tropical Station in Alma-Ata. He worked as an assistant, senior lecturer at the S.M. Kirov Kazakh National University. He was promoted to associate professor at the university after the candidate dissertation defense. Subsequently, Skopin proceeded to pursue his scientific endeavours at the Kazakh Research Institute of Plant Protection, where he assumed the leadership role of the Laboratory for the Study of Forest Pests. Thereafter, he assumed the leadership role of the Entomology Department at the Institute.

Skopin collected extensive material on darkling beetles and other insects on expeditions with colleagues to high mountain, steppe, semi-desert and desert regions of Kazakhstan. The processing of collection material was reflected in articles on insect pests, particularly sawflies and lepidopterans [9].

The second University of Kazakhstan, opened in Karaganda in 1972, needed experienced teaching staff, and N.G. Skopin was invited to join the Karaganda State University. Here he combined teaching and researching several insect groups.

In 1975 N.G. Skopin completed his dissertation on the systematics of darkling beetles. The rector of Karaganda University, Evney Arstanovich Buketov, took a great interest in N.G. Skopin's scientific career and contributed to the progress of his dissertation. Buketov's memories of his meetings with Skopin are described in the book "Yevnei Buketov: the tragedy of a bright destiny" [10]. In the same year, 1975, in Leningrad, Skopin defended his doctoral dissertation "The darkling beetles (Coleoptera, Tenebrionidae). Questions of comparative morphology and system. A review of the fauna of Kazakhstan" [11]. This was the inaugural significant dissertation research conducted in the field of entomology at Karaganda University.

Skopin was well known as a systematist in German and British scientific circles, and his work was frequently published in the Annales Historico-Naturales Musei Nationalis Hungarici (Hungary). His help in the identification of Tenebrionidae species and other coleopterological material was sought by foreign specialists.

The study of comparative morphology and ecology of larval forms of Tenebrionidae brought the scientist the greatest fame and allowed him to form an original opinion on the composition of tribes of the family and their relationships. Various revisions of the Western Palaearctic darkling beetles have been made by Skopin. He completely revised the generic composition of many Central Asian genera of the tribe Pimeliini and devoted much time to the study of Central Asian species of *Tentyria, Anatolica, Microdera* and others [12–16].

Systematists had noted inconsistencies between classifications based on adult and larval morphology of darkling beetles. The identification of larval stages has frequently been regarded as more precise due to the enhanced study of larval morphology. Consequently, Skopin's taxonomic studies, which were based on the peculiarities of larval structure, attracted a great deal of attention [17]. In Skopin's works, it was demonstrated that in cases where the separation of genera within distinct tribes is challenging using imaginal characters, it is preferable to employ larval characters. For instance, the "structure of the hypopharyngeal sclerome" or "abdominal glands" can serve as diagnostic indicators. Skopin proposed the division of the tribe Blaptini into subtribes Blaptina and Prosodina. Based on the characteristic features of the larval structure of the subtribe Blaptina, four morpho-ecological groups were distinguished, allowing us to clarify the classification of imaginal forms [18–25].

In addition, N.G. Skopin collaborated with the eminent tenebrionidologists G.S. Medvedev, A.V. Bogachev and S.M. Yablokov-Khizoryan on the revision of Central Asian species belonging to the Helopini tribe. In order to clarify the taxonomic classification of darkling beetles, key regroupings were made according to morphological criteria and modifications, including the type of structure of the spermatheca and aedeagus, amongst other characteristics. The structure of larvae of different ages was also used as an additional criterion.

As a systematist, N.G. Skopin made a significant contribution to the study of the fauna and ecology of the tribe Platyscelidini, utilising data on species from Kazakhstan and other regions. The tribe Platyscelidini comprises species that are endemic to mountainous regions, representing a significant centre of biodiversity. The majority of species within this tribe are endemic to Kazakhstan and Central Asia, yet the study of these species remains limited. Notably, the study not only described Platyscelis species from Kulja (Xinjiang Uygur Autonomous Region, People's Republic of China), but also led to the discovery of new species from the tribe [26, 27]. The genus *Somocoeloplatys* Skopin, 1968 of the tribe Platyscelidini, endemic to the Western Tien Shan, was determined and named, and the position of species of the genus *Oodescelis* was clarified. The author further summarised the available data on the ecology of the species of the tribe and created identification tables [28, 29].

N.G. Skopin's interests were wide-ranging, and entomological expeditions were a frequent occurrence. He devoted considerable time and effort to the identification and description of novel species of insects. The students' primary recollections concerning these expeditions were the considerable distances traversed and the substantial number of test tubes filled with beetles.

Zoological Institute of the Russian Academy of Sciences (ZIN RAS) houses an extensive collection of Coleoptera, comprising species of Geotrupidae. These beetles have long attracted the attention of collectors and nature lovers due to their bizarre appearance and biological peculiarities. Among them there is a specimen of a new species *Lethrus karatavicus* Nikolajev et Skopin, 1971, discovered by professor Skopin in the upper reaches of the Karachik River on the Kara-Tau Ridge (South Kazakhstan), and described by him together with the Kazakh entomologist G.V. Nikolayev (Fig. 1) [30].

Figure 1. Collectors specimen INS_COL_0000099 of Lethrus karatavicus Nikolajev et Skopin, 1971 with label. From the collection of beetles (Coleoptera) of ZIN RAS (after www.zin.ru/Animalia/Coleoptera).

Dorcadion (Acutodorcadion) zhaisanicum Shapovalov, 2007) is of special importance among the type specimens of the family Cerambycidae in the collections of ZIN RAS. This is the holotype of the new species described by A.M. Shapovalov in 2007 based on materials of N.G. Skopin from 1963. The species was found in the Jaisan Mountains (northwestern part of the Chu-Ili Mountains), South Kazakhstan (Fig. 2) [31]. Materials of field collections of N.G. Skopin of ground beetles (Carabidae) are stored in large scientific collections of the world. To illustrate, a specimen of *Amara kosagatschi* Hieke, 1988, originating from southeastern Kazakhstan (Chunja, a district of Kos-Agach), serves as the holotype for this species, and is currently housed in the collection of beetles (Coleoptera) at the renowned Museum of Natural History (Berlin, Germany). The German specialist F. Hieke elucidated the taxonomic position of the Skopin collections' specimens.

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Figure 2: General view and label of the collection specimen INS_COL_CER_0000035
Dorcadion (Acutodorcadion) zhaisanicum Shapovalov, 2007 from the collection of beetles (Coleoptera)
of ZIN RAS (after www.zin.ru/Animalia/Coleoptera).

The species *Amara (Cribrara) skopini* Hieke is described as materials from Northwestern Kazakhstan, area of Lake Koskul. The species name was given by entomologist F. Hieke in honor of the collector and systematist N.G. Skopin. The holotype of this species is kept in the collection of ground beetles in ZIN RAS. The author's paratypes from the same habitat are presented in the Museum of Natural History (Berlin, Germany) [32].

Like many renowned systematists, N.G. Skopin had a unique scientific style that helped him achieve his professional goals and overcome challenges. According to his students and colleagues, he was not an easy person to communicate with and a difficult companion in scientific work. N.G. Skopin has published more than 50 scientific papers, which is a comparatively modest output by today's standards. Nevertheless, his articles are frequently cited by specialists from various countries. His collection materials have become a standard in comparative systematics and are considered classics in the world's leading museums.

Professor Skopin was unable to proceed with the composition of his planned treatise, "Identification key to insects of Central Kazakhstan", and the "Review of the Tenebrionidae (Coleoptera) fauna of Kazakhstan", due to a period of severe illness and death that afflicted him in 1979.

Nevertheless, the work of N.G. Skopin on revising the family Tenebrionidae remains very important. It's worth noting that some of Skopin's morphological generalisations for different taxa have been confirmed in modern molecular genetic studies. In light of the data pertaining to the morphology of larvae, N.G. Skopin contended that there was a need to distinguish the genus *Lithoblaps* from other genera in the subtribe Blaptina. This classification of genera has been well-supported and aligns with the phylogenetic model based on genetic markers [33]. Skopin's classification system, based on the use of certain morphological characters and the structure of the male sexual system, after many years of rejection, is accepted by some specialists today. This is evidenced by its use for the subtribe Blaptina [34].

By assessing the reliability of the author's descriptions and the validity of classification groups over 50–60 years, we can see how many of the 32 superspecies taxa described by Skopin have already been revised and re-evaluated due to revisions of the family [35, 36, 37].

However, a sufficient proportion of the taxa with the surname Skopin is valid and has been included in various studies. To illustrate this point, we can turn our attention to the small genus *Sternotrigon*, which belongs to the tribe Pimeliini. This genus was first proposed by Skopin in 1973, and since then it has become the focus of intense research by Chinese and Mongolian scientists. The distribution of new species from this genus in the Asian region is currently being elucidated [38]. Information concerning the geographical distribution of species within the genus *Sternotrigon*, along with the location of relevant holotypes and paratypes, is accessible on the Global Biodiversity Information Facility platform. This data can be utilized without restrictions by systematists conducting research in this field. Nucleotide sequences have also been obtained for some species of genus *Sternotrigon*. This information is stored in the European Nucleotide Archive (EMBL-EBI) and is of interest to the International Barcode of Life project (iBOL) [39].

Thus we see the fundamental legacy of the past and its relevance to the present when we turn to Professor Skopin's entomological research. We would like to assume that the traditions of classical university science of Karaganda University will be continued further, supported by young specialists.

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Мерейтойлық күніне орай профессор Н.Г. Скопиннің ғылыми мұрасынан

Қарағанды мемлекеттік университетінің зоология кафедрасының профессоры Николай Георгиевич Скопиннің «Жуки-чернотелки (Coleoptera, Tenebrionidae). Вопросы сравнительной морфологии и системы. Обзор фауны Казахстана» атты еңбегінің жарық көргеніне 50 жыл өтті. Бұл ғалымның ғылыми еңбектерін түсіну, қайта бағалау немесе ұмыту үшін жеткілікті уақыт. Мақалада аға тәлімгеріміз және көрнекті ғалым, педагог және энтомологтың ғылыми мұрасын көрсетуге тырыстық. Қарағанды мемлекеттік университетінің бірінші ректоры Евней Букетов Н.Г. Скопиннің энтомология бойынша зерттеулерге қосқан үлесін жоғары бағалап, аталған қорытынды еңбекті дайындауға бастамашы болған. Ең күрделі топтардың бірін жіктеумен жұмыс істей отырып, профессор өзін таксономия саласындағы көрнекті маман ретінде көрсетті. Ғалымның есімі қара түстес қоңыздарды зерттеу және жіктеу тарихымен мәңгі байланысты. Оның дернәсілдік белгілерге және сыртқы жыныс мүшелерінің құрылымына негізделген сәйкестендіру жүйесі жеке тұқымдастар мен түрлерді ажыратуда тиімді болды. Скопиннің зерттеу нәтижелері бойынша ғылым үшін 32 жаңа таксондар сипатталған. Осы таксондардың бірқатары жарамды бола отырып, олар өз атында Skopin фамилиясын сақтайды. Шетелдік мамандар оған қара түс қоңыздар мен басқа колеоптерологиялық материалдарды анықтау кезінде сараптамалық бағалау үшін жүгінеді. Әлемдегі ең ірі энтомологиялық мұражайлар өз коллекцияларында Скопин жинаған және бірізденген үлгілерді сақтап отыр.

Кілт сөздер: энтомология, Coleoptera, Tenebrionidae, фауна, таксономия, Қазақстан, Қарағанды мемлекеттік университетінің биология-география факультеті, зоология кафедрасы.

В.С. Абукенова

К юбилейной дате из научного наследия профессора Н.Г. Скопина

Прошло 50 лет с момента публикации работы профессора кафедры зоологии Карагандинского государственного университета Николая Георгиевича Скопина «Жуки-чернотелки (Coleoptera, Tenebrionidae). Вопросы сравнительной морфологии и системы. Обзор фауны Казахстана». Это достаточный срок для того, чтобы понять, переоценить или забыть научные вклады ученого. В этой статье предпринята попытка осветить научное наследие нашего старшего наставника и выдающегося ученого, педагога и энтомолога. Первый ректор Карагандинского государственного университета, Евней Букетов, высоко оценивал вклад Н.Г. Скопина в исследования по энтомологии и инициировал подготовку упомянутого итогового труда. Работая над систематикой одной из самых сложных групп, профессор зарекомендовал себя как выдающийся специалист в области таксономии. Его имя навсегда связано с историей изучения и классификации жуков-чернотелок. Используемая им система идентификации по личиночным признакам и строению гениталий самцов оказалась эффективной для выделения отдельных родов и видов. По результатам исследования Скопина, было описано 32 таксона новых для науки. Ряд этих таксонов, оставаясь валидными, сохраняет в своем названии фамилию Skopin. Зарубежные специалисты обращались к нему за экспертной оценкой при идентификации чернотелок и другого колеоптерологического материала. Крупнейшие энтомологические музеи мира хранят в своих коллекциях образцы, собранные и идентифицированные Скопиным.

Ключевые слова: энтомология, Coleoptera, Tenebrionidae, фауна, таксономия, Казахстан, биолого-географический факультет Карагандинского государственного университета, кафедра зоологии.

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Species of the genus *Allium* L. of the western part of the Kyrgyz Alatau ridge: the current status and prospects of studying

The results of the assessment of the current state and prospects for the study of species of the genus *Allium* L. in the western part of the Kyrgyz Alatau ridge are presented. It was found that in the herbarium fund (AA) the most part (57 %) of specimen collections of *Allium* L. species falls on the periods from 1947 to 1960, further on descending 24 % of collections — in 1984–1985. The share of scattered collections is 12 %, the share of modern collections is insignificant (7 %). The preliminary list of studied species of *Allium* Kyrgyz Alatau is represented by 27 species. In 5 gorges of the western part of the Kyrgyz Alatau ridge, locations, phytocoenotic and altitudinal distribution of 7 species were revealed. Commercial thickets are formed by *A. atrosanguineum* (Kaskasu gorge) and *A. longicuspis* (Sugaty gorge). The identified species occur as part of herbaceous-grass, herbaceous-shrubby-cereal grass, petrophytic-herb-grass-shrub, petrophytic-tree-shrub communities and grow in the altitude range from 1200 to 3390 m above sea level. *Allium caeruleum, A. caesium, A. karataviense, A. leptomorphum, A. longicuspis, A. margaritae* are found in the low and middle mountains from 1170 to 1660 metres above sea level. The high-altitude species is *A. atrosanguineum*, occurring in the altitude range of 2520–3390 m above sea level. Maps of the locations and potential harvesting sites of the identified *Allium* species of the study region were compiled.

Keywords: genus *Allium* L., species diversity, Kyrgyz Alatau ridge.

Introduction

The Global Strategy for Plant Conservation [1] pays special attention to solving the issues of regional research on the inventory of species composition, identifying places of concentration of rare, endemic, relict, and economically valuable species, as well as measures to preserve botanical diversity (specific territories).

Among the economically valuable plants of Kazakhstan, wild onions are characterized by significant species diversity, wide distribution and resource potential.

At present, the genus *Allium* L. (Amaryllidaceae J.St. -Hil.) has about 1000 species [2]. About one third of onions are identified in the mountains of the Tien Shan, which is the world's largest center of onion diversity. *Allium* L. is listed in 16 major genera and is represented by 56 Tien-Shan endemics [3], of which from 9 to 21 endemic species are indicated for the territory of Kazakhstan [4, 5].

Current literature data indicate that *Allium* L. species are characterized by pronounced antioxidant properties and are promising for use in the treatment of cancer and cardiovascular diseases [6–16].

Predation of wild onions because of their ornamental, food, melliferous and medicinal properties and economic activities, including intensive grazing within their range have led to a decrease in the number of onions. The Red Data Book of Kazakhstan includes 12 species [17].

The results of a previously published review on the degree of study of 134 Kazakhstani onion species, about half of which were tested in culture, indicate the prospect of their comprehensive study in theoretical and practical terms [18].

The Kyrgyz Alatau ridge is characterized by a transitional composition of flora and a special set of species, which is associated with its location at the junction of large mountain systems of the Tien Shan. An integrated approach to their study will provide new fundamental knowledge as a scientific basis for sustainable use, conservation of plant resources and forecasting of environmental protection activities in the region.

The objects of our research are species of *Allium* L. of the Kyrgyz Alatau ridge, located within Kazakhstan.

The aim of the present research: assessment of species composition, distribution and current state of natural populations of onions of the western part of the Kyrgyz Alatau ridge for their conservation and sustainable use.

Experimental

Herbarium collections (Herbarium AA) and natural populations of onions growing in the western part of the Kyrgyz Alatau ridge served as the material for research.

The research area — the Kyrgyz Alatau ridge is located within the Zhambyl, T. Ryskulov and Merken administrative districts of Zhambyl region, characterized by a variety of relief, soil and vegetation cover, represented from high-altitude subalpine and alpine vegetation to psammophilic vegetation of Moyinkum sands.

The Kyrgyz ridge is located within the Kyrgyz Mountain Subprovince, which is part of the Dzungaro-North Tianshan Mountain Province [19].

Common methods of botanical and cartographic research were used in the work.

Classical geobotanical methods [20–22] were used in the expedition studies. Determination of plant species was carried out according to floristic summaries: "Flora of Kazakhstan" [23–31], "Illustrated identifier..." [32–33]. The taxonomy of species is agreed with the Internet resources: Plantarium [34] and Plants of the World Online (POWO) [35], but the authors adhere to their own point of view on the species affiliation of some taxa. The distribution of the studied species by nature of use and pharmacological action was carried out according to the multi-volume summary: "Plant Resources..." [36–38], "Wild Usable Plants of Russia" [39], "Annotated list of medicinal plants of Kazakhstan" [40].

The digital geographic base of 1:2500000 scale of FGBU "VSEGEI" was used as a cartographic basis for mapping, and updated by the authors' own efforts. Coordinates of the area, where the locations of bows were identified, were recorded in the field using GNSS-navigator "Garmin". To create maps of locations of fishery arrays, the coordinates obtained with the help of the navigator were plotted on the map base and processed in ESRI ArcGIS Desktop 10.8 software.

Results and Discussion

To identify species diversity and compile a preliminary list of onions of the studied region, including rare and endemic representatives, as well as their potential locations, we screened available herbarium material, literature and field data, and Internet resources. Field studies were carried out, primary material was collected and locations of identified *Allium* L. species of the study area were mapped.

As a result of screening of herbarium materials of representatives of the genus *Allium* L. of the Kyrgyz Alatau in the herbarium collection (AA), 82 specimens were reviewed, including 3 specimens of the rare species *Allium suworowii* Regel [17] (Fig. 1).

Analysis of the herbarium specimens viewed showed that the majority of herbarium specimens (19 or 23 %) represented the species *A. barsczewskii* Lipsky. For other species, the number of herbarium specimens varies from 2 to 7: *A. caesium* Schrenk, *A. fetisowii* Regel — 7 (8.5 %), *A. caeruleum* Pall. — 5 (6.1 %), *A. trachyscordum* Vved., *A. karataviense* Regel, *A. hymenorhizum* Ledeb., *A. atrosanguineum* Kar. et Kir., *A. platyspathum* Schrenk, *A. caricifolium* Kar. & Kir. (syn. *A. pallasii* Murray), *A. oreoprasum* Schrenk — 3 (3.6 %), *A. parvulum*, *A. oreophilum*, *A. oreoprasoides* Vved. — 2 (2.4 %). Eight species (1 (1.2 %) herbarium specimen each) are represented in the lowest number: *A. obliquum* L., *A. turkestanicum* Regel, *A. semenovii* Regel, *A. longicuspis* Regel, *A. kokanicum* Regel, *A. schoenoprasum* L., *A. longiradiatum* (Regel) Vved. It was revealed that the most part (57 %) of collections of species of the genus *Allium* L. falls on the periods from 1947 to 1960, further in descending order 24 % of collections — on 1984–1985. The share of collections of different years is 12 %, modern collections — insignificant (7 %).

To compile a preliminary list of species of the genus *Allium* L. in the Kazakh part of the Kyrgyz Alatau ridge, the analysis of available data on onions occurring in the Kyrgyz Alatau was continued. Comparison of published data on the distribution of species of the genus *Allium* L. according to floristic summaries [24, 32, 41]; Internet resources [34] and herbarium data (AA) showed that for 7 species (*A. caeruleum* Pall. *A. obliquum* L., *A. oreoprasoides* Vved., *A. turkestanicum* Regel, *A. longiradiatum* (Regel) Vved., *A. suworowii* Regel, *A. caricifolium* Kar. & Kir. (syn. *A. pallasii* Murr.) found new localities on the territory of the Kyrgyz Alatau that not indicated in the literature sources. At the same time, the onion species of the Kyrgyz ridge *A. altissimum* Regel and *A. leptomorphum* Vved. indicated in the literature sources are absent in the herbarium collection (AA) (Table 1).

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Figure 1. Herbarium specimens of some species of the genus *Allium* collected in the Kyrgyz Alatau

According to the "Flora of Kazakhstan" [24] there are 12 species of onions in the Kyrgyz Alatau; in the "Illustrated Plant Identifier of Kazakhstan" [32] there are 15 species; in the "Plant Identifier of Central Asia" [32] there are 15 species of onions; in the "Plant Identifier of Central Asia" [41] — 17 species [41]. The localities of *A. margaritae* B. Fedtsch. in the Kyrgyz Alatau are also absent in published sources (Table 1).

In the Red data book of Zhambyl region [42], out of 5 specified representatives of the genus *Allium* L.

(*A. galanthum* Kar. & Kir., *A. longicuspis*, *A. kasteki*, *A. karataviense*, *A. turtschicum*), only one rare species *A. karataviense* is listed for the Almalysai gorge of the Kyrgyz Alatau.

Based on screening of available herbarium material and analysis of published data, a preliminary list of species of *Allium* L. Kyrgyz Alatau is represented by 27 species was compiled: *Allium altissimum* Regel, *A. atrosanguineum* Schrenk, *A. barsczewskii* Lipsky, *A. caeruleum* Pall., *A. caesium* Schrenk, *A. caricifolium* Kar. & Kir. (syn. *A. pallasii* Murray), *A. dasyphyllum* Vved., *A. fetisowii* Regel, *A. hymenorhizum* Ledeb., *A. karataviense* Regel, *A. kokanicum* Regel, *A. leptomorphum* Vved., *A. longicuspis* Regel, *A. longiradiatum* (Regel) Vved., *A. margaritae* B. Fedtsch., *A. oreophilum* C.A. Mey., *A. oreoprasum* Schrenk, *A. oreoprasoides* Vved., *A. obliquum* L., *A. parvulum* Vved., *A. platyspathum* Schrenk, *A. polyphyllum* Kar. & Kir., *A. schoenoprasum* L., *A. semenovii* Regel, *A. suworowii* Regel, *A. trachyscordum* Vved., *A. turkestanicum* Regel, of which 1 endemic (*A. oreoprasoides*), 2 sub-endemics (*A. margaritae, A. trachyscordum*), which are also distributed in Kyrgyzstan, and 1 rare species (*A. suworowii)*.

Table 1

Comparative data on the presence of species of the genus *Allium* L. in the flora of the Kyrgyz Alatau according to floristic summaries, herbarium (AA) and Internet resources

Name of the species by FK	Species name adopted by POWO [35]	FK [24]	IIPK [32]	PICA [41]	Herba-rium (AA)	Planta-rium [34]
Allium altissimum Regel	*Allium altissimum* Regel	+	+	+	–	–
A. atrosanguineum Kar. & Kir.	*A. atrosanguineum* Schrenk	–	+	+	+	–
A. barsczewskii Lipsky	*A. barsczewskii* Lipsky	+	+	+	+	–
A. caeruleum Pall.	*A. caeruleum* Pall.	–	+	+	+	–
A. caesium Schrenk	*A. caesium* Schrenk	–	+	+	+	+
A. caricifolium Kar. & Kir.	syn. *A. pallasii* Murray	–	–	–	+	–
A. dasyphyllum Vved.	*A. dasyphyllum* Vved.	–	–	+	+	+
A. fetisowii Regel	*A. fetisowii* Regel	+	+	+	+	+
A. hymenorhizum Ledeb.	*A. hymenorhizum* Ledeb.	+	+	+	+	–
A. karataviense Regel	*A. karataviense* Regel	–	–	–	+	+
A. kokanicum Regel	*A. kokanicum* Regel	+	+	+	–	–
A. leptomorphum Vved.	*A. leptomorphum* Vved.	–	–	+	–	–
A. longicuspis Regel	*A. sativum* L.	–	–	–	+	–
A. longiradiatum (Regel) Vved.	*A. longiradiatum* (Regel) Vved.	–	–	–	+	–
A. margaritae B. Fedtsch.	*A. margaritae* B. Fedtsch.	–	–	–	+	+
A. oreophilum C.A. Mey.	*A. oreophilum* C.A. Mey.	+	+	+	–	–
A. oreoprasum Schrenk	*A. oreoprasum* Schrenk	+	+	+	+	–
A. oreoprasoides Vved.	*A. oreoprasoides* Vved.	–	–	–	+	–
A. obliquum L.	*A. obliquum* L.	–	–	–	+	–
A. parvulum Vved.	*A. parvulum* Vved.	+	+	+	+	+
A. platyspathum Schrenk	*A. platyspathum* Schrenk ex Fisch. & C.A. Mey.	+	+	+	+	–
A. polyphyllum Kar. & Kir.	*A. carolinianum* Redouté	+	+	+	+	–
A. schoenoprasum L.	*A. schoenoprasum* L.	–	–	–	+	–
A. semenowii Regel	*A. semenovii* Regel	+	+	+	+	–
A. suworowii Regel	*A. suworowii* Regel	–			+	
A. trachyscordum Vved.	*Allium trachyscordum* Vved.	+	+	+	+	+
A. turkestanicum Regel	*A. turkestanicum* Regel	–	–	–	+	–
	Total species	12	15	17	23	7

Note – POWO — Plants of the World Online; FK — Flora of Kazakhstan; IIPK — Illustrated identifier of plants of Kazakhstan; PICA — Plant Identifier of Central Asia

Since the territory of the Kyrgyz Alatau ridge is transboundary, it is possible to expand the preliminary list with other species of onions growing in Kyrgyzstan. Of the 87 species of the genus *Allium* L. identified in Kyrgyzstan, 24 grow in both Kyrgyzstan and Kazakhstan [43–46].

The ridge of application of onions in the Kazakh part of the Kyrgyz Alatau is very diverse. Six species are used as medicinal (*Allium altissimum, A. karataviense, A. longicuspis, A. obliquum, A. schoenoprasum, A. suworowii)*. Ornamental properties are characterized by 16 species, food — 9; honey-bearing — 5 species, fodder, technical and poisonous — 1 species each. 21 species have been tested in culture.

In August 2024, 5 gorges of the western part of the Kyrgyz Alatau (Syugaty, Kaskasu, Karakystak, Kursai, Ulken Almalysai) within Zhambyl, Merken and T. Ryskulov administrative districts of Zhambyl region were surveyed. The points of occurrence, altitudinal confinement, distribution of 7 species of the genus *Allium* L. (*A. atrosanguineum*, *A. caeruleum*, *A. caesium*, *A. karataviense*, *A. leptomorphum*, *A. longicuspis*, *A. margaritae*).

Field surveys in 2024 showed that the species identified in the gorges of the western part of the Kyrgyz Alatau ridge occurred in the altitude range from 1200 to 3390 m a.s.l. Locations of six species (*Allium*

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caeruleum, *A. caesium*, *A. karataviense*, *A. leptomorphum*, *A. margaritae*, *A. longicuspis*) were recorded in the low and middle mountains in the altitude range from 1170 to 1660 m a.s.l., and the high-mountain species *A. atrosanguineum* grew in the upper reaches of the Karakystak and Kaskasu rivers in the altitude range of 2520–3390 m a.s.l.

It should be noted that from 2 to 4 species of bows were found in the surveyed gorges: Syugates (*A. caeruleum, A. caesium, A. karataviense, A. longicuspis*), Ulken Almalysai (*A. caeruleum, A. karataviense, A. margaritae*), Karakystak (*A. atrosanguineum, A. leptomorphum*), Kursai (*A. caeruleum, A. karataviense*), with the exception of the Kaskasu gorge (*A. atrosanguineum*). At the same time, the locations of *A. caeruleum* and *A. karataviense were* recorded in three gorges (Kursai, Syugaty, Ulken Almalysai) in the western part of the Kyrgyz Alatau in the altitude ridge 1200–1440 m above sea level (Table 2).

The identified onions were often found as part of herbaceous-grass, herbaceous-shrubby-cereal grass, petrophytic-herb-grass-shrub and petrophytic-tree-shrub communities. Over 32 species of vascular plants were also observed in the above communities, along with onions: *Acer semenovii* Regel & Herder, *Achillea millefolium* L., *Althaea officinalis* L., *Artemisia dracunculus* L., *Artemisia serotina* Bunge, *Bassia prostrata* (L.) Beck, *Bromus japonicus* Thunb., *Cerasus tianshanica* Pojark., *Convolvulus arvensis* L., *Ephedra intermedia* Schrenk & C.A. Mey., *Euphorbia jaxartica* (Prokh.) Krylov, *Ferula diversivittata* Regel & Schmalh., *Galium aparine* L., *Galium verum* L., *Haplophyllum acutifolium* (DC.) G. Don, *Hypericum perforatum* L., *Hypericum scabrum* L., *Lomelosia songarica* (Schrenk) Soják, species of the genus *Lonicera* L., *Megacarpaea orbiculata* B. Fedtsch., *Mentha asiatica* Boriss., *Onosma irritans* Popov, *Origanum vulgare* L., *Poa bulbosa* L., *Rhaponticoides ruthenica* (Lam.) M.V. Agab. & Greuter, *Rheum tataricum* L. f., *Rosa persica* Michx. ex Juss., species of the genus *Rosa* L., *Sisymbrium altissimum* L., *Sisymbrium loeselii* L., *Sonchus palustris* L., *Spiraea hypericifolia* L., *Stipa caucasica* Schmalh., *Tulipa greigii* Regel etc. from 19 families (Fig. 2).

Maps of locations of studied onions in the region were created based on literature, herbarium and Plantarium data (Fig. 3), results of expedition studies (Fig. 4), indicating places of potential harvesting of *Allium* L. species identified in 2024.

Table 2

Distribution and altitudinal habitat of identified species of the genus *Allium* L. in the western part of the Kyrgyz Alatau ridge according to field surveys in 2024

Species	Coordinates	Elevation above sea level	Location, date, year
Allium atrosanguineum Kar. & Kir.	N 42°32′37″ E 73°12′12″	3390 m	Zhambyl region, Merken district, Kyrgyz Alatau ridge, Kaskasu village, south-eastern slope. Kaskasu, south-eastern slope. 28.08.2024.
	N 42°39'53" E 72°47'12"	2520 m	Zhambyl region, T. Ryskulov district, Kyrgyz Alatau ridge, Karakystak gorge, southern slope. 28.08.2024.
Allium caeruleum Pall.	N 42°53'54" E 71°44'20"	1440 m	Zhambyl region, Zhambyl district, Kyrgyz Alatau ridge, gorge Kursai. 26.08.2024.
	N 42°51'49" E 71°50'56"	1290 m	Zhambyl region, T. Ryskulov district, Kyrgyz Alatau ridge, gorge Syugaty, along the road, on an earthen slope. 27.08.2024.
	N 42°52'9" E 71°49'41"	1280 m	Zhambyl region, T. Ryskulov district, Kyrgyz Alatau ridge, Syugaty village, south-eastern slope, gorge Syugaty, south-eastern slope. 27.08.2024.
	N42°52'12" E71°49'40"	1270 m	Zhambyl region, T. Ryskulov district, Kirghiz Alatau ridge, gorge Syugaty, lower part of stony-rubble slope of southern exposure. 27.08.2024.
	N 42°53'56" E 71°42'43"	1200 m	Zhambyl region, Zhambyl district, Kyrgyz Alatau ridge, gorge Ulken Almalysay, southern slope. 26.08.2024.
Allium caesium Schrenk	N42°51'48" E71°51'1"	1320 m	Zhambyl region, T. Ryskulov district, Kyrgyz Alatau ridge, gorge Syugaty, stony-rubble slope of southern exposure. 27.08.2024.

Continuation of Table 2

Species	Coordinates	Elevation above sea level	Location, date, year
Allium karataviense Regel	N 42°53'54" E 71°44'20"	1440 m	Zhambyl region, Zhambyl district, Kyrgyz Alatau ridge, gorge Kursai. 26.08.2024.
	N 42°52'12" E 71°49'40"	1270 m	Zhambyl region, T. Ryskulov district, Kyrgyz Alatau ridge, gorge Syugaty, lower part of stony-rubble slope of southern exposure. 27.08.2024.
	N 42°53'56" E 71°42'43"	1200 m	Zhambyl region, Zhambyl district, Kyrgyz Alatau ridge, gorge Ulken Almalysay, southern slope. 26.08.2024.
Allium leptomorphum Vved.	N42°37'33" E72°53'29"	1660 m	Zhambyl region, T. Ryskulov district, Kyrgyz Alatau ridge, gorge Karakystak, southern slope. 28.08.2024.
Allium longicuspis Regel	N 42°52′17″ E 71°50′13″	1170 m	Zhambyl region, T. Ryskulov district, Kyrgyz Alatau ridge, gorge Syugaty. 26.08.2024.
Allium margaritae B. Fedtsch.	N42°53'56" E71°42'43"	1200 m	Zhambyl region, Zhambyl district, Kyrgyz Alatau ridge, gorge Ulken Almalysay, southern slope. 26.08.2024.

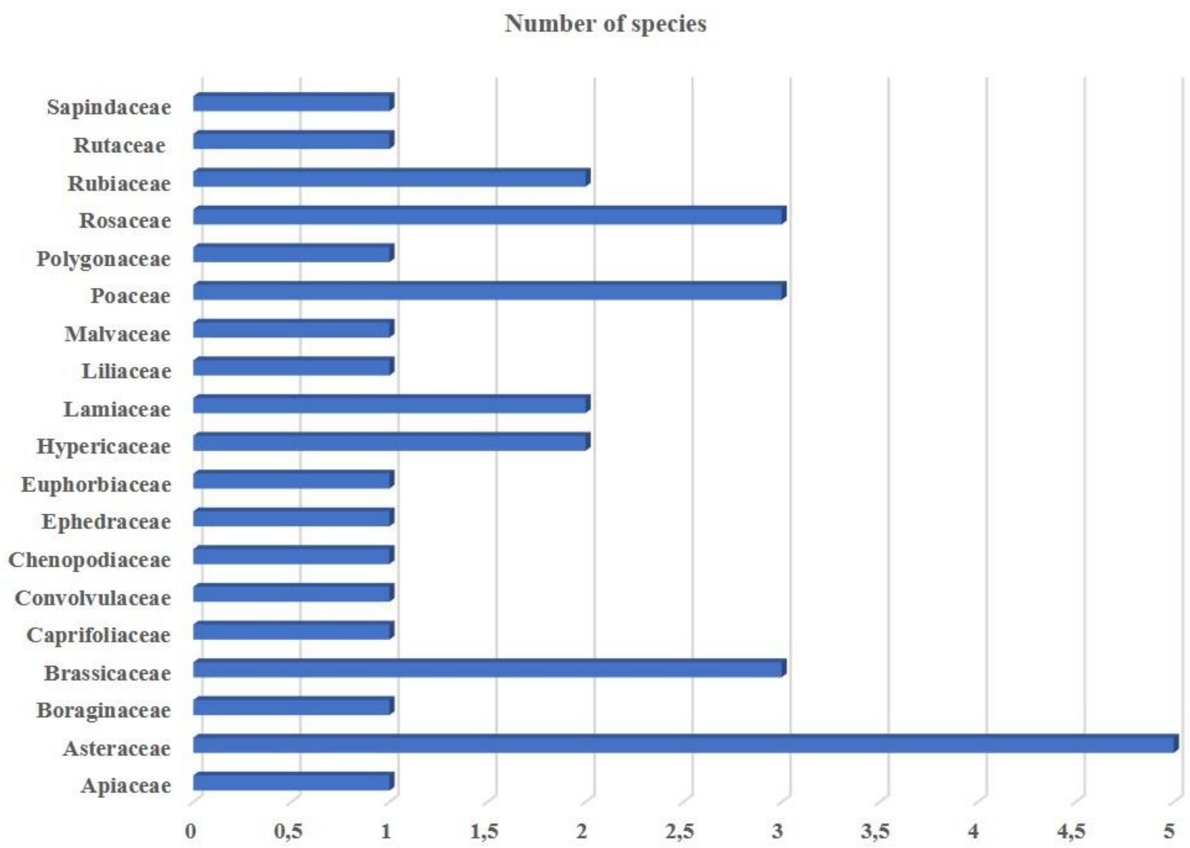

Figure 2. Distribution of associated plant species by families

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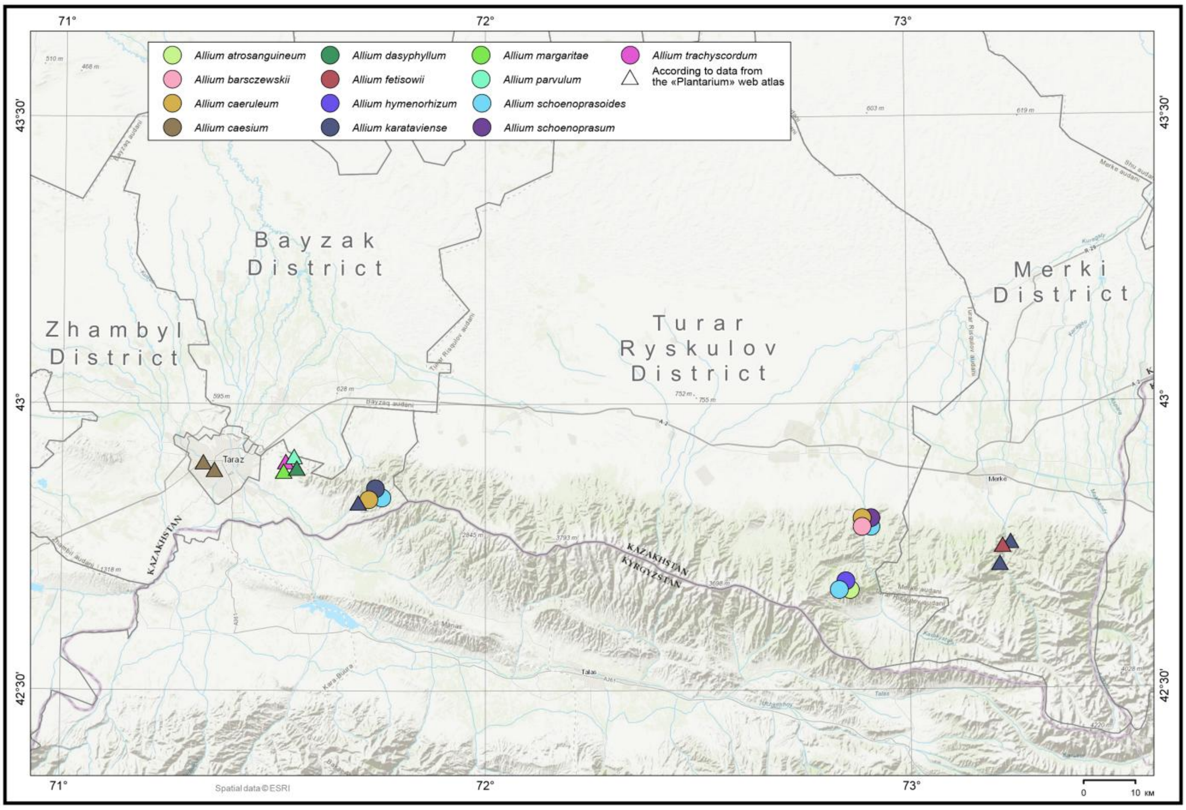

Figure 3. Map* of the locations of the studied species of the genus *Allium* L.
in the western part of the Kyrgyz Alatau according to literature, herbarium (AA) and Plantarium data
(* — author of the map Rybakov I.A.)

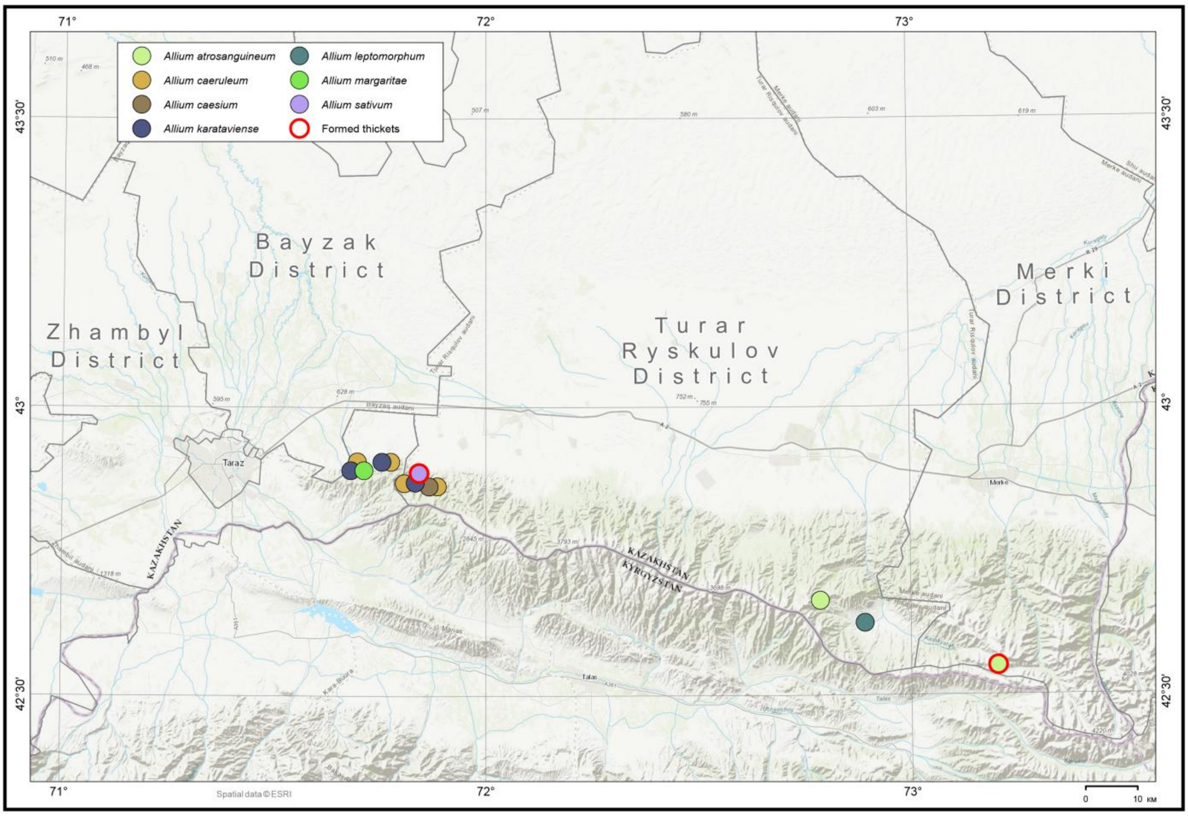

Figure 4. Map* of locations and places of potential harvesting of identified species of the genus *Allium* L.
in the western part of the Kyrgyz Alatau in 2024 (* — author of the map Rybakov I.A.)

Conclusion

Modern assessment of species composition, distribution and state of natural populations of bows of the western part of the Kyrgyz Alatau Ridge showed that the majority (57 %) of collections of species of *Allium* L. in the herbarium collection (AA) are from 1947 to 1960, followed by 24 % of collections from 1984–1985. The proportion of collections from different years is 12 % and modern collections are negligible (7 %). The preliminary list of species of the genus *Allium* L. in the Kazakh part of the Kyrgyz Alatau ridge is represented by 27 species, including 1 endemic, 2 subendemic and 1 rare species. It is possible to expand the preliminary list with other species of onions growing in the transboundary territory with Kyrgyzstan.

In 5 gorges of the western part of the Kirghiz Alatau ridge, the locations, phytocoenotic and altitudinal distribution of 7 species were revealed, of which *A. atrosanguineum* (Kaskasu gorge) and *A. longicuspis* (Syugaty gorge) form commercial thickets. The studied bows were found in the altitude ridge from 1200 to 3390 m a.s.l. They were found as part of various plant communities, including petrophytic communities. In the lowlands and midlands from 1170 to 1660 m a.s.l.: *Allium caeruleum, A. caesium, A. karataviense, A. leptomorphum, A. longicuspis, A. margaritae*.

The high-altitude species is *A. atrosanguineum*, occurring in the altitude range of 2520–3390 m above sea level. Locations and potential harvesting sites of the studied species of the genus *Allium* L. of the western part of the Kyrgyz Alatau are presented on cartographic models. Floristic and resource studies of onions continue.

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Қырғыз Алатауы жотасының батыс бөлігіндегі *Allium* L. туысының түрлері: қазіргі жағдайы және зерттеу перспективалары

Мақалада Қырғыз Алатауы жотасының батыс бөлігіндегі *Allium L.* туысының түрлерін зерттеудің қазіргі жағдайы мен болашағын бағалау нәтижелері берілген. Гербарий қорында (AA) *Allium L.* туысы түрлерінің коллекцияларының көпшілігі (57%) 1947-1960 жылдар аралығына, одан кейін кему ретімен коллекциялардың 24%-ы 1984–1985 жылдарға келетіні анықталды. Жекелеген терімдердің үлесі 12% құрайды, ал қазіргі терімдердің үлесі шамалы (7%). Қырғыз Алатауында зерттелген *Allium* туысының алдын-ала тізімі 27 түрден тұрады. Жотаның батыс бөлігіндегі 5 шатқалда 7 түрдің кездесетін орны, фитоценоздық және биіктік бойынша таралуы анықталды. Өндірістік қопаларды *A. atrosanguineum* (Қасқасу шатқалы) және *A. longicuspis* (Сыуғаты шатқалы) құрайды. Анықталған түрлер көбінесе әртүрлі шөпті-дәнді, әр түрлі шөпті-бұталы-дәнді, жартас өсімдікті-әртүрлі шөпті-бұталы, жартас өсімдікті-ағашты-бұталы қауымдастықтарда кездеседі және теңіз деңгейінен 1200-ден 3390 м-ге дейінгі биіктік аралығында өседі. Теңіз деңгейінен 1170-1660 м биіктіктегі аласа және орташа таулы аймақтарда *Allium caeruleum, A. caesium, A. karataviense, A. leptomorphum, A. longicuspis, A. margaritae* анықталды. Сонымен қатар *A. atrosanguineum* биік таулы түр, ол теңіз деңгейінен 2520–3390 м биіктік аралығында кездеседі. Зерттелген аймақтан анықталған *Allium* түрлерінің кездесетін жері мен әлеуметтік жинау орындарының карталары құрастырылды.

Кілт сөздер: түрлердің әртүрлілігі, *Allium* L. туысы, алуантүрлілік, Қырғыз Алатау жотасы.

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Виды рода *Allium* L. западной части хребта Киргизский Алатау: современное состояние и перспективы изучения

В данной работе приведены результаты оценки современного состояния и перспектив изучения видов рода *Allium* L. западной части хребта Киргизский Алатау. Установлено, что в гербарном фонде (AA) большая часть (57 %) коллекционных сборов видов *Allium* L. приходится на периоды с 1947 по 1960 годы, далее по убыванию 24 % сборов — на 1984–1985 годы. Доля разрозненных сборов составляет 12 %, доля современных сборов незначительна (7 %). Предварительный список изучаемых видов *Allium* в Киргизском Алатау представлен 27 видами. В 5 ущельях западной части хребта выявлены местонахождения, фитоценотическая и высотная приуроченность 7 видов. Промысловые заросли образуют *A. atrosanguineum* (ущелье Каскасу) и *A. longicuspis* (ущелье Сюгаты). Выявленные виды часто встречаются в составе разнотравно–злакового, разнотравно-кустарниково-злакового, петрофитно-разнотравно–кустарникового, петрофитно–древесно–кустарникового сообществ и произрастают в интервале высот от 1200 до 3390 м над ур. м. В низкогорье и среднегорье от 1170 до 1660 м над ур. м. отмечены *Allium caeruleum, A. caesium, A. karataviense, A. leptomorphum, A. longicuspis, A. margaritae*.

Высокогорным видом является *A. atrosanguineum*, встречающийся в интервале высот 2520–3390 м над ур. м. Составлены карты местонахождений и потенциальных мест заготовок выявленных видов *Allium* исследуемого региона.

Ключевые слова: видовое разнообразие, род *Allium* L., хребет Киргизский Алатау.

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Adaptation of in vitro turanga-poplar plants to greenhouse conditions

The reproduction of turanga-poplar is better carried out by the method of micropropagation, which allows you to obtain high-quality material that is advisable to use in reforestation and landscaping of cities, especially with arid climates. Adaptation of *in vitro*plants was carried out in greenhouse conditions in containers with a volume of 450 ml. Different in terms of composition substrates were used. The substrate of option 3 turned out to be the most effective: peat and perlite in layers, peat in the lower part, perlite in the upper part; and option 4 — a mixture of peat and black soil in a ratio of 6/4 with a recess filled with perlite. The experiments were carried out in natural daylight in a frame heated greenhouse with a film coating at a temperature of +20...+27 °C. Plants were used in three stages of root system development. After transplantation, they were watered with an antifungal drug solution and water. To prevent evaporation of moisture from *in vitro* plants and from the surface of the substrate, a transparent cap with a screw-off lid was covered from above. Containers with turanga plants fully adapted to non-sterile conditions were transferred to open areas outside the greenhouse for hardening.

Keywords: adaptation, turanga, micropropagation, *invitro,* plant, non-sterile conditions, drug, substrate.

Introduction

Populusdiversifolia Schrenk, further *P. diversifolia*, is a tree belonging to the genus Poplar *Populus*, reaching a height of 11–16 meters and a diameter up to 90–100 cm in individual specimens. The tree has an openwork spreading crown, which acquires a beautiful golden color in the autumn period. It is a sand fixer, capable of growing in arid conditions and on saline soils of Kazakhstan, which makes this tree indispensable not only for reforestation, but also for landscaping cities with a harsh windy arid climate [1–3].

Unfortunately, due to the difficulty of reproduction and cultivation by artificial means, this crop is practically not bred in forest nurseries. But recently, great interest has been shown in this species for its uniqueness, both for reforestation on sandy soils susceptible to wind erosion in order to consolidate them, and in order to restore degraded populations of *P. diversifolia*.

The following ways of reproduction of *P. diversifolia*exist: they are seeded and vegetative. The following vegetative methods of propagation are distinguished: by cuttings, root layering and microclonal.

Propagation by cuttings and root layering is a laborious and not always successful method due to the low rooting ability of this type of poplar [1].

The most optimal method of reproduction for *P. diversifolia* is micropropagation (in vitro), which is widely used due to its high success rate and scientific justification [4, 5].

It is especially important to obtain turanga-poplar plants with a closed root system in containers as a result of micropropagation. The plants obtained have a high survival rate for the restoration of natural populations, whose range narrows over time due to natural causes or due to human activity [6–8].

However, this method has its difficulties, especially at the stage of *in vitro* transplantation of plants into containers with a soil substrate, as well as during the period of adaptation to non-sterile conditions. With micropropagation, large losses occur when transplanting plants into non-sterile conditions (50 percent or more of death). This is due to the fact that at this stage plants are experiencing a lot of stress, primarily water stress, leading to dehydration of tissues and destruction of plant membranes. It is complemented by poor adaptation to photoautotropy due to the weak activity of carbon-fixing enzymes, that is, the ability of plants to absorb CO^2 after transplantation into non-sterile conditions decreases 4-5 times. Another significant factor that creates problems during transplantation is the poorly developed root system of adaptable plants, which is unable to absorb nutrients and water in sufficient quantities [9, 10].

The purpose of this study was to select the optimal composition of the substrate, the need to use an antifungal drug, a suitable temperature regime, the season of transplanting adaptable plants into non-sterile conditions for high survival and growth, the need for hardening on sites outside the greenhouse for planting in the open ground, for growing in nurseries to the required size in order to carry out forestry work or landscaping industrial cities with arid climate.

Experimental

The object of the study was *P. diversifolia*, propagated in culture *in vitro* in the laboratory of cryopreservation of germoplasm of the Institute of Plant Biology and Biotechnology. In order to determine the optimal composition of the nutrient medium for rooting, three options were tested: Murashige and Skuga medium (MS) with the addition of 0.5 mg/l indolylbutyric acid (IBA); MS½ + 0.5 mg/l IBA and ½MS without hormones.

Turanga (*P. diversifolia*) plants at different stages of root system development were used for transplantation from an *in vitro* culture into non-sterile conditions of the greenhouse. The first stage was characterized by the beginning of formation and active growth of the root system (root length from 0.5 to 1.0 cm). At the second stage, the roots began to branch (the appearance of second-order roots), the formation of hairs occurred; the length of the roots was 1.5-2.5 cm. The third stage was characterized by the presence of branches with the formation of root hairs and the length of the roots from 2.5 to 3.5 cm.

At the same time, when transferring to non-sterile conditions, the optimal composition of the soil substrate was selected, for which five options were tested. In the first option, peat (brown and dark sphagnum) of the Kekilla Professional brand (pH — 5.5) was used. For the second option, a mixture of peat and expanded perlite was used in a ratio of 8/2, respectively. In the third option, peat and perlite were not mixed together but filled the container with layers: peat in the lower part, perlite in the upper part. In the fourth option, the container was filled with a mixture of peat and black soil in a ratio of 6/4, respectively, and then a recess of 1.0–4.0 cm was made and filled with perlite. For the fifth option, a mixture of peat and sifted river sand with fraction sizes of 0.1-0.3 mm in a ratio of 1/1 was taken. Polypropylene containers with a volume of 450 ml, a height of 9.5 cm and a diameter of 9 cm were used as a container for transplantation.

The plant was carefully removed from the culture jar, while the remains of the nutrient medium were not removed; the transplant was carried out together with it. This was done in order not to damage the delicate root system of the adaptable plant. Next, a small recess was made in the experimental substrate, the root system was placed there, evenly without bends upwards, the plant was sprinkled and leveled.

When transferred from an *in vitro* culture to non-sterile conditions, the root system of plants can be affected by pathogenic soil-dwelling fungi, which subsequently lead to plant death. To avoid this, the effect of the drug “Maxim Dachnik” (active ingredient fludioxonyl 25 g /l) on the survival rate of *P. diversifolia* was studied. For this purpose, in the first option, the planted plants were watered with a solution of the drug in a concentration of 2 ml / 1 liter of water, 100–150 ml for each plant, and in the second option the drug was not used.

In order to avoid evaporation of moisture, both from the surface of the substrate and from the tissues of transplanted plants, the containers were covered from above with a transparent cap with a screw-off lid (diameter 2.0 cm) and placed on racks.

The plants were transplanted under natural daylight in a frame heated greenhouse with a film coating at a temperature of +20...+27 °C from mid-March to the end of September. The plant survival rate was taken into account weekly. 5–7 days after transplanting plants into containers, the caps were unscrewed to allow air to enter. After *P. diversifolia* showed signs of active growth and development, the caps were gradually lifted and completely removed with full adaptation to non-sterile conditions, the entire stage took from 3 to 4 weeks.

After the plants transplanted from the *in vitro* culture were fully adapted to the non-sterile conditions of the closed ground, they were placed on sites outside the greenhouse in order to harden for planting in the open ground.

Results and Discussion

To determine the optimal composition of the nutrient medium for rooting, three options were tested: MS, IBA — 0.5 mg/l; ½MS + IBA — 0.5 mg/l and ½MS without hormones.

The results of optimizing the nutrient medium for obtaining the root system of *P.diversifolia* showed that a decrease in the concentration of macro and microelements by MS and the introduction of phytohormone IBA into the medium at a concentration of 0.5 mg/l leads to the formation of roots in 95–97 % of plants in *in vitro* culture. In this case, the first roots began to appear after 14 days, followed by intensive growth, development, and branching accompanied by the formation of root hairs. After 30 days, they reached a length of 1.0-1.5 cm and had a white color with a beige tint.

The conducted studies have shown that the stage of development of the root system and its length had a significant impact on the survival and adaptation of plants in non-sterile conditions. As can be seen from Figure 1, plants at the first stage of root system development had the lowest survival rate of 43 %. This was due to the fact that plants at this stage completely lacked second-order roots and root hairs responsible for the absorption of water and nutrients. The highest rate was in plants at the second stage — 92 %. The reason was the active growth of second-order roots with the formation of root hairs on them, and a length not exceeding 2.5 cm. Survival rate at the third stage was 79 %. The root system, which was more than 3.0 cm long, bent and broke during transplantation, which prevented the supply of nutrients and contributed to damage by pathogenic microflora. This led to a decrease in the survival rate of turanga in the third stage of root development.

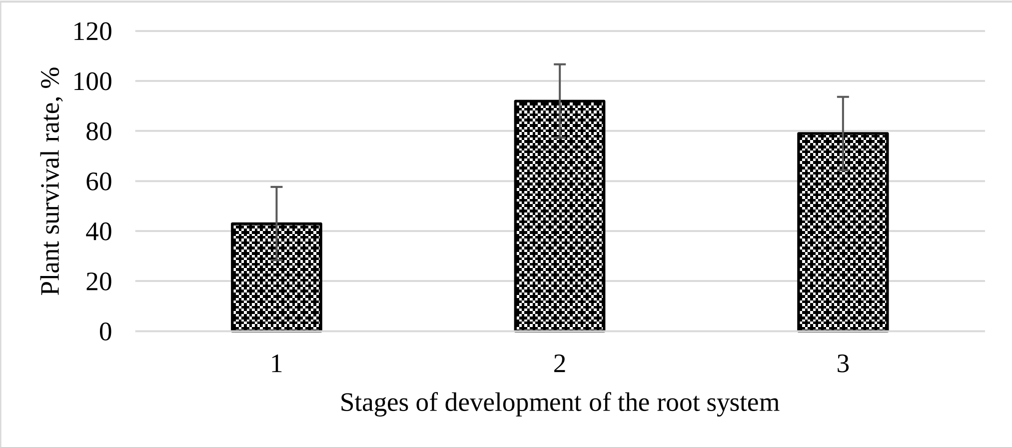
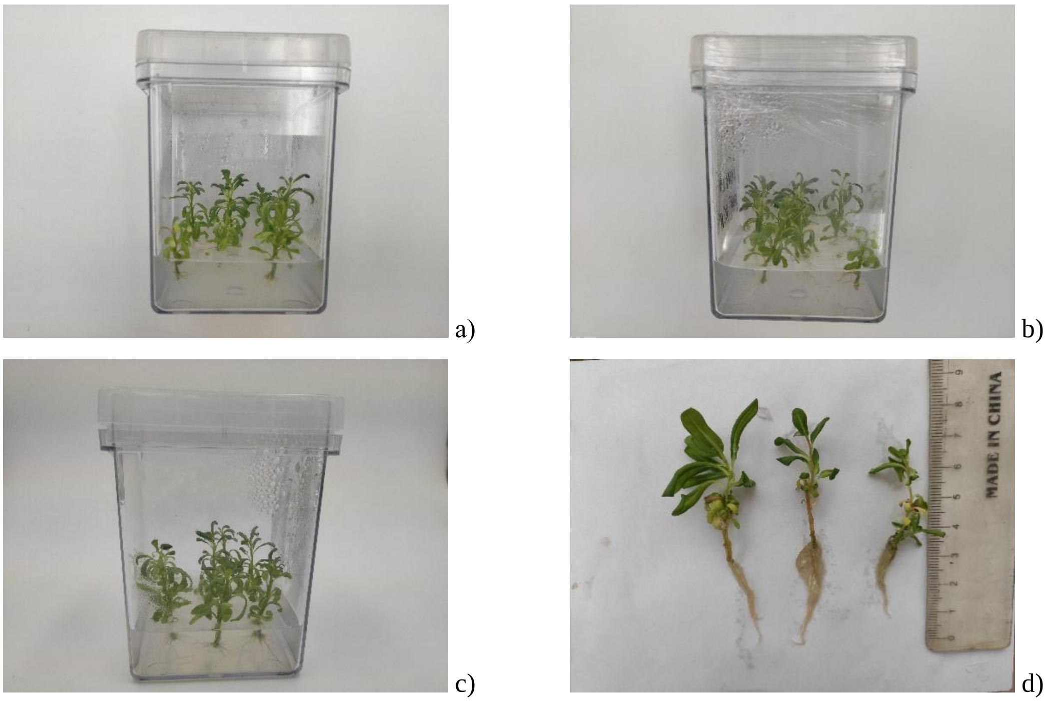


Figure 1. Survival rates of *P. diversifolia* at different stages of root system development

Figure 2 shows *P. diversifolia* plants at various stages of root system formation in *in vitro* culture.



a) the first stage of development*; b)* the second stage of development*;*
c) the third stage*; d)* the development of the root system at different stages

Figure 2. Development of the root system of *P. diversifolia* in *in vitro* culture.

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As a result of the conducted studies, it was found that the highest percentage of plant survival during adaptation from *in vitro* culture was when using substrate options 3 and 4 and amounted to 50.7 % and 65.7 %, respectively. Planting in pure perlite resulted in active root system growth. This is due to the good aeration and hygroscopicity of the material, the absence of pathogenic microflora in it, which causes rotting of the roots and the base of the stem. When using options 1, 2 and 5, the survival rate of adaptable plants did not exceed 35 %, 31 % and 22.3 %, respectively. This was due to the close contact of roots and shoots with pathogenic microorganisms living in a non-sterile substrate. At the same time, the aeration of these substrate options was less intense than when using pure perlite. Data on the survival rate of plants are presented in the Table.

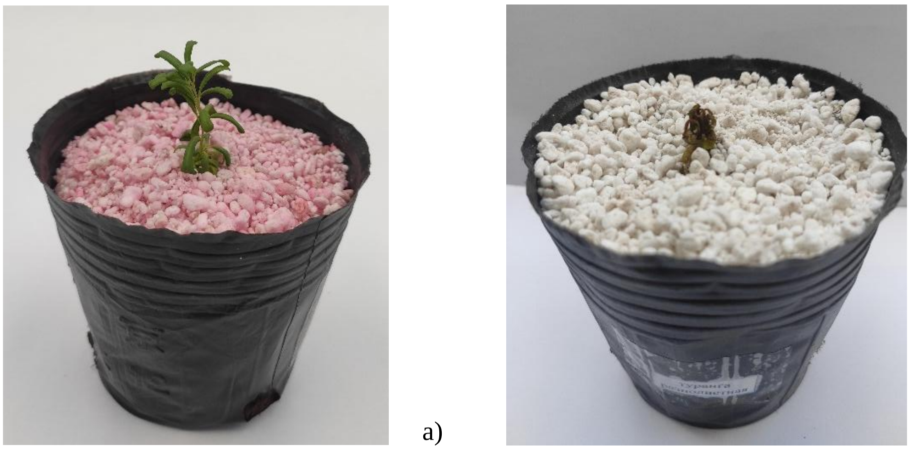
Table

Survival results of *P. diversifolia* on different substrates (average)

The composition of the substrate	The number of plants that took root, %
peat (option 1)	35±2,0
peat + perlite mixture 8:2 (option 2)	31±1,7
peat bottom layer + perlite top layer (option 3)	50,7±1,03
peat + black soil mixture 6:4 + recess with perlite (option 4)	65,7±5,1
peat + sand mixture 1:1 (option 5)	22,3±3,3

The results achieved were compared with data from previous studies on the use of substrates using the example of various crops. For example, the number of plants that took root when transplanted into non-sterile conditions of strawberries of the Redgontlit variety with the use of perlite was 80 %; when using the peat: sand substrate 1:1, the number of plants that took root was 58.6 % [9]. The survival rate of triploid aspen test tube plants planted in peat tablets averaged 46.6 % [10]. Thus, our studies have allowed us to obtain sufficiently high rates of *P. diversifolia* survival to non-sterile conditions.

The use of an antifungal drug to treat the substrate directly during transplantation gave a positive result compared to watering with just water. The bases of the shoots of some plants, the soil under which was watered without the use of a fungicide, began to darken a week after transplantation, then wilting and complete rotting were observed. In specimens planted with the use of a fungicide, such symptoms were observed much less frequently or were absent altogether (Fig. 3).



a) b)

a) with the use of a fungicide; *b)* without the use of a fungicide

Figure 3. Plants of *P. diversifolia*, a week after transplantation

The results of the effect of the fungicide "Maxim Dachnik" on the *in vitro* survival of plants after transplantation into non-sterile conditions are presented in Figure 4.

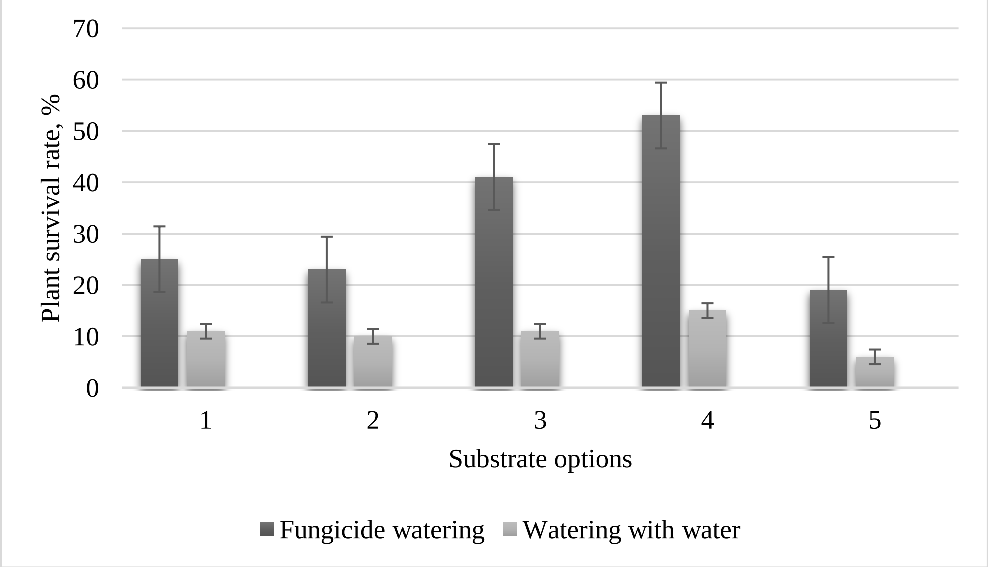


Figure 4. The effect of a fungicide on the survival rate of *P. diversifolia* in non-sterile conditions

As can be seen from Figure 4, the survival rate of turanga when watered with an antifungal drug after transplantation into non-sterile conditions was on average 53 %, without the use of the drug on average did not exceed 15 %.

During the experiments, it was noted that the optimal temperature for adaptation to non-sterile conditions was 20...23 °C and natural daylight in the greenhouse conditions. The optimal time for the transfer of *P. diversifolia* from an *in vitro* culture to a soil substrate is the period from mid-March to the end of September. During this period, the transplanted plants did not lack sunlight for active growth and development.

Hardening of *P. diversifolia* for cultivation in the open ground was carried out on a site outside the greenhouse and seedlings with a height of 20–30 cm with a closed root system in containers were obtained (Fig. 5).

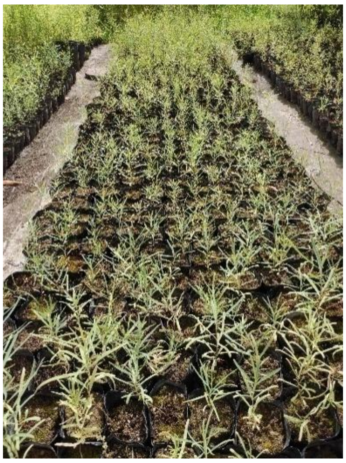



Figure 5. Hardening in the open area of *P. diversifolia*

Conclusions

The best results for the rooting of *P.diversifolia* under *in vitro* conditions were obtained using the medium MS½ + IBA — 0.5 mg/l.

When transferring to non-sterile conditions, it is recommended to use *in vitro* plants with a root system having second-order roots with root hairs and a length of 1.5-2.5 cm.

As a result of the experiments conducted on the adaptation of *P.diversifolia* plants to non-sterile indoor conditions, the highest percentage of survival was shown by substrate 3, consisting of a mixture of brown and dark sphagnum peat with expanded perlite, placed into a container in layers in the lower part peat, in the

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upper part perlite; and substrate 4 — a mixture of peat and black soil in a ratio of 6/4, respectively, with a recess filled with perlite.

After transplantation, it is recommended to abundantly spill the substrate with a solution of the fungicide “Maxim Dachnik” (active ingredient fludioxonyl 25 g/ l) in a concentration of 2 ml / 1 liter of water to reduce the negative effect of pathogenic microflora on the immature and vulnerable root system of plants *in vitro*.

In order to avoid evaporation of moisture from the tissues of the adapted plant, it is necessary to cover the top with a transparent cap with a screw-off lid (diameter 2.0 cm) and remove the lid after 5–7 days. After the appearance of signs of active growth of *P.diversifolia*, it is advisable to gradually open the caps until the plants fully adapt to non-sterile conditions. The whole stage takes from 3 to 4 weeks.

Transplantation of *in vitroP. diversifolia* plants is best performed at a temperature of 20...23 °C in natural daylight from mid-March to the end of September.

To prevent additional stress from plants adapted to greenhouse conditions when planting in open ground conditions, it is effective to carry out hardening in open areas outside the greenhouse.

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Тораңғы-терек өсімдіктерінің *in vitro* жабық топырақ жағдайларына бейімделуі

Тораңғы-теректі көбейту үшін микроклональды әдісті қолдану тиімді, себебі бұл сапалы материал алуға мүмкіндік береді, оны орманды қалпына келтіру мен қалаларды көгалдандыруда, әсіресе құрғақ климатта пайдалануға болады. *In vitro* өсімдіктерін жабық топырақта 450 мл көлеміндегі контейнерлерде бейімдеу жүргізілді. Әртүрлі субстрат құрамдары қолданылды. Ең тиімді нәтиже 3-нұсқа бойынша алынды: төменгі қабатта шымтезек, жоғарғы қабатта перлит; сондай-ақ 4-нұсқа перлитпен толтырылған шымтезек және қара топырақтың 6/4 қатынасындағы қоспасы. Эксперименттер табиғи күн сәулесінде пленкамен жабылған жылыжайда +20…+27°С температурада өтті. Өсімдіктер тамыр жүйесінің дамуының үш кезеңінде қолданылды. Қайта отырғызылғаннан кейін олар саңырауқұлаққа қарсы препарат ерітіндісімен және сумен суарылды. *In vitro* өсімдіктерінің және субстрат бетінен ылғалдың булануын болдырмау үшін үстіңгі жағы бұралмалы қақпағы бар түссіз қалпақпен жабылды. Толығымен стерильді емес жағдайға бейімделген торанғы-терек өсімдіктері бар контейнерлер қатаю үшін жылыжайдан тыс ашық жерлерге ауыстырылды.

Кілт сөздер: бейімделу, торанғы-терек, микроклональды көбейту, *in vitro*, өсімдік, стерильді емес жағдай, препарат, субстрат.

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Адаптация растений *in vitro* туранга-тополя к условиям закрытого грунта

Размножение туранга-тополя лучше проводить способом микроклонального размножения, что позволяет получать качественный материал, который целесообразно использовать в лесовосстановлении и в озеленении городов, особенно с засушливым климатом. Адаптацию *in vitro* растений проводили в условиях закрытого грунта в контейнерах объемом 450 мл. При этом использовали различные по составу субстраты. Наиболее эффективным оказался состав варианта 3: торф и перлит слоями, в нижней части торф, в верхней — перлит; и вариант 4 — смесь торфа и чернозема в соотношении 6/4 с углублением, заполненным перлитом. Эксперименты проводили при естественном дневном освещении в каркасной отапливаемой теплице с пленочным покрытием при температуре +20 –+27°С. Использовали растения в трех стадиях развития корневой системы. После пересадки поливали раствором противогрибкового препарата и водой. Для предотвращения испарения влаги из *in vitro* растений и с поверхности субстрата сверху накрывали прозрачным колпаком с откручивающейся крышкой. Контейнеры с полностью адаптированнными к нестерильным условиям растениями туранги переносили на открытые площадки вне теплицы для закаливания.

Ключевые слова: адаптация, туранга, микроклональное размножение, *in vitro*, растение, нестерильные условия, препарат, субстрат.

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Phytocenotic and resource characteristics of *Rheum tataricum* L.f. in the Northern Aral region

The article presents the results of a study on the phytocenotic characteristics and resource assessment of *Rheum tataricum* L.f. in the Northern Aral region. *Rh. tataricum* has significant resource potential and is the most widespread species of the genus *Rheum* L. on the territory of Kazakhstan. Under the arid climate conditions of the Northern Aral region, *Rh. tataricum* demonstrates high adaptability and resistance to extreme environmental conditions. The purpose of the study is to inventory the commercial thickets and evaluate the raw material base of tatar rhubarb in the territory of the Northern Aral region for further use as a natural resource. Field studies were conducted, along with assessments of the yield of tatar rhubarb, the operational stock of the root, the volume of possible annual stocks of air-dry raw material. A comparative analysis of contemporary and retrospective data was also conducted. Five massifs were identified, ranging from 0.08 to 8751 hectares. It was found that on the area of 535.75 hectares occupied by *Rh. tataricum*, the total operational stock of the air-dry underground biomass is 455.6 tons, with a possible annual processed volume of 75.94 tons of air-dry roots. Industrial harvesting of the underground part of *Rh. tataricum* is possible in compliance with the recommended volume of annual harvesting of raw materials in the territory of the Northern Aral region.

Keywords: tatar rhubarb, commercial thickets, yield, stock of raw materials, operational reserve, Northern Aral region, arid lands, anthropogenic habitats.

Introduction

Rheum tataricum L.f. has significant resource potential and is the most widespread species of the genus *Rheum* L. on the territory of Kazakhstan. Under the arid climate conditions of the Northern Aral region, *Rh. tataricum* demonstrates high adaptability and resistance to extreme environmental conditions. However, despite its raw material importance, there is no current data on the resource study of this species in the Northern Aral region.

Tatar rhubarb (*Rheum tataricum*) is a perennial herbaceous plant belonging to the Polygonaceae family, a geophyte, an ephemeroid. Its life cycle, from the opening of overwintering buds and leaf formation to the seeding and the withering of aboveground organs, takes 40–45 days [1, 2]. The root system is represented by the main taproot that begins branching into 4-5 lateral roots at a depth of 40 cm. The depth of lateral root placement depends on soil composition [3]. The plant produces 2-3 sturdy stems with a grooved surface that densely branch from the middle. Tatar rhubarb possesses the following characteristics: rounded leaves which are heart-shaped at the base; three visible veins; leaf underneath and the leafstalk are covered with small villi; the upper leaf surface is glabrous; yellowish flowers have 3–5 brown veins and 5 equal perianth lobes; three-angled fruits, which are heart-shaped, finely wrinkled and dark brown, nuts are winged. Its blooming period takes place in April-May; fructification period occurs from May to early June [1, 2]. Its wide-spreading area is desert and semi-desert plains. Beyond our country the species grows in the eastern and southern parts of European Russia, Ukraine, Uzbekistan and China (Xinjiang) [4].

The raw material of *Rh. tataricum* is the underground part, which is included in the State Register of Medicines of the Republic of Kazakhstan [5]. It contains carbohydrates, organic acids, phenols, catechins, tannins, anthraquinones, and higher aliphatic hydrocarbons [5]. The root of tatar rhubarb has a significantly higher tannin content compared to the aboveground parts [6]. The maximum tannin concentration in the roots is observed during the early budding phase [7]. In the underground part, tannins account for up to 25.7 % [8]. It is used in medicine as a hemostatic, astringent, anti-inflammatory, laxative, antitumor, vitamin [7]. Additionally, *Rh. tataricum* contains vitamins C, K, and PP [8].

Also, *Rh. tataricum* is a forage plant. During the early spring shortage of forage resources, the succulent leaves of *Rh. tataricum* serve as an important source of nutrition for camels, sheep, goats and horses [7]. These leaves contain a small amount of fiber (20 %), 6 % sugar, 19.6 % protein, and 5 % fat [9].

Rh. tataricum does not create pure thickets, but it is found in significant areas among sagebrush, *Haloxylon ammodendron*(C.A. Mey.) Bunge ex Fenzl, *Oreosalsola arbusculiformis* (Drobow), *Atriplex cana* Ledeb. communities. According to literature, the yield of tatar rhubarb in the Northern Aral region is 5.1 centners per hectare (c/ha) of above-ground weight and 50 c/ha of underground weight [9].

The first data on industrial reserves of *Rh. tataricum* in the Aral region were obtained by S.A. Nikitin, who in 1943 identified huge thickets of this plant near the Chelkar railway station. In subsequent years, the widespread distribution of *Rh. tataricum* in the region was noted by botanists such as N.V. Pavlov, N.I. Rubtsov, and S.R. Schwartzman [10].

Significant reserves of this species in the Aral region were identified in the 1960s as a result of research conducted by researchers of the Plant Resources Department of the Institute of Botany of the Sciences Academy of the Kazakh SSR [10]. In the studied area, 12 arrays of *Rh. tataricum* thickets with a total area of up to 268,000 hectares with a large supply of tannin-rich raw materials were identified. The gross reserves of raw root was 121,000 tons, and the production stock was up to 31,500 tons of dry roots.

Raw material reserves are known to be exposed to constant fluctuations due to the particular year ecological conditions, age species structure, anthropogenic impact, irrational harvesting, etc. [11]. It is necessary to understand that monitoring the condition of medicinal and promising for medicine wild plants is important for preserving their resource potential.

This article discusses the results of a study of the territory of the Northern Aral region in order to inventory commercial thickets and the raw material base of tatar rhubarb.

Materials and Methods

The objects of research are the natural populations of *Rh. tataricum*.

The resource survey of the territory was carried out by a route reconnaissance method [12] and in accordance with the generally accepted “Methodology for determining the reserves of medicinal plants” [13].

Geobotanical descriptions were conducted at each site containing resource objects [12]. For this purpose, special geobotanical forms are used, which provided detailed descriptions of the main landscape components: relief, soils, vegetation and their condition. Particular attention was given to investigating the spatial structure of plant communities and its connections to relief, soils, and moisture levels. 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. The impact of both natural and anthropogenic factors on vegetation was also considered.

During describing the plant communities certain herbarium samples were collected. Unknown plant species were identified by means of “Illustrated Guide for Identification of Plants of Kazakhstan” (2 volumes) [14] and “Flora of Kazakhstan” (9 volumes) [15]. The taxonomy of the species are given according to the Internet resource “Plants of the World Online” [4].

Raw material reserves were assessed in specific thickets using the method of clipping (usually on square plots) and model bushes (on transects). Additionally, the operational reserves of the species’ raw material were calculated [13]. All the data obtained were compiled into an inventory statement.

Results and Discussion

The research was conducted in April 2024 in the Shalkar district of Aktobe region and the Aral district of Kyzylorda region. Taking into account the botanical and geographical demarcation the investigated territory is located in the Northern-Turanian province of the Western-Northern-Turanian subprovince, which belongs to the Iran-Turanian subarea of the Sahara-Gobi desert area [16].

The surroundings of the Tereskent botanical field station (Shokysu railway station), as well as the territories located near the villages Saksaulsk and Akespe were surveyed (Fig. 1).

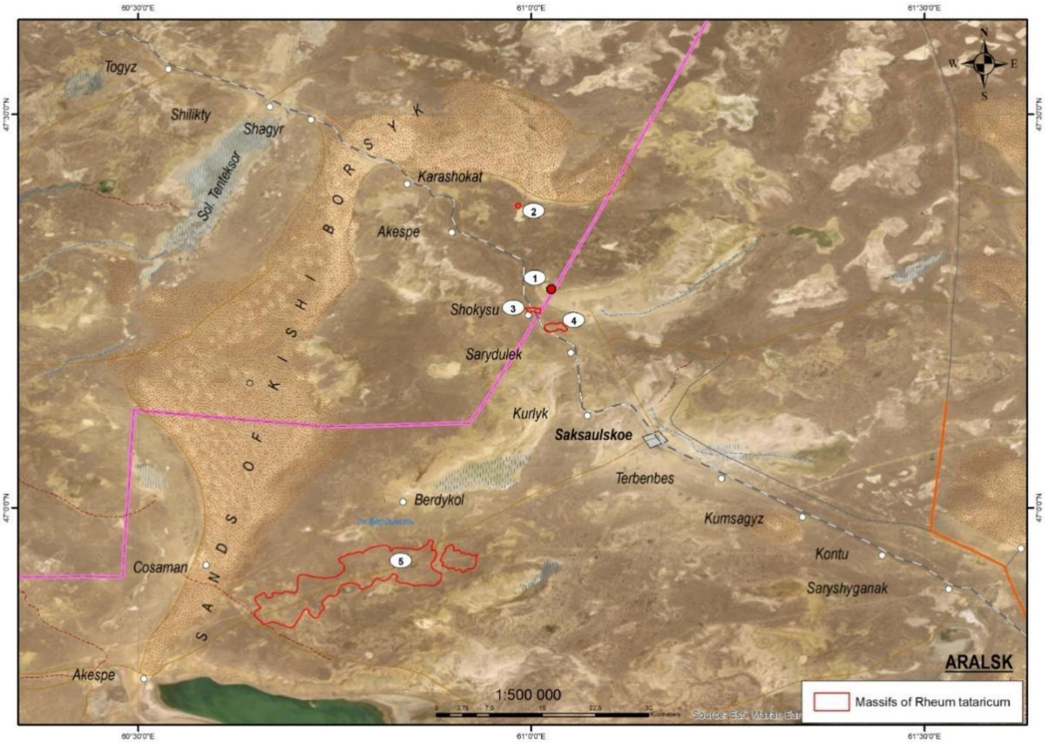

Figure 1. Locations of the identified *Rheum tataricum* massifs

To determine the yield of the aboveground and underground phytomass of tatar rhubarb, 5 massifs with different areas and projective coverage of the resource species were surveyed. The area of the massifs was initially determined in the field, and later it was adjusted based on satellite images.

In each massif, 5 sample sites of 5x5 sq. m. were laid. On each plot, the number of model plants of large (L), medium (M) and small (S) sizes was counted, after which the average density of the thicket and the projective coverage of *Rh. tataricum* were determined based on the area occupied by the model plants (Table 1).

Table 1

Quantitative indicators of model plants

Model plants	Parameters of model plants (sq. m)	The density on the site 5x5 sq. m	The amount of plants per ha	Projective coverage of tatar rhubarb (%)
1	2	3	4	5
Massif 1				
Large	0,53x0,43	3	1200	6,5
Medium	0,45x0,32	6	2400	
Small	0,30x0,16	2	800	
Massif 2				
Large	0,80x0,59	4	1600	10
Medium	0,54x0,30	3	1200	
Small	0,34x0,16	2	800	
Massif 3				
Large	0,90x0,55	3	1200	44
Medium	0,55x0,50	26	10400	
Small	0,40x0,25	24	9600	
Massif 4				
Large	0,65x0,75	6	2400	32
Medium	0,64x0,45	16	6400	
Small	0,31x0,22	6	2400	

Continuation of Table 1

1	2	3	4	5
Massif 5				
Large	0,55x0,45	2	800	5
Medium	0,45x0,30	5	2000	
Small	0,30x0,15	1	400	

The yield assessment of *Rh. tataricum* was during the budding and flowering phases on the sample plots. In the field, the raw weight of the aboveground and underground phytomass of each model plant was determined. After weighing, the samples were packed in kraft paper for drying to air-dry condition, with final weight determined in laboratory conditions.

Table 2 presents integral data for each studied massif of tatar rhubarb, including projective coverage, raw and air-dry weight of model plants, % of shrinkage.

Table 2

Characteristics of *Rheum tataricum* massifs in the Northern Aral region

Location of the thickets (massif number)	The name of the community	General projective coverage / projective coverage of tatar rhubarb (%)	Raw weight of model plants		Air-dry weight of model plants	
			weight of aboveground part (g)	weight of underground part (g)	weight of aboveground part (g) / shrinkage (%)	weight of underground part (g) / shrinkage (%)
Massif 1 Aktobe region, Shalkar district, at the top of the plateau	ephemeroid-lichen-anabasis	60-70 / 6,5	565	2275	68 / 12,0	910/ 40
Massif 2 Aktobe region, Shalkar district, pre-suspension strip near the temporary lake (between the railway stations Shokysu and Karashokat)	sagebrush-ephemeroid	60 / 10	885	2505	92 / 10,4	870 / 35
Massif 3 Aktobe region, Shalkar district, surroundings of the Shokysu railway station	sagebrush-ephemeroid-rhubarb	65-70 / 44	690	2205	86 / 12,5	880 / 35
Massif 4 Kyzylorda region, Aral district, surroundings of Shokysu railway, 2.4 km south of Shokysu railway station	sagebrush-ephemeroid	60-65 / 32	1015	2580	116 / 11,4	990 / 38
Massif 5 Kyzylorda region, Aral district, on the road between the villages of Akespe and Berdykol	sagebrush-ephemeroid	40-45 / 5	595	1222	75 / 12,6	550 / 45

The data from Tables 1 and 2 were used to determine the area occupied by *Rh. tataricum* in each massif, to recalculate the reserves of raw materials in centners per hectare (c/ha), the operational stocks of the root and the volume of possible annual processed of raw materials (Table 3).

Table 3

Stocks of air-dry raw materials of *Rheum tataricum* in the identified massifs

No of massif	The area of the thicket, ha		Yield of air-dry raw materials, c/ha		Operational stock of air-dry raw materials, metric tons	Volume of possible annual processed air-dry raw material, metric tons
	total	occupied by the tatar rhubarb	aboveground	underground		
1	0,08	0,005	0,85±0,11	0,34±0,04	–	–
2	25,5	2,55	1,29±0,16	12,43±1,61	2,35	0,4
3	74,0	32,6	3,06±0,4	23,49±3,05	56,69	9,45
4	197,0	63,0	4,33±0,56	41,47±5,39	193,35	32,22
5	8751,0	437,6	0,85±0,11	6,27±0,81	203,21	33,87

On the first massif, located at the top of the plateau, the total area was 0.08 ha, of which 0.005 ha were occupied by *Rh. tataricum*. The yield of air-dry raw materials of the above-ground part was 0.85±0.11 c/ha, of the underground part — 0.34±0.04 c/ha. Since the area of this massif is less than one hectare, annual harvesting of air-dry roots from this massif is not feasible.

The second massif is located in a sandy belt near a temporary lake, with a total area of 25.5 ha, of which 2.55 haare occupied by rhubarb. This massif is situated on an anthropogenically disturbed area used for livestock grazing. The level of degradation of the site is average. The yield of air-dry aboveground biomass was 1.29±0.16 c/ha, and for underground biomass, it was 12.43±1.61 c/ha. The operational stock of air-dry root is 2.35 tons. The volume of possible annual processed of air-dry root was 0.4 tons.

The third massif is located near the village of Shokysu (Fig. 2). The total area of the massif is 74.0 ha, of which 32.6 haare occupied by *Rh. tataricum*. A high level of degradation was noted, mainly due to livestock grazing. The yield of air-dry aboveground biomass was 3.06 ± 0.4 c/ha, and for underground biomass, it was 23.49±3.05 c/ha. The operational reserve of air-dry root is 56.69 tons. The volume of possible annual processed of air-dry root was 9.45 tons.

A B

Figure 2. The third massif of tatar rhubarb: A — model plant; B — the territory of the survey

The fourth massif is located 2.4 km southeast of Shokysu, near a road. The total area of the massif is 197 ha, of which 63 haobserved. The yield of air-dry aboveground biomass was 4.33±0.56 c/ha, and for underground biomass, it was 41.47±5.39 c/ha. The operational stock of air-dry root is 193.35 tons. The volume of possible annual processed of air-dry root was 32.22 tons.

On the fifth massif, located along the road between the villages of Akespe and Berdykol, the total area was 8,751 ha, of which *Rh. tataricum* occupied 437.6 ha. The level of anthropogenic disturbance of the site

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is average with strong foci, characterized by livestock grazing, technogenic, and road degradation. The yield of air-dry aboveground biomass was 0.85±0.11 c/ha, and for underground biomass, it was 6.27±0.81 c/ha. The operational reserve of air-dry root on the fifth massif was the largest and amounted to 203.21 tons, while the volume of possible annual processed of air-dry root was 33.87 tons.

An assessment of the anthropogenic disturbance of *Rh. tataricum* massifs showed that thickets with commercial reserves are formed in anthropogenic habitats (massifs 3 and 4 in the surroundings of the Shokysu railway station), where grazing pressure and road digression are observed. This is primarily due to the fact that *Rh. tataricum* is a plant with a short vegetative cycle (ephemeroid). As previously noted, during its short growing season (March-April), the species completes all the phenophases. By May the dried panicles with seeds are dispersed by the wind, and the seeds find micro-niches for germination in spring. In heavily disturbed areas, where indigenous pasture species (*Artemisia terrae-albae*, *Anabasis salsa*, *Bassia prostrata*, *Agropyron fragile*, *Krascheninnikovia ceratoides*, etc.) are eaten almost all year round and degradation frees ecological niches, *Rh. tataricum* uses free space to form large rosettes of 3–5 leaves in early spring with a projective coverage of 32 % to 44 % in these communities. In moderately disturbed areas (massifs 1, 2, 5), the projective coverage of *Rh. tataricum* varies from 5 % to 10 %. In zonal slightly disturbed communities with fully occupied ecological niches, the participation of this resource species in the total projective coverage of communities is less than 5 %.

A comparative analysis of contemporary and retrospective data was conducted, using the article of N.F. Kashkarova [7] on the Chokusu (Shokysu) massif, which located in close proximity to the railway station (Table 4).

Table 4

Comparative characteristics of the *Rheum tataricum* massif near the Chokusu railway station (L, M, S — model plants)

Plant association	Area of the massif / area occupied by *Rheum tataricum* (ha)	The density of the specimen / ha	Yield of raw root (t/ha)
1963			
Artemisia terrae–albae–Rheum tataricum	26000 / 15700	1500–1800	1,4–6,5
Anabasis salsa–Rheum tataricum		1000–1600	0,5–0,8
Rheum tataricum–Artemisia terrae–albae		500–800	0,3–0,8
2024			
Artemisia terrae–albae–ephemeroid–*Rheum tataricum*	271 / 95,6	1200 L + 10400 M + 9600 S	6,71
Artemisia terrae-albae–ephemeroid		2400 L + 6400 M + 2400 S	10,91

A comparison of the data revealed that the area of the massif decreased due to the expansion of the settlement. On the other hand, the density of *Rh. tataricum* per hectare increased, which affected the yield of the raw root.

Regarding the Shokysu massif, Kashkarova N.F. stated in her article that, due to its convenient location near the railway station, significant reserves of *Rh. tataricum*, and the availability of drinking water, this massif represents a valuable and promising site for organization of a procurement point [7].

As a result of the study, it was found that *Rh.tataricum* occurs in the following types of plant communities within the surveyed area: ephemeroid-lichen-anabasis, sagebrush-ephemeroid, sagebrush-ephemeroid-tatarrhubarb. The floristic composition of plant communities was determined for each massif (Table 5). The studied communities contain 32 species of vascular plants and one species of lichen. Among the associated species were often found: *Alyssum desertorum* Stapf, *Artemisia terrae-albae* Krasch., *Descurainia sophia* (L.) Webb ex Prantl, *Ranunculus falcatus* L., *R. platyspermus* Fisch. ex DC., *Tulipa biflora* Pall.

Table 5

The floristic composition of plant communities of the studied thickets of *Rheum tataricum*

Families / Species	Massifs / Abundance by Drude				
	1	**2**	**3**	**4**	**5**
Amaranthaceae Juss.					
Anabasis aphylla L.	-	-	sol	sol	-
*Anabasis salsa (*Ledeb.) Benth. ex Volkens	sp-cop$_1$	-	-	-	sol
Bassia prostrata (L.) Beck	sol	-	-	-	-
Ceratocarpus arenarius L.	-	-	-	-	-
Girgensohnia oppositiflora (Pall.) Fenzl	-	-	-	-	-
Pyankovia brachiata (Pall.) Akhani & Roalson	-	-	-	-	-
Soda foliosa (L.) Akhani	-	-	-	-	-
Apiaceae Lindl.					
Prangos odontalgica (Pall.) Herrnst. & Heyn	-	-	-	sol	-
Asparagaceae Juss.					
Asparagus breslerianus Schult. & Schult.f.	sol	-	-	-	-
Asteraceae Bercht. & J. Presl					
Artemisia semiarida (Krasch. & Lavrenko) Filatova	-	sp	-	-	sp
Artemisia terrae-albae Krasch.	-	-	sol-sp	sp-cop$_1$	sol
Takhtajaniantha pusilla (Pall.) Nazarova	sol-sp	-	-	-	-
Berberidaceae Juss.					
Leontice incerta Pall.	sol	-	-	-	-
Boraginaceae Juss.					
Lappula spinocarpos (Forssk.) Asch. ex Kuntze	sol	sol-sp	sol	-	-
Brassicaceae Burnett					
Alyssum dasycarpum Stephan ex Willd.	sol	-	-	-	-
Alyssum desertorum Stapf	sol	sp-cop$_1$	cop$_1$	sol	sp
Descurainia sophia (L.) Webb ex Prantl	sol	sol	sol	sol	-
Lepidium perfoliatum L.	sol	-	-	-	sp
Megacarpaea megalocarpa (Fisch. ex DC.) Schischk. ex B.Fedtsch.	sol	-	-	-	-
Strigosella africana (L.) Botsch.	-	-	sol	sol	-
Chorispora tenella (Pall.) DC.	-	-	sol	-	-
Cyperaceae Juss.					
Carex pachystylis J.Gay	-	sp	-	-	-
Geraniaceae Juss.					
Geranium linearilobum DC.	-	-	-	sol	-
Liliaceae Juss.					
Gagea reticulata (Pall.) Schult. & Schult.f.	-	sol	-	-	-
Tulipa biflora Pall.	sol-sp	sol	sol	-	sol
Poaceae Barnhart					
Agropyron desertorum (Fisch. ex Link) Schult.	-	-	-	-	-
Eragrostis minor Host	-	-	sol	sol-sp	sol-sp
Eremopyrum bonaepartis (Spreng.) Nevski	-	-	-	-	sp
Eremopyrum orientale (L.) Jaub. & Spach	sp	-	-	sol	-
Eremopyrum triticeum (Gaertn.) Nevski	-	-	sol	-	-
Poa bulbosa L.	sol-sp	sol	sol	-	-
Polygonaceae Juss.					
Atraphaxis spinosa L.	-	-	-	-	sol
Rheum tataricum L.f.	sol-sp	sp	cop$_1$	sp-cop$_1$	sp
Ranunculaceae Juss.					
Ranunculus falcatus L.	sol-sp	-	sol	sol	-
Ranunculus platyspermus Fisch. ex DC.	sol	sol	sol	sol	-
Thalictrum isopyroides C.A. Mey.	sol-sp	-	-	-	-
Circinaria affinis (Eversm.) Sohrabi(lichen)	cop$_1$	-	-	-	-

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Conclusions

A contemporary assessment of the resource potential of *Rh. tataricum* in the Northern Aral region has revealed five massifs ranging in size from 0.08 to 8,751 hectares. It was found that in the area of 535.75 hectares occupied by *Rh. tataricum*, the total operational stock of the air-dry underground biomass is 455.6 tons, with a possible annual processed volume of 75.94 tons of air-dry roots. Industrial harvesting of the underground part of *Rh. tataricum* is possible in compliance with the recommended volume of annual harvesting of raw materials in the territory of the Northern Aral region. The collection and harvesting of rootstocks from plants at least 4 years old are carried out after the aboveground parts have died off, leaving younger plants for the regeneration of the thickets. *Rh. tataricum* raw material can be harvested on the same thicket every 4-5 years [17].

The floristic composition of the *Rh. tataricum* communities which forming thickets includes 32 species of vascular plants and 1 lichen species, with the most frequent associated species being *Alyssum desertorum, Artemisia terrae-albae, Descurainia sophia, Ranunculus falcatus, R. platyspermus, Tulipa biflora.*

An assessment of the anthropogenic disturbance of *Rh. tataricum* massifs revealed that thickets with commercial reserves are formed in anthropogenic altered habitats (massifs 3 and 4 near the Shokysu railway station), which are characterized by grazing pressure and road degradation.

A comparative analysis of current and retrospective data from 1963 on the Chokusu (Shokysu) massif, located near the railway station, showed a reduction in the area of the massif, which is associated with the expansion of the settlement and the increase in the number of residential buildings. At the same time, the density of *Rh. tataricum* per hectare increased, which positively affected the yield of the raw roots.

The new data on the stocks of raw materials of *Rh. tataricum* in the Northern Aral region can serve as a basis for developing a rational and scientifically grounded system of procurement of medicinal raw materials in the region. *Rh. tataricum* is a valuable natural resource, which with a competent approach, can make a significant contribution to the development of various industries. However, it is important to note that without a scientific approach and sustainable use of natural thickets of *Rh. tataricum*, its reserves could be quickly depleted.

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Ж.Қ. Салмуханбетова, Л.А. Димеева

Солтүстік Арал маңындағы татар рауғашының (*Rheum tataricum* L.f.) фитоценоздық және ресурстық сипаттамасы

Мақалада Солтүстік Арал маңындағы татар рауғашының (*Rheum tataricum* L.f.) фитоценоздық ерекшеліктері мен ресурстық сипаттамасын бағалау бойынша зерттеу жұмыстарының нәтижелері келтірілген. *Rh. tataricum* — ресурстық потенциалы жоғары Қазақстан аумағындағы *Rheum* туысының ішіндегі кеңінен таралған түрлердің бірі. Татар рауғашы Солтүстік Арал маңының аридті климаты жағдайындағы қоршаған ортаның қолайсыз жағдайларына жоғарғы деңгейде бейімделушілік пен төзімділік көрсетті. Зерттеу жұмысының мақсаты — Солтүстік Арал маңы территориясындағы татар рауғашының өндірістік қамыстарын инвентаризациялау және шикізат қорын бағалау. Далалық зерттеу жұмыстары, татар рауғашының өнімділігін есептеу, тамырдың эксплуатациялық қорын және шикізатты даярлаудың жылдық мүмкін болатын көлемін анықтау, сонымен қатар, қазіргі және ретроспективті мәліметтерді салыстырмалы талдау жұмыстары жүргізілді. Ауданы 0,08-8751 га аралығындағы 5 массив анықталды. Зерттеу жұмысы нәтижесінде татар рауғашы алып жатқан 535,75 га ауданда жеңіл-құрғақ күйіндегі жерасты мүшелерінің жалпы эксплуатациялық қоры 455,6 т, ал жеңіл-құрғақ күйіндегі тамырды даярлаудың жылдық мүмкін болатын көлемі 75,94 т құрады. Солтүстік Арал маңында татар рауғашының жылдық шикізатты даярлаудың ұсынылған көлемін сақтаған жағдайда, жерасты мүшелерінің өндірістік қорларын дайындау мүмкіндігі бар екендігі анықталды.

Кілт сөздер: татар рауғашы, өндірістік қамыстар, өнімділік, шикізат қоры, эксплуатациялық қор, Солтүстік Арал маңы, аридті жерлер, антропогенді тіршілік орталары.

Ж.К. Салмуханбетова, Л.А. Димеева

Фитоценотическая и ресурсная характеристика ревеня татарского (*Rheum tataricum* L.f.) в Северном Приаралье

В статье представлены результаты исследования фитоценотических особенностей и оценки ресурсной характеристики ревеня татарского (*Rheum tataricum* L.f.) в Северном Приаралье. *Rheum tataricum* обладает значительным ресурсным потенциалом и является наиболее распространенным видом рода *Rheum* L. на территории Казахстана. В условиях аридного климата Северного Приаралья ревень татарский демонстрирует высокую приспособляемость и устойчивость к экстремальным условиям окружающей среды. Цель исследования — инвентаризация промысловых зарослей и оценка сырьевой базы ревеня татарского на территории Северного Приаралья для дальнейшего использования в качестве природного ресурса. Проведены полевые исследования, подсчет урожайности ревеня татарского, определение эксплуатационного запаса корня и объема возможной ежегодной заготовки сырья, а также сравнительный анализ современных и ретроспективных данных. Выявлено 5 массивов площадью от 0,08 до 8751 га. Установлено, что на площади занимаемой ревенем 535,75 га суммарный эксплуатационный запас воздушно-сухой подземной части составляет 455,6 т при возможном объеме ежегодной заготовки - 75,94 т воздушно-сухого корня. На территории Северного Приаралья возможны промышленные заготовки подземной части ревеня татарского при соблюдении рекомендуемого объема ежегодной заготовки сырья.

Ключевые слова: ревень татарский, промысловые заросли, урожайность, запас сырья, эксплуатационный запас, Северное Приаралье, аридные земли, антропогенные местообитания.

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Current status of the population of the medicinal species *Ajania fastigiata* in Trans-Ili Alatau

The genus *Ajania* Poljakov is a perennial herbaceous plant, usually with grayish shade, without shortened vegetative shoots, with erect or often ascending and branched, well-developed, densely oleate stems. Leaves are ordinary with dissected laminae covered with appressed bipinnate, sometimes with admixture of simple hairs. The purpose of this research work is to clarify the current state of the population of *Ajania fastigiata* occurring in the Trans-Ili Alatau. The objects of the study are phytocenoses with participation and dominance of the medicinal species *Ajania fastigiata* growing in Trans-Ili Alatau. As a result of the analysis of the described 3 large populations of the medicinal species *Ajania fastigiata*, the following conclusions were obtained. According to the analysis of floristic composition of communities with participation and dominance of the studied species, 104 associated species (23 families) were identified. Asteraceae — 15 species, Poaceae — 11, Fabaceae — 10, Ranunculaceae and Rosaceae — 9 each, Lamiaceae — 8, Apiaceae — 7, Boraginaceae and Caryophyllaceae — 6 each, Liliaceae — 5 species (possibly more), 18 species belong to different families. For Pop1 the tallest individuals, 120 cm in height, were recorded. Pop1 (cop2) and Pop3 (cop3) were the most abundant populations. According to the percentage of Pop1 juveniles was about 43 %, Pop2 juveniles 44 %, and Pop3 juveniles 55 %. The age composition relative to the number of individuals showed that Pop1 and Pop3 are growing populations, while Pop2 is close to a regressive population caused by anthropogenic pressure.

Keywords: Asteraceae, *Ajania fastigiata*, medicinal plant, ecology, phytocenosis, population, dominant, Trans-Ili Alatau.

Introduction

The Asian genus *Ajania* Poljakov comprises between 30 and 40 species, according to various authors [1, 2]. These species are predominantly distributed across China and Japan, while also being native to Afghanistan, Kazakhstan, Kyrgyzstan, Mongolia, Northern India, Russia, and Tajikistan. This taxon was first segregated from the genus *Artemisia* by L.P. Polyakov [3], who proposed that *Ajania* originated from ancestral taxa closely related to *Dendranthema* (DC.) Des Moul. and that its adaptation to the steppes and deserts of Central Asia led to a high degree of morphological similarity with *Artemisia* species inhabiting these ecosystems. Subsequently, to explain the phylogenetic relationships among these three genera, Bremer and Humphries [1] hypothesized that independent evolutionary lineages had descended from a common dendranthemoid ancestor. Later, A.A. Muldashev [4] segregated three species from *Ajania* into a distinct new genus, *Phaeostigma* Muldashev. Recently, a palynological analysis was conducted on two species of *Ajania* — *Ajania fastigiata* (C.Winkl.) Poljakov and *A. fruticulosa* (Ledeb.) Poljakov — as well as one species of *Phaeostigma*, *Phaeostigma salicifolium* (Mattf.) Muldashev [5, 6].

Due to its complex taxonomic history, characterized by the frequent reassignment of species between the major groups within the subtribe *Artemisiinae*, *Ajania* represents a particularly intriguing subject for research. The genus occupies a vast distribution range across Central Asia, with a predominant presence in China (from the northwestern to the northeastern and southwestern regions), as well as in Korea, Japan, and the Russian Far East [7–9].

Despite a number of cladistic studies based on morphological and molecular data, a substantial number of taxa within the subtribe *Artemisiinae* remain of uncertain systematic placement [1, 5, 10–14].

Ajania fastigiata is a perennial herbaceous plant from the Asteraceae family. The leaves of A. fastigiata have a silvery-green color and a fluffy texture, and the flowers are yellow or orange in color collected in a brush [15, 16].

This plant has medicinal properties and is used in traditional medicine to treat various diseases. For example, a decoction of the leaves of *A. fastigiata* can help with digestive problems, and also has anti-inflammatory and antiseptic properties [17–19].

In addition, *A. fastigiata* is often used in landscape design due to its decorative appearance. It can be planted both in groups and in single plantings to create a beautiful and spectacular view in the garden or in a flower bed [20].

A. fastigiata is a plant species that forms phytocenoses in various ecosystems. It belongs to the Asteraceae family and grows mainly in the mountainous regions of Eurasia.

Phytocenoses of *A. fastigiata* can be found in alpine meadows, steppes, forest-steppes and other types of vegetation. These plants have a high adaptive ability to various environmental conditions and can form dense thickets. In the phytocenoses of *A. fastigiata*, other plant species such as grasses, shrubs and mosses are usually found. They create unique ecosystems, providing food and shelter for various species of animals. These phytocenoses play an important role in maintaining biodiversity and ecological balance in natural communities. They can also be used in landscaping and landscaping to create beautiful and functional gardens and parks. *A. fastigiata* is a relatively little studied plant that is commonly used in landscaping due to its decorative appearance. It has stems that grow vertically and form dense bushes with silver-green leaves. Flowering occurs in late summer or autumn, when small yellow flowers appear. *A. fastigiata* grows in sunny or semi-shaded places and prefers fertile soils with a good drainage system. It can be used as a ground cover or to create hedges. In general, this plant is easy to care for and does not require special attention. However, despite its popularity in landscape design, *A. fastigiata* is still a poorly studied species, and its potential medicinal properties or other beneficial qualities may not yet be studied [21–23].

Ajania fastigiata, also known as *Ajania* shrub, is a plant that has a high ecological affinity. It is a valuable plant for gardeners and landscape designers, as it is able to adapt to various environmental conditions, including dry and poor soils [24, 25].

Ajania contributes to the conservation of biodiversity, as it provides shelter and food for various species of insects, birds and other animals. Its lush flowers also attract bees and other pollinators, which helps preserve the flora. In addition, *A. fastigiata* has the ability to phytoremediate, that is, the ability to purify the soil from harmful substances and toxins. This makes it a valuable plant for improving soil quality and protecting the environment. Thus, the ecological relevance of *A. fastigiata* makes it an important plant for maintaining biodiversity and improving the ecological state of the environment [24, 25].

The floral composition of the *A. fastigiata* population may include various plant species that grow in the natural environment of this species. Some of the possible components of the population may include: *Ajania fastigiata* and species such as Festuca ovina, Poa pratensis, *Achillea millefolium*, *Echinacea purpurea*, *Geranium sanguineum*, *Sedum spectabile*, etc. This is just a small list of possible plants that can make up the floral composition of the *A. fastigiata* population in the natural environment. The specific composition will depend on habitat conditions and environmental factors.

Ajania fastigiata is usually found in dry and sunny places in the phytocenosis, such as steppes, savannas and meadows. It can be part of the vegetation cover in plant communities with other herbaceous plants, shrubs or trees. *Ajania fastigiata* usually grows in groups or thickets, creating a dense and stable vegetation cover.

The age spectrum of *A. fastigiata* usually ranges from 3 to 5 years. At this age, the plant reaches its full height and shape, and begins to bloom. *A. fastigiata* can continue to grow and bloom for many years, provided proper care and optimal growth conditions are maintained.

Experimental

The objects of the study are phytocenoses with the participation and dominance of the medicinal species *Ajania fastigiata* growing in the Trans-Ili Alatau (within the Almaty region).

The Trans–Ili Alatau is a large mountain range of the Northern Tien Shan, which is located on the border of Kazakhstan and Kyrgyzstan. The average height of the Trans–Ili Alatau is 4000 m. The river network of the Trans-Ili Alatau belongs to the Ili River basin, which flows into Lake Balkhash. Mountain rivers have extensive catchment basins, and their sources lie at an altitude of more than 3,000 m (Fig. 1).

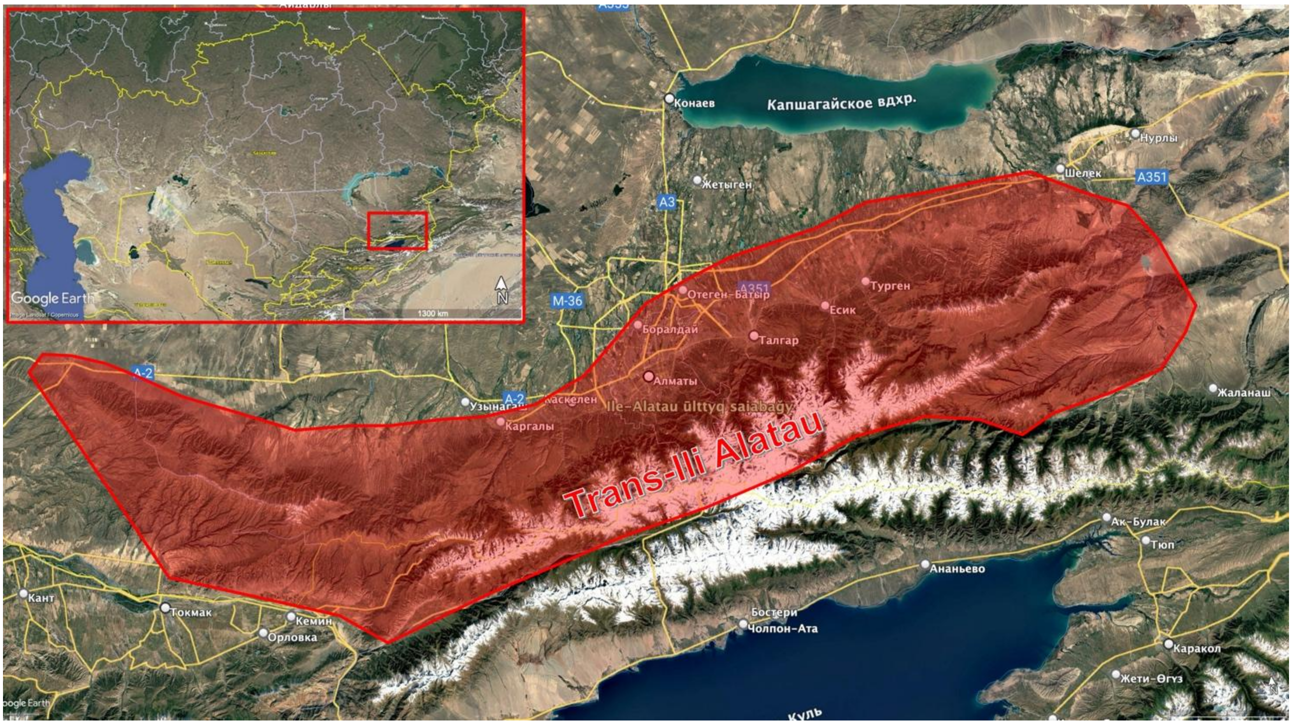

Figure 1. The study area of the Trans-Ili Alatau

The genus *Ajania* Poljakov comprises perennial herbaceous plants, typically exhibiting a characteristic grayish hue, lacking shortened vegetative shoots, and possessing erect or often ascending and branched, well-developed, densely foliated stems. The leaves are alternate, with dissected laminae covered in appressed bipartite hairs, sometimes interspersed with simple hairs.

The distribution range of the genus extends across the Eastern Palearctic [4]. In Kazakhstan, it is represented by three species, one of which is endemic—*Ajania korovinii* Kovaleusk. (Kyrgyz Alatau).

According to A.A. Muldashev, “the emergence of at least most species of the genus occurred at the end of the Neogene”. However, it is also plausible that the genus began forming earlier, during the early Neogene [4, 24–26].

The aim of this study is to clarify the current population status and morphological characteristics of *Ajania fastigiata*, found in the Trans-Ili Alatau (Fig. 2).

Figure 2. *Ajania fastigiata* (C. Winkl.) Poljak in the Trans-Ili Alatau

Classical botanical (route-reconnaissance, ecological-systematic, ecological-geographical) methods were used in the research process. To identify the collected material, fundamental summaries were used: “Flora of Kazakhstan” [27], “Determinant of plants of Central Asia and Kazakhstan” [28], etc. [4, 24–26]. Latin and Russian names (in accordance with the International Plant Names Index (INPI) and Plants of the

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World Online (POWO) database, while the former names were left for some species due to the lack of sufficient phylogenetic data confirming the need for nomenclature changes) and the work of authors who study species of the Asteraceae family [5–10].

Vegetation was studied using traditional methods of field geobotanical research. The standard area of the described plots is 30x30 m [29].

Results and Discussion

In the period from 2021–2023, several expeditionary work was carried out to identify the population of the medicinal species *Ajania fastigiata*. For comparative analysis, we have described and marked the 3 largest populations of the studied species in the Trans-Ili Alatau. Which are located at the following coordinates (Fig. 3):

Pop1 — N43.126460° E76.511690°, Karasai district, Almaty region

Pop2 — N43.229525° E76.991620°, Medeu district, Almaty

Pop3 — N43.0609796° E78.30461082°, Kegensky district, Almaty region

According to our data, shrubby thickets and grass-grass meadows are common in mountain gorges and river valleys. In the river valleys, thickets of shrubs form barberry, sea buckthorn and apricot with cereals and herbs. The lowest parts of the ridge are occupied by desolate sagebrush-feather grass steppes dominated by turf grasses with the participation of steppe grasses, confined to chestnut soils. Shrubs appear on rocky slopes in steppe communities. The belt of real steppes on typical chernozems can be divided into 2 bands: the lower — turf-slag steppes, dominated by *Stipa capillata*, *Festuca valesiaca*, with the participation of Agropyron pectinatum, Helictotrichon desertorum, as well as our studied species *Ajania fastigiata* and the upper — grass-turf-slag steppes, dominated by *Festuca valesiaca*, *Stipa lessingiana*, *S. capillata*, *Koeleria cristata* and steppe grasses, sometimes with the participation of Bothriochloa ischaemum. *Stipa kirghisorum, Festuca valesiaca* and *Helictotrichon schellianum* of the steppe are also found. But since *Ajania fastigiata* is a more xerophilic plant, it dominates drier slopes. The ecological amplitude of the studied species is quite wide, therefore it allows it to occur in various types of vegetation, mainly in grassy dry meadows and on southern slopes among shrub communities.

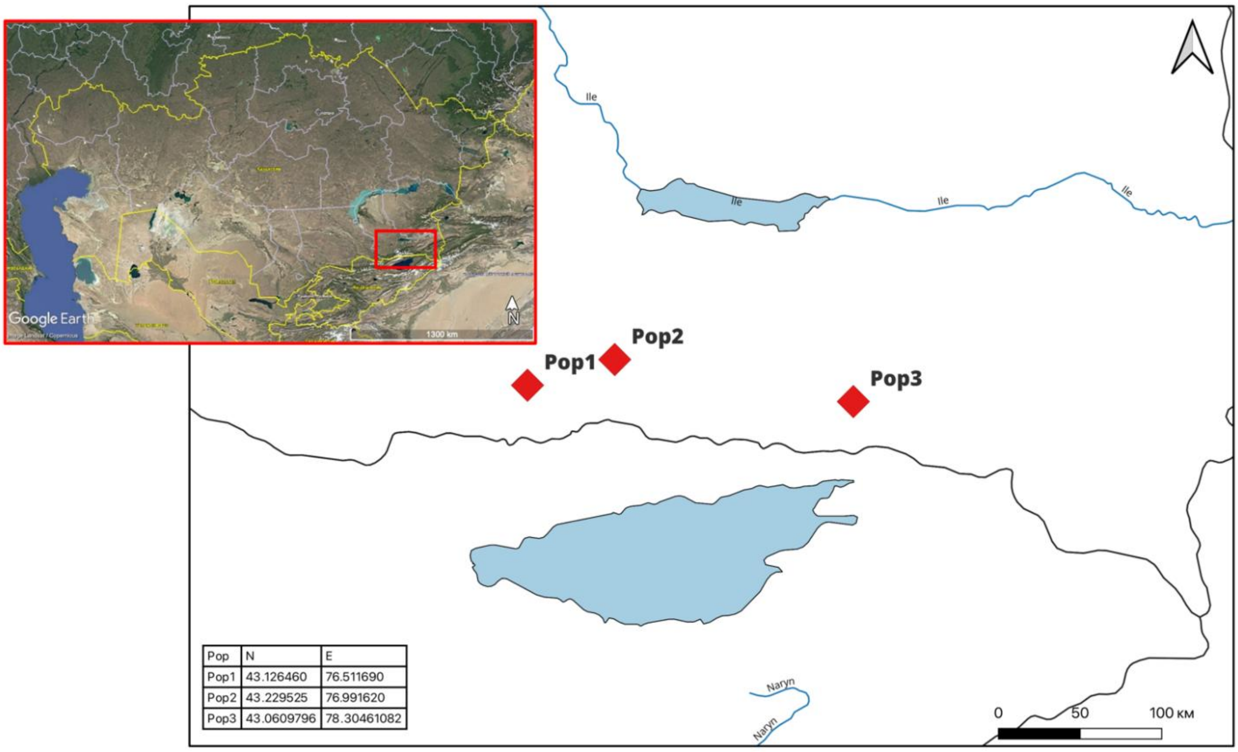

Figure 3. A map of the locations of the described populations

According to our analysis of the floral composition of communities with the participation and dominance of the studied species, 104 associated species were identified, which are divided into 68 genera and 23 families. Of these, Asteraceae Dumort. 15 species prevail the most, 7 of which belong to the genus *Artemisia* L., *Ajania fastigiata* belongs to the same family. The genera *Ajania* and *Artemisia* are considered to be closely related. Then we have other families by the number of species: Poaceae Barnhart. — 11 species, Fabaceae Lindl. — 10 species, Ranunculaceae Juss. and Rosaceae Juss. — 9 types each. Lamiaceae Lindl. — 8 species, Apiaceae Lindl. — 7 species, Boraginaceae Juss. and Caryophyllaceae Juss. — 6 species each, Liliaceae Juss. — 5 species (possibly more) and 18 species from other families (Fig. 4).

Frequently encountered species in populations and cenopopulations with dominance and participation of the studied species: *Achillea millefolium* L., *Aconitum leucostomum* Worosch., *Aegopodium alpestre* Ledeb., *Allium oreophilum* C.A. Mey., *Allium tianschanicum* Rupr., *Althaea officinalis* L., *Anemone petiolulosa* Juz., *Anthriscus sylvestris* (L.) Hoffm., *Aquilegia atrovinosa* M. Pop., *Atragene sibirica* L., *Calamagrostis epigeios* (L.) Roth, *Calamagrostis pseudophragmites* (Haller f.) Koeler., *Campanula glomerata* L., *Centaurea ruthenica* Lam., *Dracocephalum integrifolium* Bunge, *Elymus caninus* (L.) L., *Epilobium hirsutum* L., *Eragrostis minor* Host., *Euphorbia alatavica* Boiss., *Festuca pratensis* Huds., *Geranium transversal* Vved., *Geum rivale* L., *Hierochloe odorata* (L.) Wahl., *Koeleria cristata* (L.) Pers., *Lathyrus gmelini* Fritsch., *Lonicera altmannii* Regel & Schmalh., *Medicago romanica* Prod., *Mentha asiatica* Borris., *Oxytropis brachycarpa* Vass., *Oxytropis chinobia* Bunge, *Oxytropis globiflora* Bunge, *Poa bulbosa* L., *Potentilla reptans* L., *Potentilla sericea* L., *Prangos didyma* (Regel) M. Pimen. & V. Tichomirov, *Pulsatilla campanella* Fisch.ex Regel et Til., *Ranunculus repens* L., *Rosa alberti* Regel, *Rosa fedtschenkoana* Regel, *Scutellaria galericulata* L., *Seseli schrenkianum* (C.A. Mey.ex Schischk.) M. Pimen. & Sdobnina, *Sonchus arvensis* L., *Stachyopsis lamiiflora* (Rupr.) M. Pop.et Vved., *Stipa lessingiana* Trin.et Rupr., *Thalictrum collinum* Wallr., *Thalictrum foetidum* L., *Thermopsis alpina* (Pall.) Ledeb., *Thymus marschalianus* Willd., *Trigonella geminiflora* Bunge, *Tulipa ostrowskiana* Regel, *Vicia tenuifolia* Roth, *Ziziphora clinopodioides* Lam.

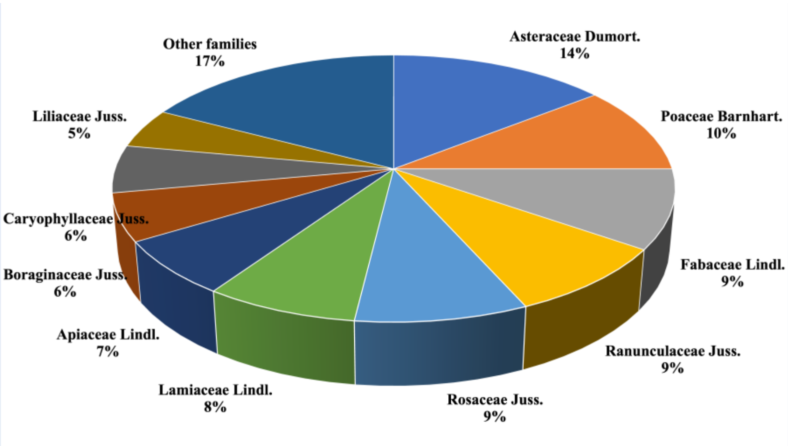

Figure 4. The spectrum of families by the number of species

The populations for comparative analysis were not chosen by chance, geographical location, features of floral composition and environmental characteristics were taken into account. Geographically, Pop1 and Pop2 populations are located close to each other, but nevertheless have sufficient distance and geographical factors that allow them to be considered different populations. From an ecological point of view, Pop1 is located on the northern slope, and Pop2 on the zapodny, Pop3 at all on the southern slope of the Trans-Ili Alatau ridge. If in Pop1 and Pop2 populations, the main dominants were woody plants, then in Pop3 we also had shrubby species. Of course, in grass stands, due to competition for sunlight, plant growth varies quite a lot. So, in Pop1, the tallest individuals were noted, reaching 120 cm in height. Pop2 individuals took the second place, and Pop3 individuals took the third place, with an average height of 35–40 cm. Pop1 (sor2) and Pop3 (cop3) populations have become more abundant. The depressed state of the Pop2 (sp-cop1) population can be attributed to the fact that it is located too close to the city of Almaty, and is subject to strong anthropogenic influence (Fig. 5).

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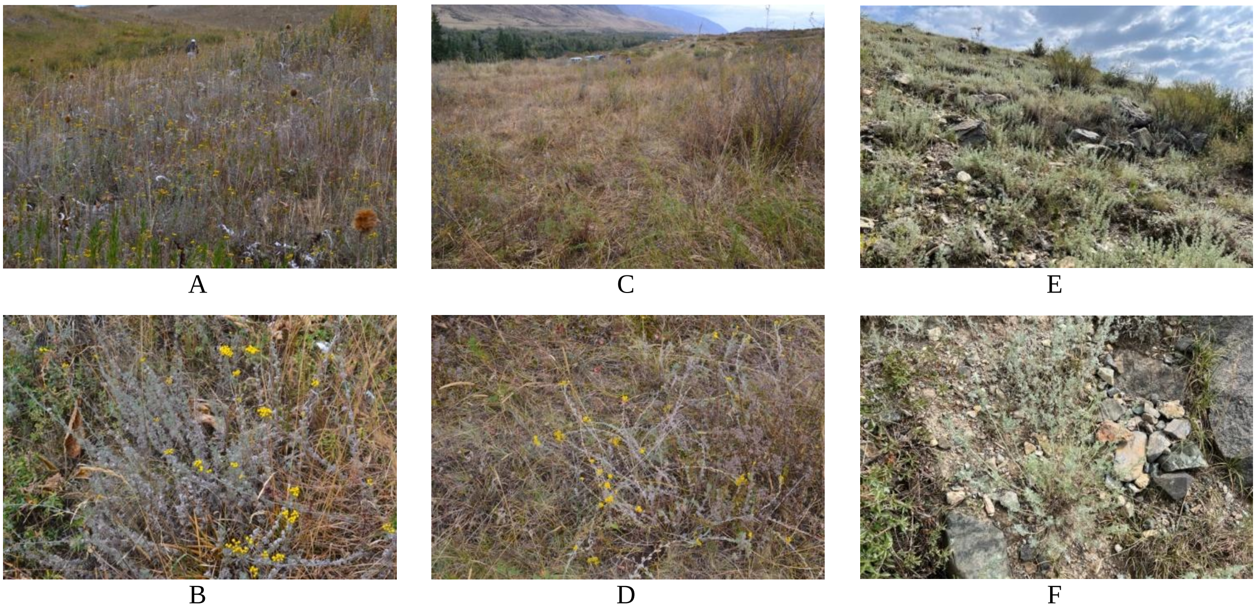

A-B — population 1 (Pop1); C-D — population 2 (Pop2); E-F — population 3 (Pop3)

Figure 5. Illustrations of the described populations

The age composition of the *Ajania fastigiata* population was considered more carefully, this is the distribution of individuals by age and developmental phases, the indicator of which is the main one in assessing the current state of the population.

We have identified the following age stages: p — seedlings; j — juvenile plants; im — immature; v — virgin_nile; g1 — young generative; g2 — middle-aged generative; g3 — old generative; ss — subsenile; s — senile [29].

At the seedling stage, plants exhibit a mixed nutrition strategy, utilizing both the seed's stored reserves and their own assimilation processes. At this phase, small plants develop with embryonic structures, including cotyledons, an actively growing radicle, and, typically, a uniaxial shoot with small leaves that often have a simpler morphology compared to those of mature plants.

Juvenile plants transition to complete autotrophic nutrition. Cotyledons are absent, but the overall structural organization remains relatively simple. Morphological uniformity is often preserved, and the leaves are distinct in shape and smaller in size compared to adult individuals.

Immature (pre-reproductive) plants exhibit transitional characteristics between the juvenile and fully mature vegetative stages. At this stage, shoot branching commonly begins, leading to an expansion of the photosynthetic apparatus.

Adult vegetative plants display the typical structural features of their life form, including well-developed underground and aerial organs. The vegetative body fundamentally corresponds to the generative state, yet reproductive organs have not yet formed.

Young generative plants enter the reproductive phase, initiating flowering and fruit production, while their structural development reaches full maturity. In some years, interruptions in flowering may occur.

Middle-aged generative plants achieve peak biological capacity, demonstrating the highest annual growth rates and maximum seed production. In clonal species, this stage is often accompanied by the onset of individual fragmentation and clone formation. Periodic interruptions in flowering may also occur.

Old generative plants are characterized by a marked decline in reproductive function, a weakening of shoot and root formation, and a gradual dominance of senescence processes over new growth. Structural disintegration becomes increasingly pronounced.

Old vegetative (subsenile) plants experience the cessation of fruiting, a significant reduction in vigor, and the intensification of degenerative processes. The connection between shoot and root systems weakens, and in some cases, the life form simplifies, with leaves reverting to an earlier developmental type.

Senile plants are characterized by extreme decrepitude, a decrease in size, few buds are realized upon renewal, some juvenile features appear a second time (leaf shape, character of shoots, etc.).

According to the percentage ratio in Pop1, the undergrowth of the population was about 43 %, and generative individuals were about 47 %, at this time 10 % of individuals belong to sub-senile and senile. In Pop2, the undergrowth of the population is also 44 %, generative individuals are 31 %, and withering individuals are 35 %. Pop3 undergrowth is 55 %, generative 41 %, withering only 4 % (Fig. 6).

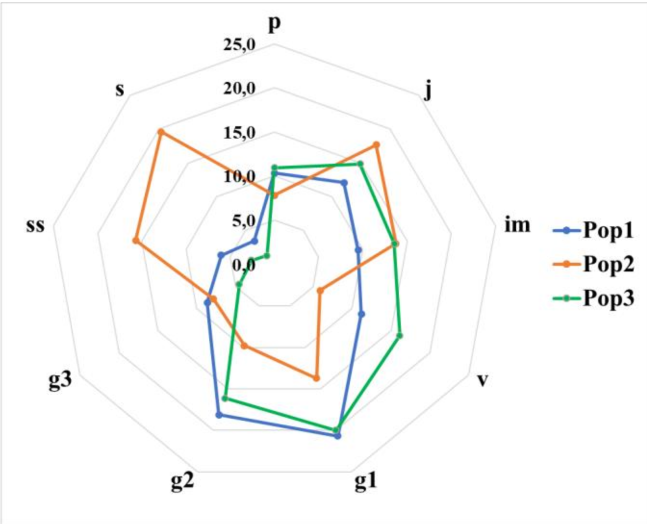

Figure 6. Percentage ratio of the age composition of the population

As we can see, the percentage of the age composition of the population does not always provide accurate objective data, as in our case, the state of Pop2 visually seems to be averaged. But if we consider the same conditions for all populations not by percentage, but by the quantitative ratio of individuals in populations, then we will get a different picture (Fig. 7). Regarding the data obtained, we will consider them according to the following points: the ratio of age groups of plants [29].

The invasive one consists mainly of young individuals, is not capable of self-maintenance and depends on the introduction of rudiments from the outside.

In a normal population, there are all age groups (if this is typical of the life cycle of the species). Such populations are further subdivided into young, middle-aged and old.

The regressive one mainly consists of old individuals. The age structure of populations is adaptive. It is formed on the basis of the biological properties of the species, but it always reflects the strength of environmental factors.

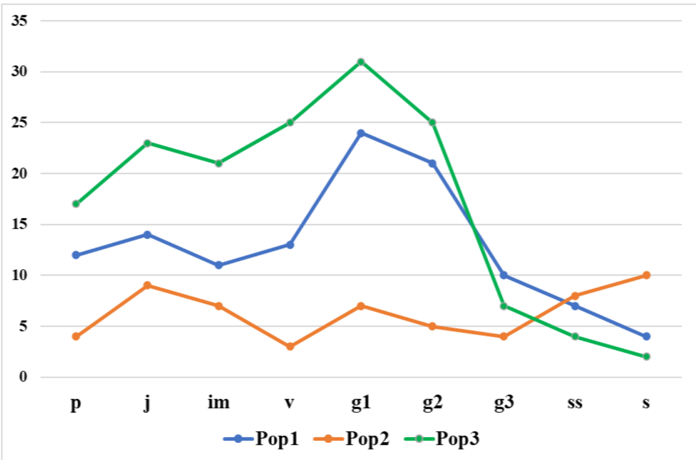

Figure 7. Population age structure

p — seedlings; j — juvenile plants; im — immature; v — virginal; g1 — young generative; g2 — middle-aged generative; g3 — old generative; ss — subsenile; s — senile

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As we can see from the data obtained, more than one population does not belong to the invasive group. Pop1 and Pop3 belong to normal (growing) populations, and Pop2 belongs to the beginning regressive population.

Conclusion

As a result of the analysis of the described 3 large populations of the medicinal species *Ajania fastigiata*, the following conclusions were obtained. According to the analysis of the floral composition of communities with the participation and dominance of the studied species, 104 associated species (23 families) were identified. Asteraceae by the number of species — 15, Poaceae — 11, Fabaceae — 10, Ranunculaceae and Rosaceae — 9 each, Lamiaceae — 8, Apiaceae — 7, Boraginaceae and Caryophyllaceae — 6, Liliaceae — 5 species (possibly more), 18 species belong to different families. For Pop1, the tallest individuals were noted, 120 cm in height. Pop1 (cop2) and Pop3 (cop3) populations prevailed in abundance. According to the percentage ratio in Pop1, the undergrowth was about 43 %, Pop2 undergrowth of the population was 44 %, and Pop3 undergrowth was 55 %. The age composition relative to the number of individuals showed that Pop1 and Pop3 are growing populations, and Pop2 is close to a regressive population caused by anthropogenic pressure.

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Іле Алатауындағы *Ajania fastigiata* дәрілік түрдің популяцияларының қазіргі жағдайы

Ajania Poljakov туысы — көпжылдық шөптесін өсімдіктер, әдетте сұрғылт реңктері бар, қысқартылған вегетативті өсінділері жоқ, тік немесе жиі өсетін және тармақталған, жақсы дамыған, жапырақ сабақтары тығыз. Жапырақтары екі жақты түктермен, кейде қарапайым түктермен араласып жабылған, тілімді тақшайшалары кезектесіп отырады. Зерттеу жұмысының мақсаты Іле Алатауында кездесетін *Ajania fastigiata* популяциясының қазіргі жағдайын нақтылау. Зерттеу нысаны Іле Алатауында өсетін *Ajania fastigiata* дәрілік түрінің қатысуымен және үстемдігімен болатын фитоценоздар. *Ajania fastigiata* дәрілік түрінің сипатталған 3 ірі популяциясын талдау нәтижесінде келесі тұжырымдар алынды. Зерттелетін түрдің қатысуымен және үстемдігімен қауымдастықтардың флористикалық құрамын талдау бойынша 104 түр (23 тұқымдас) анықталды. Asteraceae түрлерінің саны бойынша — 15, Poaceae — 11, Fabaceae — 10, Ranunculaceae және Rosaceae — әрқайсысы 9, Lamiaceae — 8, Apiaceae — 7, Boraginaceae және Caryophyllaceae — әрқайсысы 6, Liliaceae-5 түрі (мүмкін одан да көп), 18 түрі әртүрлі тұқымдастарға жатады. Pop1 үшін биіктігі 120 см болатын ең биік даралар белгіленді. Pop1 (cop2) және Pop3 (cop3) популяцияларының көптігі басым болды. Pop1-дегі пайыздық көрсеткіш шамамен 43 % құрады, Pop2 — популяция 44 %, ал Pop3 — 55 %. Жеке даралар санына қатысты жас құрамы, Pop1 және Pop3 өсіп келе жатқан популяциялар, ал Pop2 антропогендік қысым тудыратын регрессивті популяцияға жақын екенін көрсетті.

Кілт сөздер: Asteraceae, *Ajania fastigiata*, дәрілік өсімдік, экология, фитоценоз, популяция, доминант, Іле Алатауы.

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Современное состояние популяции лекарственного вида *Ajania fastigiata* в Заилийском Алатау

Род *Ajania* Poljakov — это многолетние травянистые растения, обычно с сероватым оттенком, без укороченных вегетативных побегов, с прямостоячими или часто восходящими и разветвленными, хорошо развитыми, густолиственными стеблями. Листья очередные с рассеченными пластинками, покрытыми прижатыми двураздельными, иногда с примесью простых, волосками. Целью данной исследовательской работы является уточнение современного состояния популяции *Ajania fastigiata*, встречающегося в Зайлийском Алатау. Объектами исследования являются фитоценозы с участием и доминированием лекарственного вида *Ajania fastigiata*. В результате анализа описанных 3 крупных популяций лекарственного вида *Ajania fastigiata*, были получены следущие выводы. По анализу флористического состава сообществ с участием и доминированием изучаемого вида, выявлено 104 сопутствующих видов (23 семейства). Asteraceae по количеству видов — 15, Poaceae — 11, Fabaceae — 10, Ranunculaceae и Rosaceae — по 9, Lamiaceae — 8, Apiaceae — 7, Boraginaceae и Caryophyllaceae — по 6, Liliaceae — 5 видов (возможно больше), 18 видов относятся к различным семействам. Для Pop1 были отмечены самые высокие особи – 120 см в высоту. По обилию приобладали популяции Pop1 (cop2) и Pop3 (cop3). Согласно процентному соотношению в Pop1 подрост составило около 43 %, в Pop2 – 44 %, а подрост в Pop3 – 55 %. Возрастной состав по количеству особей показал, что Pop1 и Pop3 являются растущими популяциями, тогда как Pop2 приближается к регрессивной популяции, причиной которой является антропогенное давление.

Ключевые слова: Asteraceae, *Ajania fastigiata,* лекарственное растение, экология, фитоценоз, популяция, доминант, Заилийский Алатау.

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Study of the prevalence of ESKAPE pathogens and their resistance to antimicrobial drugs

A prospective microbiological study of the prevalence of ESKAPE microorganisms and antibiotic resistance rates of strains was conducted in patients of the pediatric cardiac surgery department of a highly specialized clinic in the period from 2019 to 2023. During the study, classical routine bacterial methods for identifying isolates were used, as well as the automated system for final identification and susceptibility testing Vitek 2 — Compact. The study included 3725 clinical samples, the frequency of pathogen detection was: *S.aureus* 35.2 %, *K.pneumoniae* 27.3 %, *A.baumannii* 14.5 %, *Ps.aeruginosa* 12.4 %, *Enterobacter sp.* 8.7 % and *Enterococcus faecium* 1.2 %. A significant increase in resistance was detected in MRSA from 13.7 % to 41.9 % (p = 0.041), in *K.pneumoniae*, resistance to carbapenems increased from 0 % to 8.3 % (p = 0.057), while we note a decrease in the prevalence of ESBL-producing strains of *K.pneumoniae* from 63.3 %. to 45.2 % (p=0.058), resistance to carbapenems in *P.aeruginosa* strains decreased from 64.3 % to 37.7 % (p=0.037), and in *A.baumannii* from 48.5 % to 19.1 % (p=0.039). According to the obtained results, in our pediatric cardiac surgery department, ESKAPE pathogens accounted for 64.2 %. The most common isolates were *S.aureus*, *K.pneumoniae* and *A.baumannii*, while there was a sharply increasing trend towards resistance of *K.pneumoniae* to carbapenems and MRSA. Our results showed that well-designed infection control in each hospital is necessary, including a good hygiene strategy, microbiological monitoring and in-hospital control.

Keywords: microbiological monitoring, ESKAPE microorganisms, prevalence, antibiotic resistance, pediatric cardiac surgery.

Introduction

Despite technological advances in modern microbiological laboratory diagnostics, efforts to prevent infections, and the use of last-line antibiotics, bacterial infections remain a significant concern in the postoperative period of pediatric cardiac surgery [1-2]. Several key factors contribute to an increased risk of infection, including young age, delayed sternal closure, the use of intravascular devices, and prolonged ICU stays [3–5].

Cephalosporin-class antibiotics are considered the first-line treatment for severe infections caused by Gram-negative bacteria such as *Klebsiella pneumoniae*, *Enterobacter sp*., and *Escherichia coli* (*E. coli*). However, their efficacy is increasingly compromised by the widespread production of extended-spectrum β-lactamase (ESBL) enzymes, which confer resistance to these crucial antibiotics [6].

Among carbapenem-resistant clinical strains of *Enterobacterales*, *K. pneumoniae* is the most frequent and predominant pathogen [7].

Most bacterial infections caused by *Acinetobacter baumannii* occur in hospitalized patients with prolonged exposure to the healthcare system [8]. Approximately 45 % of *A. baumannii* isolates worldwide are multidrug-resistant [9], with resistance rates exceeding 60 % in the USA [10] and 41.5 % in Latin America and the Middle East [11]. Furthermore, the detection rate of multidrug-resistant *A. baumannii* isolates is more than four times higher compared to *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* [12].

It is essential to utilize local, national, and global antimicrobial resistance surveillance data to develop effective guidelines and programs for empirical antimicrobial therapy.

These factors highlight the urgent need to study the prevalence and antibiotic resistance of bacterial pathogens, as well as to implement measures to control the spread of multidrug-resistant microorganisms.

The aim of this study was to determine the prevalence of ESKAPE microorganisms — including *Enterococcus faecium*, *Staphylococcus aureus*, and Gram-negative bacteria such as *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter sp.* — as well as the level of antimicrobial resistance in the pediatric cardiac surgery department of a highly specialized clinic in Central Kazakhstan.

Experimental

Study Design

A prospective study on the microbial landscape and antibiotic resistance rates of bacterial strains in patients from the pediatric cardiac surgery department of a highly specialized hospital was conducted between 2019 and 2023.

Sample Collection

Clinical specimens were collected from symptomatic inpatients, neonates and children up to three years of age, who were hospitalized in the pediatric cardiac surgery unit for surgical interventions involving the heart and major vessels.

Isolates were analyzed based on the site of infection. Upper respiratory tract samples included nasopharyngeal and pharyngeal swabs, while lower respiratory tract samples consisted of tracheobronchial swabs and sputum. Other samples were obtained from surgical wounds, urine, and bloodstream infections.

All specimens were collected at the patient's bedside, transported to the microbiology laboratory under appropriate conditions, and subjected to microbiological examination within the first two hours.

Microbiological methods

Microbial cultures were grown on 5 % blood agar, MacConkey agar, Chromagar Staphylococcus aureus, Chromagar Pseudomonas aeruginosa, Chromagar Acinetobacter spp., and Oriental Chromagar (Himedia, India), with incubation at 37 °C for 18–24 hours.

Identification of Isolates

Routine microbiological identification methods included the assessment of colony morphology, hemolytic activity on selective media, Gram staining, rapid biochemical tests (coagulase, oxidase, catalase, indole), and automated identification using the Vitek 2 — Compact microbiological analyzer (bioMérieux, Marcy-l'Étoile, France).

Antibiotic Sensitivity Testing

The minimum inhibitory concentration (MIC) for antibiotic susceptibility testing was determined using an automated microdilution method on the Vitek 2 — Compact microbiological analyzer, following the manufacturer's recommendations. After 18–24 hours of incubation, the obtained strains were tested against a panel of antibiotics to determine the MIC for ESKAPE pathogens. The MIC results were interpreted according to the European Committee on Antimicrobial Susceptibility Testing (EUCAST) guidelines [13].

Statistical Analysis

All obtained data were analyzed using Microsoft Access and Excel. Trends in prevalence and antibiotic resistance levels were assessed through linear regression based on annual data. A p-value <0.05 was considered statistically significant.

Results and Discussion

A total of 3060 isolates from 3725 clinical specimens (including upper and lower respiratory tract, wound, bloodstream, and urine samples) were included in the study from January 2019 to December 2023. Over the five years of the study, 1899 ESKAPE strains were collected, with a prevalence of 64.2 %. The ESKAPE strains were most commonly found in the upper respiratory tract (81.1 %, 1541 isolates), followed by the lower respiratory tract (12.1 %, 230 isolates), blood and wound samples (2.7 %, 52 isolates), and the urinary tract (1.2 %, 24 isolates).

The most frequently isolated pathogens from the clinical specimens were *S. aureus* (35.2 %, 670 isolates), *K. pneumoniae* (27.3 %, 528 isolates), *A. baumannii* (14.5 %, 276 isolates), *P. aeruginosa* (12.4 %, 236 isolates), *Enterobacter sp.* (8.7 %, 166 isolates), and *Enterococcus faecium* (1.2 %, 23 isolates) (Table 1).

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Table 1

Distribution of ESKAPE pathogens in clinical samples

Microorganism	Upper respiratory tract	Lower respiratory tract	Surgical wound	Urinary tract	Blood	Total ESKAPE strains
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Enterococcus faecium	1 (4,3)	3 (13,0)	6 (26,0)	11 (47,8)	2 (8,6)	23 (1,2)
Staphylococcus aureus	629 (93,8)	18 (2,6)	20 (2,9)	0	3 (0,4)	670 (35,2)
Klebsiella pneumoniae	464 (87,8)	41 (7,7)	12 (2,2)	2 (0,3)	9 (1,7)	528 (27,8)
Acinetobacter baumannii	158 (57,2)	78 (28,2)	8 (2,8)	3 (1,0)	29 (10,5)	276 (14,5)
Pseudomonas aeruginosa	135 (57,2)	83 (35,1)	4 (1,6)	7 (2,9)	7 (2,9)	236 (12,4)
Enterobacter sp.	154 (92,7)	7 (4,2)	2 (1,2)	1 (0,6)	2 (1,2)	166 (8,7)
Total isolated strains	1541 (81,4)	230 (12,1)	52 (2,7)	24 (1,2)	52 (2,7)	1899

More than 90 % of *S. aureus* and *Enterobacter sp.* strains were isolated from the upper respiratory tract, with *K. pneumoniae* accounting for 87.8 %. Non-fermenting Gram-negative microorganisms, such as *P. aeruginosa* (35.1 %, 83 isolates) and *A. baumannii* (28.2 %, 78 isolates), were the most frequent pathogens in the lower respiratory tract. The highest number of *E. faecium* isolates (47.8 %, 11 isolates) was found in the urinary tract.

Microbiological prevalence monitoring revealed an increasing trend in the detection rate of *S. aureus* from 14 % to 29.8 % ($p = 0.051$), *K. pneumoniae* from 11.3 % to 20.9 % ($p = 0.044$), and *Enterobacter sp.* from 2.7 % to 10.3 % ($p = 0.028$). At the same time, no statistically significant changes were observed in the percentage of *A. baumannii* and *P. aeruginosa* strains detected (Table 2).

Table 2

Change in prevalence trends of ESKAPE isolated microorganisms by year (2019–2023)

Microorganism	2019 n (%)	2020 n (%)	2021 n (%)	2022 n (%)	2023 n (%)	p-value[1]
Enterococcus faecium	3 (0,6)	2 (0,4)	8 (1,0)	6 (0,8)	4 (0,6)	0,631
Staphylococcus aureus	62 (14,0)	83(16,7)	200 (26,7)	147 (21,7)	178 (29,8)	0,051
Klebsiella pneumoniae	50 (11,3)	89 (17,9)	134 (17,9)	130 (19,2)	125 (20,9)	0,044
Acinetobacter baumannii	34 (7,7)	61(12,3)	68 (9,0)	71 (10,5)	42 (7,0)	0,704
Pseudomonas aeruginosa	38 (8,6)	43 (8,6)	56 (7,4)	51 (7,5)	48 (8,0)	0,245
Enterobacter sp.	12 (2,7)	7 (1,4)	29 (3,8)	56 (8,2)	62 (10,3)	0,028
Total isolates	441	495	748	676	597	

[1] Linear regression

The results of antibiotic susceptibility testing demonstrated dynamic changes in the resistance patterns of ESKAPE microorganisms, with both increasing and decreasing trends (Fig.). A significant rise in resistance was observed in *S. aureus* strains, with the prevalence of methicillin-resistant *S. aureus* (MRSA) increasing from 13.7 % to 41.9 % ($p = 0.041$). Additionally, *K. pneumoniae* strains exhibited a rise in carbapenem resistance from 0 % to 8.3 % ($p = 0.057$). During the same study period, a declining trend was observed in the prevalence of *K. pneumoniae* strains resistant to third-generation cephalosporins, decreasing from 63.3 % to 45.2 % ($p = 0.058$), as well as in carbapenem-resistant *P. aeruginosa* strains, which declined from 64.3 % to 37.7 % ($p = 0.037$), and carbapenem-resistant *A. baumannii* strains, which decreased from 48.5 % to 19.1 % ($p = 0.039$).

According to the results of resistance, there are two species (A.baumannii and P.aeruginosa), they are not susceptible to cephalosporins of the 3rd generation, and this concept applies only to K.pneumoniae. For A.baumannii and P.aeruginosa strains, it is important to determine resistance only to carbapenems, as these antibiotics are the first-line drugs of choice in the treatment of infections caused by these pathogens.

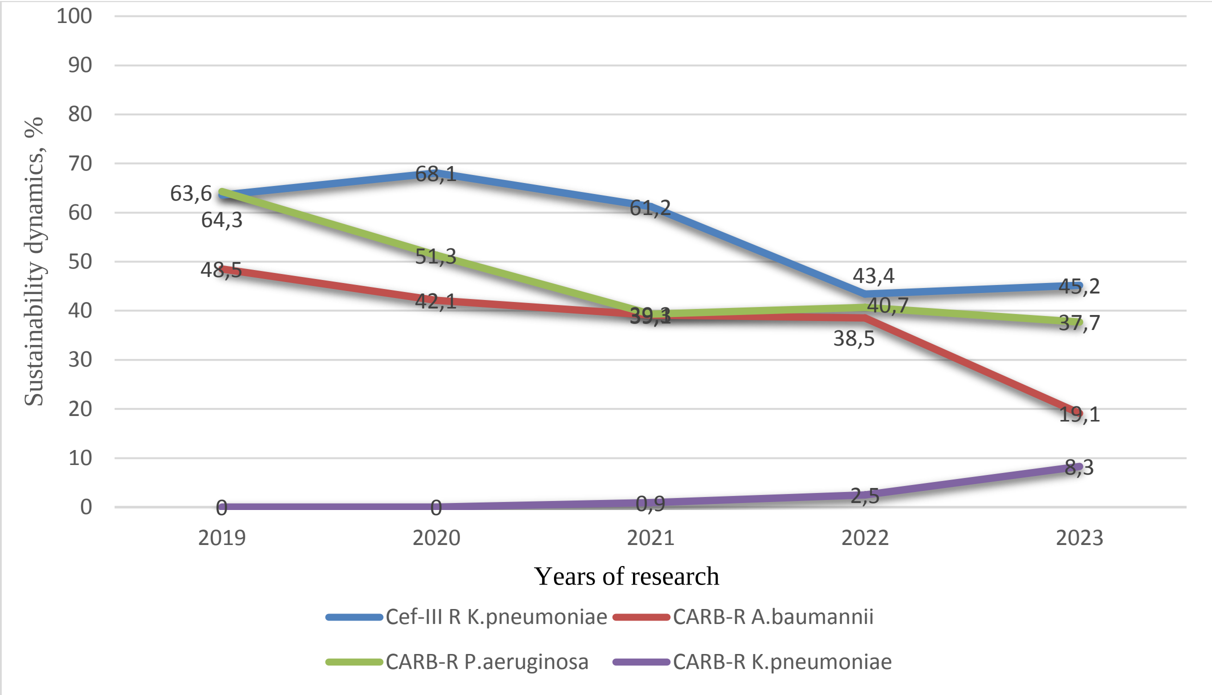

Figure. Resistance dynamics of ESKAPE Gram-negative pathogens
to third-generation cephalosporins (Cef-III R) and carbapenems (CARB-R) from 2019 to 2023.

The primary objective of this study was to assess the prevalence of ESKAPE microorganisms in clinical specimens and to evaluate their resistance to major antibacterial agents in patients from the pediatric cardiac surgery department. A total of 4114 patients hospitalized in this department were included in the study, from whom 3725 clinical specimens were collected. Among the ESKAPE pathogens, *S. aureus* was the most frequently isolated microorganism (35.2 %), followed by *K. pneumoniae* (27.8 %) and *A. baumannii* (14.5 %). *Enterobacter sp*. accounted for 8.7 % of isolates, while *E. faecium* was the least frequently detected pathogen, comprising only 1.2 % of the total isolates.

Undoubtedly, the distribution of microorganisms in patients varies between hospitals, leading to different microbiological findings [14–17]. According to previous studies, the most common pathogens in pediatric cardiac surgery patients include *K. pneumoniae*, *P. aeruginosa*, and *S. aureus* [18-19]. Bo-Tao Ning et al. reported that the predominant pathogens were *A. baumannii* (25.6 %), *K. pneumoniae* (16.2 %), and *P. aeruginosa* (9.4 %) [19]. However, the present study on ESKAPE pathogen prevalence revealed an increasing trend in *K. pneumoniae* from 11.3 % to 20.9 % (p = 0.044), *S. aureus* from 14 % to 29.8 % (p = 0.051), and, unexpectedly, *Enterobacter sp*. from 2.7 % to 10.3 % (p = 0.028). In contrast to prior research by Bissenova et al. (2017) [20], no statistically significant changes were observed in the prevalence of *A. baumannii* and *P. aeruginosa*. These findings suggest a shift in the dominant pathogens within our pediatric cardiac surgery unit, with a potential emerging trend favoring *Enterobacterales*. Additionally, the majority of isolates (81.4 %) were recovered from the upper respiratory tract, likely due to the accessibility of this clinical material in the studied patient population.

The lower respiratory tract, particularly the tracheobronchial tree, is frequently contaminated with various pathogens, especially in ventilated and critically ill patients [21]. However, the correlation between bacterial colonization and the development of pulmonary infection remains unclear. A study by Johanson et al. [22] demonstrated that in 23 % of cases, bacterial colonization of clinical specimens led to pulmonary infection. Non-fermenting Gram-negative microorganisms are the predominant pathogens in the tracheobronchial tree [23], which is consistent with our findings: *A. baumannii* accounted for 28.2 % and P. aeruginosa for 35.1 % of isolates from the lower respiratory tract. Additionally, as expected, the highest proportion of *E. faecium* strains (47.8 %) was detected in the urinary tract, with no vancomycin-resistant strains identified.

Many clinical studies have reported increasing rates of ESKAPE pathogen resistance in paediatric cardiac intensive care units, making it a significant factor in nosocomial infections [24-25]. For example, Wang L.J. et al. reported that over 50 % of *P. aeruginosa* isolates (n = 126) were resistant to carbapenems [26]. Similarly, in our study, the rate of carbapenem resistance in *P. aeruginosa* was initially 64.3 % but showed a significant decline, reaching 37.7 % by 2023 ($p = 0.037$). A comparable trend was observed for *A. baumannii*, where carbapenem resistance decreased from 48.5 % in 2019 to 19.1 % in 2023 ($p = 0.039$). In contrast, the antimicrobial resistance patterns of *K. pneumoniae* demonstrated divergent trends over the five-year study period. While resistance to third-generation cephalosporins declined from 63.3 % to 45.2 % ($p = 0.058$), carbapenem resistance showed a concomitant increase from 0 % to 8.3 % ($p = 0.057$). Additionally, a significant rise in resistance was observed in *S. aureus*, with the prevalence of methicillin-resistant *S. aureus* (MRSA) increasing from 13.7 % to 41.9 % ($p = 0.041$).

The findings of this study highlight the potential for pathogen replacement, underscoring the critical need for continuous surveillance of both pathogen prevalence and antibiotic resistance rates at the hospital level and even across different departments.

It is well established that the emergence of antimicrobial resistance significantly limits therapeutic options for the management of severe infections, particularly in pediatric patients. Given the current challenges, the implementation of improved diagnostic methodologies is essential to curb the rapid dissemination of infections caused by ESKAPE microorganisms. Early and appropriate empirical antibiotic therapy — guided by clinical expertise and antimicrobial susceptibility data — is crucial for optimizing patient outcomes. Moreover, effective management of the most frequently encountered pathogens remains a key strategy in preventing the further development of multidrug resistance.

Conclusion

The findings of this study indicate that ESKAPE pathogens accounted for 64.2 % of the cases identified in the paediatric cardiac surgery department. The most frequently isolated microorganisms were *S. aureus*, *K. pneumoniae*, and *A. baumannii*, with a marked upward trend in carbapenem resistance among *K. pneumoniae* strains and an increasing detection rate of MRSA. These results underscore the critical need for stringent nosocomial infection control strategies, complemented by continuous microbiological surveillance and antimicrobial stewardship programs.

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ESKAPE патогендерінің таралуы мен микробқа қарсы тұрақтылығын зерттеу

Жоғары мамандандырылған емхананың балалар кардиохирургиясы бөлімшесінің емделушілеріне 2019-2023 жылдар аралығында ESKAPE микроорганизмдерінің таралуына және штамдардың антибиотиктерге төзімділік көрсеткіштеріне перспективалық микробиологиялық зерттеу жүргізілді. Зерттеу кезеңінде изоляттарды анықтаудың классикалық әдеттегі бактериялық әдістері, сондай-ақ Vitek 2 — Compact түпкілікті сәйкестендіру және сезімталдықты сынаудың автоматтандырылған жүйесі пайдаланылды. Зерттеуге 3725 клиникалық үлгілер енгізілді, қоздырғыштарды анықтау көрсеткіші: S.aureus 35,2 %, K.pneumoniae 27,3 %, A.baumannii 14,5 %, Ps.aeruginosa 12,4 %, Enterobacter sp. 8,7 % және Enterococcus faecium 1,2 %. MRSA-да 13,7 %-дан 41,9 %-ға (p=0,041) төзімділіктің айтарлықтай артуы анықталды, K.pneumoniae-де карбапенемдерге төзімділік 0 %-дан 8,3 %-ға (p=0,057) артты, бұл ретте жиіліктің төмендеуін атап өтеміз. K.pneumoniae ESBL түзетін штамдарының таралуы 63,3 %-дан 45,2 %-ға (p=0,058), P.aeruginosa штамдарында карбапенемдерге төзімділік 64,3 %-дан 37,7 %-ға (p=0,037), A.baumannii 48,5 %-дан 19,1 %-ға (p=0,039) төмендеді. Алынған нәтижелер бойынша біздің балалар кардиохирургиясы бөлімінде ESKAPE қоздырғыштары

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64,2 % құрады. Ең көп таралған изоляттар S.aureus, K.pneumoniae және A.baumannii болды, K.pneumoniae-нің карбапенемдерге және MRSA-ға төзімділігінің күрт өсу тенденциясы байқалды. Біздің нәтижелеріміз әрбір ауруханада жақсы жобаланған инфекциялық бақылау стратегиясы қажет екенін көрсетті, соның ішінде жақсы гигиеналық стратегия, микробиологиялық мониторинг және ауруханаішілік бақылау.

Кілт сөздер: микробиологиялық мониторинг, ESKAPE микроорганизмдері, таралу, антибиотиктерге төзімділік, балалар кардиохирургиясы.

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Исследование распространенности ESKAPE патогенов и их резистентность к антимикробным препаратам

Проведено проспективное микробиологическое исследование распространенности микроорганизмов ESKAPE и показателей антибиотикорезистентности штаммов у пациентов детского кардиохирургического отделения высокоспециализированной клиники за период с 2019 по 2023 год. В исследовании использовались классические рутинные бактериальные методы выявления изолятов, а также автоматизированную систему окончательной идентификации и тестирования чувствительности Vitek 2 — Compact. В исследование было включено 3725 клинических образцов, частота обнаружения патогенов составила: *S.aureus* – 35,2 %, *K.pneumoniae* – 27,3 %, *A.baumannii* – 14,5 %, *Ps.aeruginosa* – 12,4 %, *Enterobacter sp*. – 8,7 % и *Enterococcus faecium* – 1,2 %. Значительное увеличение резистентности было выявлено у MRSA – с 13,7 % до 41,9 % (p=0,041), у *K.pneumoniae* устойчивость к карбапенемам увеличилась с 0 % до 8,3 % (p=0,057) при этом отмечается снижение частоты распространенности ESBL-продуцирующих штаммов *K.pneumoniae* с 63,3 %. до 45,2 % (p=0,058). Резистентность к карбапенемам у штаммов *P.aeruginosa* снизилась с 64,3 % до 37,7 % (p=0,037), а у *A.baumannii* – с 48,5 % до 19,1 % (p=0,039). По результатам исследования микроорганизмы ESKAPE составили 64,2 %. Наиболее частыми изолятами были *S.aureus, K.pneumoniae* и *A.baumannii*, при этом отмечается резко возрастающая тенденция к устойчивости K.pneumoniae к карбапенемам и MRSA. Полученные результаты подчеркивают необходимость инфекционного контроля в каждой больнице, включающего хорошую стратегию гигиены, микробиологический мониторинг, а также внутрибольничный контроль.

Ключевые слова: микробиологический мониторинг, ESKAPE-микроорганизмы, распространенность, антибиотикорезистентность, детская кардиохирургия.

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Cotton (*Gossypium* L.) production and importance of sequencing technology for improving agronomic traits

Gossypium L. is one of the largest genera, known for its diversity and economic value among field crops, while allotetraploid cotton species have a valuable source of a model system for studying plant polyploidy, phylogeny, and breeding. This review provides, first, the production and use of Cotton (*Gossypium*) in the world. Second, important information on cotton cultivation and production in Kazakhstan was provided in detail. Third, we summarized the phylogeny of *Gossypium* L. Fourth, we provided a brief summary of morphological characteristics and whole genome sequence studies of seven allotetraploid cotton species including *G. hirsutum* (AD)1, *G. barbadense* (AD)2, *G. tomentosum* (AD)3, *G. mustelinum* (AD)4, *G. darwinii* (AD)5, *G. ekmanianum* (AD)6 and *G. stephensii* (AD)7. This review is valuable for future agronomic and molecular research studies on cotton.

Keywords: Cotton (*Gossypium* L.) production, phylogenesis, allotetraploid species, whole genomic sequences.

1 Production and uses of cotton (Gossypium L.)

Cotton (Gossypium L.) has been cultivated for fiber production more than 7000 years. Despite the presence of synthetic fibers derived from petroleum, it continues to serve as the most important natural renewable source in the world for textiles. Cotton is mainly grown in more than 80 countries around the world, including China, India, USA and Pakistan [1, 2].

Furthermore, cotton is the main economic driver for some developing countries. In addition to fiber, cotton is the third largest arable crop in the world in terms of tons of edible oilseed after soybeans and rapeseed. In addition to its 21 % fat content, cottonseed is a source of relatively high quality protein.

Industrial cotton species include diploids (*G. herbaceum* and *G. arboreum*) and tetraploids (*G. barbadense* and *G. hirsutum*). The origin of both diploid species is considered to be South Asia and Africa, while the origin of two allotetraploid species are considered to be from Central, North, and South America. Among these four cultivated species, *G. hirsutum* has high yield potential, wide adaptability, and moderate fiber quality and accounts for about 90–95 % of the total cotton production [3].

The cotton industry is an important part of the economy of several countries. In India, the cotton sector employs more than 40 million people, including farmers, workers from refining and pressing plants, and workers from textile factories. The US cotton industry provides about 250,000 jobs and contributes about 21 billion to the economy each year. Cotton farming also plays an important role in the socio-economic structure of countries such as Pakistan and Brazil, providing a livelihood for millions of families [1].

Cotton is grown mainly in Asia (~70 %), followed by the Americas (20 %), Africa (6 %), Europe (2 %), and other regions (~1 %) (Fig. 1).

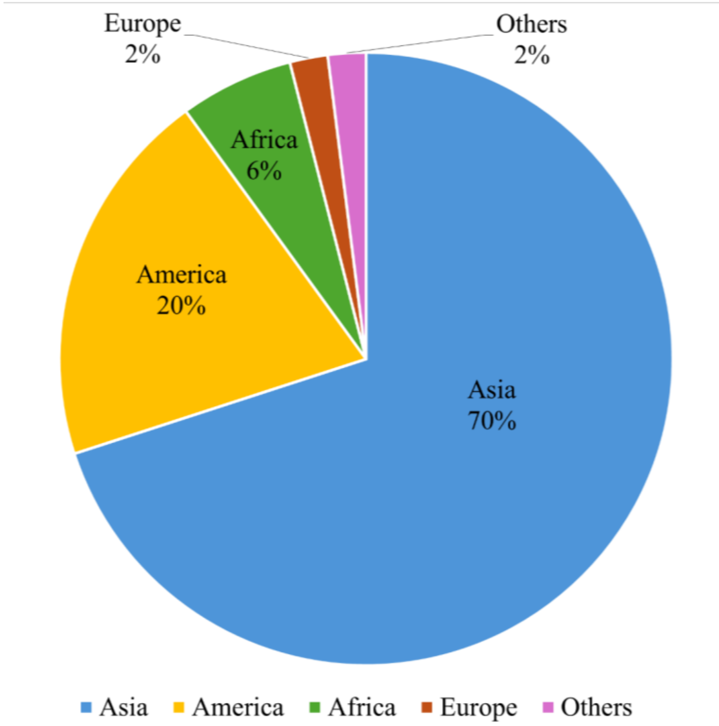

Figure 1. Trend in cotton cultivation around the world

China, India, the United States, Brazil, Australia, Turkey, Pakistan, Uzbekistan, Argentina, and Mali are known as world's leading cotton producing countries in 2022 and 2023 (in 1,000 metric tons) (Fig. 2).

According to foreign media reports, cotton production in 2023 will reach 24.123 million tons, an increase of 6.2 % over previous years, according to data published by the International Cotton Advisory Committee (ICAC). The projected volume of world cotton production for 2024-2025 is expected to reach 25.6204 million tons. World cotton production for the 2023-24 season is projected to increase by 3 % to 25.41 million tons, while consumption is expected to decrease by 0.43 % to 23.35 million tons [5]

Seed cotton goes through a disassembly process in ginning factories to produce fiber, cottonseed, and waste. Cotton fiber is a raw material for the textile industry. Oil can be extracted from the seeds (about 20 % of the seed mass is fat), it can be a vegetable oil, margarine, soap, etc. Several by-products of seed cotton are obtained along with the main product — fiber. After ginning, the by-products are used as animal feed and for the production of biofuels [6]. Cotton consumption in China will decrease by 15 %, and India will become the largest consumer with 6.7 million tons. Consumption growth is also expected to increase in Vietnam, Bangladesh, Indonesia, and Turkey [7].

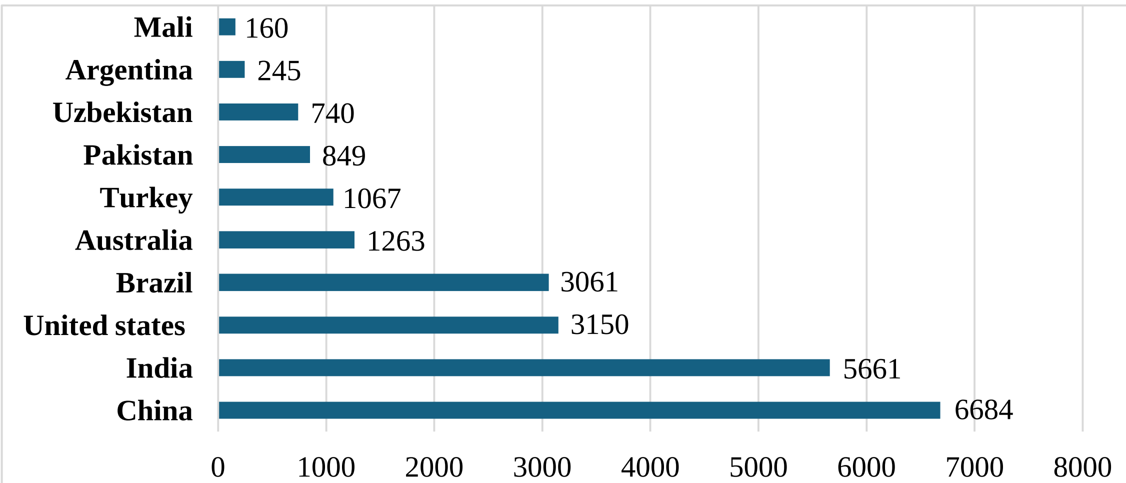

Figure 2. Leading cotton producing countries of the world in 2022 and 2023 years [4]

1.1 Cotton production in Kazakhstan

The Turkestan region is the world's northernmost cotton-growing region in southern Kazakhstan. Every year, 115,000–125,000 hectares of medium-staple cotton (G. hirsutum L.) are planted, with 80,000–85,000 hectares being in Maktaaral and Zhetysay Districts of Kazakhstan. This area is particularly vulnerable to drought, salt, and the invasion of harmful pests, including beetroot borer, cotton budworm, spider mites, and aphids, as well as illnesses like gummosis and fusarium blight (wilt). Through genotype selection based on genetic principles, the adverse effects of extremely high salinity and aridity in arable soil can be effectively and economically mitigated [8]. The dynamics of sown areas in the Turkestan region have shown significant changes over the past decades (Fig. 3). In order to better understand the dynamics of sown areas in the Turkestan region, we have divided the analysis into five distinct periods: 1991–1997, 1998–2004, 2005–2010, 2011–2015, and 2016–2023 years.

In 1991–1997 years, according to the analysis of sown area, the sown area decreased from 116.6 thousand hectares to 103.6 thousand hectares, with an average of 112 thousand hectares.

In 1998–2004 years, the sown area was increased significantly from 118 thousand hectares to 223.1 thousand hectares, with an average of 118 thousand hectares.

In 2005–2010 years, the sown area significantly decreased from 206.1 thousand hectares to 137.3 thousand hectares, with an average of 172 thousand hectares.

In 2011–2015 years, the sown area did not show stable characteristics and decreased from 160.6 thousand hectares to 99.3 thousand hectares, with an average of 135,18 thousand hectares.

In 2016–2023 years, the sown area showed increasing characteristics from 109,6 thousand hectares to 135,5 thousand hectares, with an average of 123,4 thousand hectares.

Figure 3. 1991–2023 years, dynamics of sowing areas in the Turkestan region of Kazakhstan (thousand hectares)

Out of the 13 cotton varieties developed by the "Agricultural Experimental Station of Cotton and Melon Growing" LLP, 9 varieties — Bereke-07, Maktaaral-4005, Maktaaral-4007, Maktaaral-4011, Myrzashol-80, Pakhtaaral-3031, Pakhtaaral-3044, Maktaaral-4017, and Maktaaral-5027 — have been included in the Register of Breeding Achievements recommended for use in the Republic of Kazakhstan. These varieties have been widely adopted and cover more than 90 % of the cotton growing areas in the Turkestan region. All 13 varieties have received patents for breeding achievements. In 2021, a patent was granted for a new promising cotton variety, Maktaaral-5027, which has relatively high resistance to pests such as cotton bollworm and spodoptera [8].

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The major challenges in cotton production include salinization, irrigation water scarcity, climate change, pests and diseases, and soil depletion. In response, breeding efforts are focused on developing crops with early maturity (within 105–110 days), high salt tolerance, drought resistance, diseases and pest resistance, and the ability to improve soil fertility in crop rotation systems.

Currently, the Agricultural Experimental Station of Cotton and Melon Growing maintains a cotton gene pool of 700 samples from different countries around the world as of 2024.

The soil of the experimental area is light fertile gray soil with a medium loam mechanical composition. The characteristics of light fertile grey soil include a low humus content, high carbonate content, and a relatively low absorptive capacity.

This soil type is characterized by good microstructure, water permeability, porosity, relatively low cohesiveness, and moderate mobility of water and nutrients.

2 Phylogenesis and whole genome sequences of cotton

The genus cotton (*Gossypium L.*) not only has the highest economic value among field crops, but also plays an important role in research on plant taxonomy, polyploidization, phylogeny, cytogenetics, and genomics.

Gossypium L. belongs to the tribe *Gossypieae,* the family *Malvaceae,* and the order *Malvales* [9]. Species belonging to the genus *Gossypium* are grouped into 8 diploid genomes (A to G and K) and one allopolyploid genome (AD) based on relative chromosome sizes and chromosome features in interspecific hybrids [10]. A fairly well-documented review article has been published on the taxonomic, cytogenetic, and geographic diversity of *Gossypium* species and the nomenclature of individual genomes and chromosomes [11].

2.1 Genomes of allotetraploid species

The new allotetraploid or amphidiploid cotton (AD genome) is thought to have emerged from an ancient fusion between the A genome of the African Species *G. arboreum* and the D genome American Species *G. raimondii*, and chromosome duplication from their ancestors. The polyploids were found to contain 7 species, namely *G. hirsutum* (AD)1, *G. barbadense* (AD)2, *G. tomentosum* (AD)3, *G. mustelinum* (AD)4, *G. darwinii* (AD)5, *G. ekmanianum* (AD)6 and *G. stephensii* (AD) 7 [11]. Almost complete genome sequences have been determined for all these species. The aim of this review to provide a comparative overview of the characteristics of allotetraploid species and the features of their genomes based on previously published studies.

2.1.1 Gossypium hirsutum

G. hirsutum has 14 different Latin synonyms: G. hirsutum var. punctatum, G. jamaicense, G. lanceolatum, G. mexicanum, G. morrillii, G. punctatum, G. purpurascens, G. religiosum, G. schottii, G. taitense, G. tridens, G. tricuspidatum, G. hirsutum var. marie-galante and G. hirsutum var. palmeri. It is colloquially referred to as American tetraploid, American upland cotton, Mexican cotton and upland cotton.

G. hirsutum is the most widely cultivated cotton species and the dominant source of natural plant fiber in the world [12]. It originated in Central America, but it is cultivated worldwide. Due to its high productivity and quality, it is an important species from the perspective of breeders and serves as the primary material for scientific research aimed at combining high yield with other valuable traits. It produces medium-length fibers and can grow to a height of approximately 2 meters. During development, G. hirsutum typically has 3 to 5 lobed leaves that are generally flat and diaheliotropic, requiring sunlight to maximize light absorption.

The benefits of genomic sequencing and resequencing data are enabling the study of the genetic basis of G. hirsutum. In 2015, for the first time, the complete genome sequence of G. hirsutum cotton was developed [13]. According to the results of this study, the allotetraploid genome of *G. hirsutum* TM-1 was estimated to be 2.25–2.43 Gb using various methods. This genome was found to consist of a total of 44 816 contigs, 8591 scaffolds, 76,943 annotated protein-coding genes, 602 microRNAs (miRNAs), 2153 ribosomal RNAs (rRNAs), 2050 transfer RNAs (tRNAs), and 8325 small nuclear RNAs (snRNAs). Comparative transcriptomic studies in this research revealed the crucial role of nucleotide-binding site (NBS)-encoding genes in *Verticillium dahliae* resistance and the involvement of ethylene in cotton fiber cell development. Following this study, the complete genome sequence of *G. hirsutum* has been updated and refined several times [14–22]

According to the study by Chen, Sreedasyam et al. (2020), accession TM-1 had a genome size of 2.3 Gb with genome coverage of 94.06x and 75 376 genes [18]. The GC content is 34.5 %. Chromosome D09 had the smallest nucleotide of 54 445 796 bp and chromosome A06 had the largest nucleotide of 128 195 338 bp (Table).

2.1.2 Gossypium barbadense

G. barbadense has eight Latin synonyms, including G. peruvianum, G. vitifolium, G. acuminatum, G. barbadense var. acuminatum, G. barbadense var. brasiliense, G. brasiliense, G. guyanense var. braziliense, and G. evertum. It is colloquially known as Pima cotton, American Pima cotton, Sea Island cotton, long staple cotton, Egyptian cotton, and Brazilian cotton. It originated in South America, but it is cultivated worldwide. G. barbadense is a tropical cotton plant that can grow to the size of a small tree. It is highly valued for its long, high-quality fibers and its resistance to Verticillium wilt disease [23].

In 2015, the complete genome sequence of. *G barbadense* was completed. The genome of *G. barbadense* was found to be 2.57 gigabases, including a high-quality set of 80 876 protein-coding genes, along with information on the dynamic changes of genes and their expression [24].

In 2019, the complete genome sequence of *G. barbadense* was determined using the PacBio RSII method. The genome was found to contain 71 297 protein-coding genes with a contig length of 2 222 525 789 base pairs [16].

The study by Chen, Sreedasyam et al. (2020) found that the genome of *G. hirsutum* variety 3–79 has a genome size of 2.2 Gb, containing 74 561 genes with a coverage of 90.1x [18]. The GC content is 34 %. The smallest nucleotide sequence was found on chromosome D09, with 50 685 742 base pairs, while the largest nucleotide sequence was found on chromosome A08, with 119 114 718 base pairs (Table). Ma, Zhang et al. (2021). The genome of *G. barbadense* was presented with a high quality assembly of 2.57 gigabases, including the identification of 80 876 protein-coding genes [3].

2.1.3 Gossypium tomentosum

G. tomentosum has unique agronomic characteristics, including strong fibers, hairy leaves and stems, resistance to pests or insects on the leaves, and heat tolerance, which are traits of the *Gossypium* species. These excellent agronomic properties of *G. tomentosum* can be introduced into *G. hirsutum* through interspecific hybridization, allowing for its use in the genetic selection of *G. hirsutum* by expanding its genetic diversity [25]. Gossypium tomentosum, known as Ma'o, huluhulu, or Hawaiian cotton, is a cotton species native to the Hawaiian Islands. Genetic studies have shown that Hawaiian cotton belongs to the American species of the genus *Gossypium*, with its closest relative being *G. hirsutum*. Focusing on specific research, a 2016 study compared two genetic linkage maps based on F2 hybrids of *G. hirsutum x G. tomentosum and G. hirsutum x G. darwinii*. Seven inverted fragments were found on chromosomes chr02, chr05, chr08, chr12, chr14, chr16, and chr25, and three translocated fragments were identified on chr05, chr14, and chr26. These results indicate that *G. tomentosum* is genetically closer to *G. hirsutum* than to *G. darwinii* [26].

G. tomentosum is a shrub that grows to a height of 0.46 to 1.52 meters and has a diameter ranging from 1.5 to 3.0 meters. The plant's seed fibers (lints) are short and red-brown in color, making them unsuitable for spinning or turning into thread. Its flowers are light yellow with 3–5 petals and bloom from late summer to early winter. It is characterized by heat resistance, resistance to harmful beetles, flea beetles, weevil rot, and worms, as well as resistance to jassids and thrips. Additionally, it is known for its high quality fibers, fiber length, and fiber fineness [23].

The study by Chen, Sreedasyam et al. (2020) found that the genome of G. *tomentosum* varieties 7179.01, 7179.02, and 7179.03 has a genome size of 2.2 Gb, containing 78 281 genes with a coverage of 76.8x. The GC content is 34 %. The smallest nucleotide sequence was found on chromosome D09, with 51 553 955 base pairs, while the largest nucleotide sequence was found on chromosome A06, with 121 609 178 base pairs (Table).

2.1.4 Gossypium mustelinum

G. mustelinum is the only cotton species native to Brazil, and it is typical of the semi-arid regions in the northeastern part of the country [27]. It is a shrub-like plant that grows primarily in seasonally dry tropical

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biomes [28]. In 2013, Brazilian scientists genotyped two hundred eighteen mature *G. mustelinum* plants using SSR markers and found high genetic diversity among the populations. The results of this study indicated that *G. mustelinum* plants have a high level of inbreeding and low observed heterozygosity, suggesting that the populations reproduce primarily through self-fertilization and cross-pollination between related individuals [27]. The genomic and genetic resources of *G. mustelinum* have proven effective in identifying genes for both qualitative and quantitative traits. *Gossypium* mustelinum represents the earliest divergent evolutionary lineage of *Gossypium* polyploids, and its cotton varieties possess a gene pool rich in many essential traits that have been lost in other cotton species [29]. For example, in 2020, an interspecific extended-fixed population of *G. mustelinum* × *G. hirsutum* was developed, and more than a one hundred QTLs for fiber quality traits were mapped [30]

The study by Chen, Sreedasyam et al. (2020) found that the genome of *G. tomentosum* has a genome size of 2.3 Gb, containing 74,660 genes with a coverage of 94.1x. The GC content is 34.5 %. The smallest nucleotide sequence was found on chromosome D09, with 53 194 044 base pairs, while the largest nucleotide sequence was found on chromosome A08, with 129 182 752 base pairs (Table).

2.1.5 Gossypium darwinii

Gossypium darwinii, or Darwin's cotton, is a species of cotton plant found only in the Galapagos Islands. It is characterized by several excellent traits, including fine fibers, drought tolerance, and resistance to *Fusarium* and *Verticillium* wilt diseases. Genetic studies indicate that it is closely related to the native American species *Gossypium barbadense*, suggesting that its seeds may have been dispersed from South America by wind, bird droppings, or marine debris [26].

According to the study by Chen, Sreedasyam et al. (2020), the sequenced isolate (AD)5-032 has a genome size of 2.2 Gb with a genome coverage of 80.6x and 78 303 genes. The GC content is 34 %. Chromosome D09 had the smallest nucleotide number of 52 096 622bp and chromosome A08 had the largest nucleotide number as 120 009 936 bp (Table).

The cultivated species *G. hirsutum* accounts for 90 % of world cotton production. However, its narrow genetic base limits the improvement of modern *G. hirsutum* cultivars. In contrast, the abundant genetic diversity found in wild species, such as *G. darwinii*, provides valuable resources to address this issue.

Here we would like to review some key studies as examples. For example, an interspecific high-density linkage map of *G. hirsutum* × *G. darwinii* was constructed by Chen, Khan et al. (2015), using an F2 population based entirely on genome-wide simple sequence repeat (SSR) markers [38]. As a result of this study, a total of 2,763 markers were mapped across 26 linkage groups (chromosomes), covering a genome length of 4,176.7 cm, with an average inter-locus distance of 1.5 cm. The map will offer essential information regarding the origin and evolution of the cotton genus, along with insights into genome structure and function. Additionally, it will aid in cotton genome assembly, fine mapping, map-based cloning, and the utilization of genetic germplasm from *G. darwinii* through marker-assisted selection. In the study by Xu, Ilyas et al. (2022), the RNA-seq transcriptome analysis revealed that a total of 32,693 up-regulated genes and 25,919 down-regulated genes were differentially expressed [37]. Gene ontology and KEGG pathway analyses revealed that the upregulated genes were associated with all gene ontology terms, as well as molecular functions, biological processes, and cellular components, which were significantly related to enhancing drought stress tolerance. In the study Wang, Li et al. (2024), a chromosome segment substitution line population of 553 individuals was created using *G. darwinii* × *G. darwinii*. As the result, three candidate genes were identified for three stable QTLs, including GH_A01G1096 (ARF5) and GH_A10G0141 (PDF2) associated with lint percentage, and GH_D01G0047 (KCS4) associated with seed index or oil content [36].

These findings enhance our understanding of the molecular regulatory mechanisms development of cotton breeding and provide valuable insights for marker-assisted genetic improvement in cotton.

2.1.6 Gossypium ekmanianum

Gossypium ekmanianum has three synonyms name such as *Gossypium hirsutum* var. *ekmanianum* (Wittm.) Roberty, *Gossypium latifolium* var. *ekmanianum* (Wittm.) Roberty, and *Gossypium tricuspidatum* var. *ekmanianum* (Wittm.) Mauer. Furthermore, there are also three common names Ekman's Cotton, Ekman's *Gossypium*, and Ekman's Wild Cotton. The native range of *G. ekmanianum* species is the southwest

Dominican Republic. It is a shrub and grows primarily in the seasonally dry tropical biome. *G. ekmanianum* has small, white flowers with five petals. The seeds are small, round, and brown [31] (Table).

According to the study by Peng, Xu et al. (2022), the sequenced isolate AD6 had a genome size of 2.3 Gb with genome coverage 106.0x and 74 178 genes. GC content is 34.5 %. Chromosome D09 had the smallest nucleotide number with 54 144 365 bp and chromosome A11 had the largest nucleotide number with 132 145 079 bp (Table) [35].

2.1.7 Gossypium stephensii

Its historical importance dates back to 1966, when Stephens (1966), an eminent natural historian, evolutionary geneticist, and cotton biologist, examined Wake Island cotton in his study of oceanic dispersal and identified it as a wild form of *G. hirsutum*. He noted that "Wake Island cotton does not closely resemble either Caribbean or other Pacific varieties. Stephens emphasized its distinctive characteristics, including its sprawling shrub-like growth habit, dense hairy pubescence, and larger-than-average petal spot when compared to other Pacific cottons [32]. Also, in 1992 years, Paul A. Fryxell provided a revised taxonomic interpretation of *Gossypium L*. and confirmed the distinguishing characteristics of the Wake Atoll forms in comparison with *G. hirsutum* [33]. In 2017, American scientists Gallagher, Grover, et al. (2017) reported that a new species of cotton from Wake Atoll was described as a new species of *Gossypium* by considering morphological distinctions, geographic isolation, and new molecular data including both nuclear and chloroplast genome sequence data. The morphological characteristics of the new species were well described and were named *Gossypium Stephens* after S.G. Stephens, the eminent natural historian, evolutionary geneticist, and cotton biologist [34].

In 2022, according to Peng, Xu et al. (2022) study, the sequenced isolate AD7 has a genome size of 2.3Gb with genome coverage of 127.0x and gene number are 74,970. The GC content is 34.5 %. Chromosome D09 had the smallest nucleotide number of 54 019 951bp and chromosome A06 had the largest nucleotide number of 125 976 056 bp (Table) [35].

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T a b l e

Analysis of taxonomic, geographic diversity, and genomic characteristics of 7 allotetraploid cotton species

Sample details, assembly statistics, methods and annotation details	***Gossypium hirsutum***	***Gossypium barbadense***	***Gossypium tomentosum***	***Gossypium mustelinum***	***Gossypium darwinii***	***Gossypium ekmanianum***	***Gossypium stephensii***
family	**Malvaceae**	**Malvaceae**	**Malvaceae**	**Malvaceae**	**Malvaceae**	**Malvaceae**	**Malvaceae**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Synonym	*G. hirsutum var. punctatum, G. jamaicense, G. lanceolatum, G. mexicanum, G. morrillii, G. punctatum, G. purpurascens, G. religiosum, G. schottii, G. taitense, G. tridens, G. tricuspidatum, G. hirsutum var.* marie-galante and *G. hirsutum* var. *palmeri*	*G. peruvianum, G.vitifolium, G. acuminatum, G. barbadense var. acuminatum, G.barbadense var. brasiliense, G. brasiliense, G.guyanense var. braziliense, G. evertum*	*Gossypium hirsutum f. tomentosum* (Nutt. ex Seem.) Roberty, *Hibiscus tomentosus (Nutt. ex Seem.),*	*Gossypium hirsutum* subsp. *mustelinum* (Miers ex G.Watt) Roberty; *Gossypium caicoense Condorcet*	*Gossypium barbadense* var. *darwinii*	*Gossypium hirsutum* var. *ekmanianum* (Wittm.) Roberty, *Gossypium latifolium* var. *ekmanianum* (Wittm.) Roberty, and *Gossypium tricuspidatum* var. *ekmanianum* (Wittm.) Mauer	not applicable
Common name	American Tetraploid, American upland cotton, upland cotton	Pima cotton, American Pima cotton, Sea Island cotton, long-staple cotton, Egyptian cotton, Brazilian cotton	Hawaiian cotton	Brazilian cotton	Darwin's Cotton, Galapagos cotton	Ekman’s Cotton, Ekman’s *Gossypium*, and Ekman's Wild Cotton	Wake island cotton
Origin	Central America	South America	Hawaiian Islands	NE Brazi	Galapagos Islands	Dominican Republic	Wake Atoll, Pacific Ocean
Description	*G. hirsutum* is the most widly cultivated cotton species and a predominant source of natural plant fibers in the world. It is native to Central America but cultivated worldwide.	*G. barbadense* is a tropical cotton that grows to the size of a small tree. It is valued for its long, high-quality fiber and resistance to Verticillium wilt.	*G. tomentosum* has its own special agronomic characteristics, including strong fibers, hairy leaves and stems, nectarilessness on leaves or bracteoles, insect-pest resistance, and the most heat-tolerant species of Gossypium.	Small, thorny, deciduous, and xerophytic trees	Has finer fibers, shows resistance to drought, Fusarium and Verticillium wilt.	It is a shrub and grows primarily in the seasonally dry tropical biome. G. ekmanianum has small, white flowers with five petals. The seeds are small, round, and brown.	The new species morphological characteristics was well described by Gallagher, Grover et al. 2017.

Continuation of Table

1	2	3	4	5	6	7	8
Sequenced Cultivar	acc.TM-1	acc.3-79	isolate 7179.01,02,03	isolate1408120.09, 1408120.10,1408121 .01, 1408121.02, 1408121.03	(AD)5-032	AD6	AD7
Genome group	AD	AD	AD	AD	AD	AD	AD
Individual genome	$(AD)_1$	$(AD)_2$	$(AD)_3$	$(AD)_4$	$(AD)_5$	$(AD)_6$	$(AD)_7$
Haploid chromosomes number	26	26	26	26	26	26	26
Ploidy	allotetraploid	allotetraploid	allotetraploid	allotetraploid	allotetraploid	allotetraploid	allotetraploid
Individual chromosome	A_h01-A_h13; D_h01-D_h13	A_b01-A_b13; D_b01-D_b13	$A_{tt}01$-$A_{tt}13$; $D_{tt}01$-$D_{tt}13$	A_m01-A_m13; D_m01-D_m13	A_d01-A_d13; D_d01-D_d13	A_e01-A_e13; D_e01-D_e13	A_s01-A_s13; D_s01-D_s13
Development stage	young seedling	young seedling	young seedling	young seedling	young seedling	young seedling	young seedling
Tissue	leaf	leaf	leaf	leaf	leaf	leaf	leaf
Geographic location	USA	USA	USA	USA	USA	China	China
GenBank	CM017662.1 - CM017687.1	CM018202.1 - CM018227.1	CM017610.1 - CM017635.1	CM017636.1 - CM017661.1	CM017688.1 - CM017713.1	CM046631.1 - CM046656.1	CM045525.1 - CM045550.1
RefSeq	NC_053424.1- NC_053449.1	n/a	n/a	n/a	n/a	n/a	n/a
Submitter	HudsonAlpha Genome Sequencing Center	HudsonAlpha Genome Sequencing Center	HudsonAlpha Genome Sequencing Center	HudsonAlpha Genome Sequencing Center	HudsonAlpha Genome Sequencing Center	The institute of Cotton Research of Chinese Academy Agricultural Sciences	The institute of Cotton Research of Chinese Academy Agricultural Sciences
Date	Feb 25, 2021	Oct 8, 2019	Aug 27, 2019	Aug 27, 2020	Aug 27, 2019	Oct 6, 2022	Aug 17, 2022
Assembly type	haploid	haploid	haploid	haploid	haploid	haploid	haploid
Assembly level	Chromosome	Chromosome	Chromosome	Chromosome	Chromosome	Chromosome	Chromosome
Sequencing technology	Shotgun sequence, PacBio RSII	Shotgun sequence, PacBio RSII	Shotgun sequence, PacBio RSII	Shotgun sequence, PacBio RSII	Shotgun sequence, PacBio RSII	Shotgun sequence, PacBio Sequel	Shotgun sequence, PacBio Sequel
Assembly method	Mecat v. 1.0	Mecat v. 1.0	Mecat v. 1.1	Mecat v. 1.2	Mecat v. 1.1	FALCON v. 1	FALCON v. 1
Genome size	2.3 Gb	2.2 Gb	2.2 Gb	2.3 Gb	2.2 Gb	2.3 Gb	2.3 Gb
Total ungapped length	2.3 Gb	2.2 Gb	2.2 Gb	2.3 Gb	2.2 Gb	2.3 Gb	2.3 Gb
Genome Coverage	94.06x	90.1x	76.8x	94.1x	80.6x	106.0x	127.0x
Genes	75,376	74,561	78 281	74 660	78 303	74178	74,970
GC percent	34.5	34	34	34,5	34	34.5	34.5
chromosome A01	119,761,559	113 238 469	114 172 108	121 752 893	111 731 133	124 031 627	118 745 647
chromosome A02	108,141,443	99769429	105 044 580	109 867 862	102 188 074	109 822 344	108 788 785

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Continuation of Table

1	2	3	4	5	6	7	8
chromosome A03	113,693,209	105 981 974	106 988 191	114 197 739	108 106 663	114 352 146	110 887 122
chromosome A04	89,180,822	80 954 414	83 431 537	92 465 543	82 123 192	89 349 839	87 570 184
chromosome A05	111,098,753	102 458 744	104 743 809	113 805 608	105 499 638	124 669 549	113 168 133
chromosome A06	128,195,338	116 119 172	121 609 178	126 788 839	119 414 621	130 785 536	125 976 056
chromosome A07	98,902,531	93 754 744	96 764 941	99 644 675	95 097 007	98 644 386	98 532 636
chromosome A08	127,495,948	119 114 718	119 265 125	129 182 752	120 009 936	127 240 960	125 152 893
chromosome A09	85,335,976	77 140 527	79 219 835	82 652 960	79 385 658	84 756 691	83 529 980
chromosome A10	118,182,687	109 871 119	110 988 805	118 586 504	113 192 719	117 158 140	117 398 810
chromosome A11	124,181,751	114 694 469	120 496 074	126 800 230	115 039 066	132 145 079	122 787 908
chromosome A12	109,474,314	99 282 030	102 861 178	106 758 837	101 902 339	108 057 877	108 204 208
chromosome A13	111,646,624	108 235 369	110 351 505	115 677 886	110 366 452	115 830 965	114 611 390
chromosome D01	65,205,008	62 611 448	63 967 270	65 691 877	63 351 384	66 297 838	66 300 157
chromosome D02	72,186,496	66 877 699	69 897 195	71 596 151	68 431 162	73 472 059	72 813 539
chromosome D03	54,956,272	53 043 351	52 197 648	56 565 278	54 072 262	56 012 142	55 007 171
chromosome D04	58,229,188	54 342 187	54 488 862	57 383 358	54 473 739	62 932 355	58 287 303
chromosome D05	66,484,719	62 429 648	62 680 911	65 850 227	63 570 493	68 714 917	65 884 442
chromosome D06	66,684,206	62 820 931	63 218 559	66 874 005	63 279 081	68 485 142	66 657 206
chromosome D07	59,440,927	56 075 531	57 081 155	58 050 881	57 165 345	62 021 339	59 415 676
chromosome D08	69,427,147	65831471	67 500 665	69 705 406	66 245 736	71 546 767	69 992 981
chromosome D09	54,445,796	50 685 742	51 553 955	53 194 044	52 096 622	54 144 365	54 019 951
chromosome D10	68,089,194	65 066 651	65 609 545	67 709 701	65 927 692	70 211 476	69 146 489
chromosome D11	72,823,778	69 577 400	70 776 713	73 590 885	69 104 961	74 825 825	73 228 295
chromosome D12	65,099,798	59 787 526	60 769 583	63 954 031	61 226 500	64 434 879	62 814 374
chromosome D13	65,099,798	60 421 729	61 396 220	64 530 457	60 827 587	67 089 636	63 971 005
References	[12], [13], [16], [18]	[11], [18], [23]	[11], [18], [25]	[11], [18]	[11], [18]	[11], [35]	[11], [34], [35]

Author contributions

OA: data curation, formal analysis, software, and writing-original draft. MSA: supervision and editing. MSP: data resources, data curation, formal analysis, visualization. RMB: data curation, software. KB: data curation, software. TLA: analysis and writing. TD: data curation, writing — review and editing, conceptualization, formal analysis, investigation, supervision.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

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Мақта (*Gossypium L.*) өндірісі және агрономиялық сипаттамаларын жақсарту үшін секвенирлеу технологиясының маңызы

Gossypium L. — дақылдардың әртүрлілігімен және экономикалық құндылығымен танымал ең ірі тұқымдардың бірі, ал аллотетраплоидты мақта түрлері өсімдіктердің полиплоидиясын, филогенезін және селекциясын зерттеудің құнды көзі және модельдік жүйесі. Бұл шолуда, біріншіден, әлемдегі мақта (*Gossypium L.*) өндірісі мен қолданылуы туралы ақпарат қамтылған. Екіншіден, Қазақстанда мақта ауыл шаруашылығы және мақта өндірісі туралы толық ақпарат ұсынылған. Үшіншіден, *Gossypium L.* филогенезі туралы қысқаша ақпарат берілген. Төртіншіден, *G. hirsutum* (AD)1, *G. barbadense* (AD)2, *G. tomentosum* (AD)3, *G. mustelinum* (AD)4, *G. darwinii* (AD)5, *G. ekmanianum* (AD)6 және *G. stephensii* (AD)7 сияқты жеті аллотетраплоидты мақта түрлерінің толық геномының морфологиялық сипаттамалары мен зерттеулеріне қысқаша шолу берілген. Бұл шолу мақтаның агрономиялық және молекулалық зерттеулері үшін құнды ақпаратты ұсынады.

Кілт сөздер: мақта өндірісі (Gossypium L.), филогенез, аллотетраплоидты түрлер, геномның толық тізбегі.

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Производство хлопчатника (*Gossypium L.*) и важность технологий секвенирования для улучшения агрономических характеристик хлопка

Gossypium L. — один из крупнейших родов, известных своим разнообразием и экономической ценностью среди сельскохозяйственных культур, в то время как аллотетраплоидные виды хлопчатника являются ценным источником и модельной системой для изучения полиплоидии растений, филогении и селекции. Этот обзор включает, во-первых, информацию о производстве и использовании хлопчатника (*Gossypium*) в мире. Во-вторых, подробные сведения о сельском хозяйстве и производстве хлопчатника в Казахстане. В-третьих, приведена сводка о филогении *Gossypium L*. В-четвертых, представлен краткий обзор морфологических характеристик и исследований полного генома семи аллотетраплоидных видов хлопчатника, включая *G. hirsutum* (AD)1, *G. barbadense* (AD)2, *G. tomentosum* (AD)3, *G. mustelinum* (AD)4, *G. darwinii* (AD)5, *G. ekmanianum* (AD)6 и *G. stephensii* (AD)7. Данный обзор представляет собой ценный источник информации для будущих агрономических и молекулярных исследований хлопчатника.

Ключевые слова: Производство хлопчатника (*Gossypium* L.), филогенез, аллотетраплоидные виды, полная последовательность генома.

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Ferns of the Southwestern Altai as an object of studying the pteridoflora (class Polypodiopsida) of the Kazakhstan Altai

In accordance with the study's objective, the article presents the results of systematic and chorological analyses of ferns of the Southwestern Altai in the Kazakhstan Altai mountains, and also analyzes the specificity of the pteridoflora to soil substrates and moisture. The pteridoflora (class Polypodiopsida) was established as consisting of 32 species, belonging to 12 genera and 9 families. In terms of the number of species, the leading families are Woodsiaceae, Dryopteridaceae, Cystopteridaceae, and Athyridaceae, which together account for over 75.0 % of the total number of species in the study area. The family-species coefficient of the pteridoflora of the Southwestern Altai at the level of 0.28 indicates a low saturation of families with species and its primeval age. The pteridoflora was found to be associated with five distinct geographical areas. Species with a Holarctic distribution were the most prevalent, comprising 68.75 % of the total, suggesting a strong connection to Holarctic floras. According to the growing conditions, ferns are divided into 3 belt-zonal groups: plain-mountain-forest, mountain-forest and high-mountain. The dominant position is occupied by the mountain-forest group — 23 species (71.75 %), growing in coniferous, mixed and small-leaved forests, confined to the mountains in the altitude limit of 900–1700 m above sea level. A specificity of pteridoflora to various types of rocky habitats and cliffs was revealed. According to the requirement for moisture supply of ecotopes, ferns are divided into 6 groups, where the dominant position is occupied by the mesophilic ecomorph, represented by mesophytes — 46.8 % and mesopetrophytes — 37.5 % of the total species composition.

Keywords: habitat, species, Southwestern Altai, pteridoflora, zonal distribution, ecomorph.

Introduction

Fern-like plants (pteridophytes) represent the most numerous group of ancient vascular spore-bearing plants, and their historically formed species composition in a specific territory — pteridoflora — has a relict character. In terms of antiquity, ferns are probably second only to Rhyniophyta and Lycopodiophyta and are approximately the same geological age as Equisetophyta [1]. The antiquity of their origin, along with the complex biology of their development and reproduction, determines their low competitiveness in the formation of modern phytocenoses. The diversity of sporophyte structures and the high polymorphism of ferns often lead to challenges in their systematic identification [2]. Despite the continuous interest of specialists in pteridophytes, the study of their natural-territorial distribution and various aspects of their biology and ecology remains highly relevant, especially in light of increasing economic development and changing climatic conditions [3].

Currently, there are about 300 genera and more than 10,000 species of ferns worldwide. Their greatest species diversity is concentrated in the mountainous tropics of both the Old and New Worlds, particularly in regions with an equatorial or tropical uniformly humid climate, which has remained largely unchanged since the Carboniferous period — the heyday of ferns. In contrast, the boreal regions of the Old and New Worlds are less rich in fern species. In countries with temperate and cold climates, only a few species have survived, having demonstrated the ability to adapt to new environmental conditions. However, many ferns play a significant role in the formation of vegetation cover and have practical uses, including medicinal and decorative purposes [4].

The study of Kazakhstan's flora has received considerable attention over the past decades, with various systematic plant groups identified to varying degrees of detail. In most cases, botanical studies focus on seed plants, which are the most common in modern ecosystems. Ferns have been recognized as an integral spore-bearing component of the vascular plant flora in the analyzed territory or its subdivisions. Studies on ferns in mountainous regions are of particular scientific interest, as mountain systems being the richest in flora serve as reservoirs of the gene pool of ancient relict taxa and centers of biodiversity [5].

All of the above underscores the relevance of conducting comprehensive and in-depth research on the ferns of Kazakhstan's flora in general, and specifically in the Kazakhstan Altai. According to A.A. Sokolov's interpretation [6], the Kazakhstan Altai includes the Southwestern Altai, characterized by a complex and diverse mountainous landscape, as well as varying soil-climatic and hydrological conditions.

Research objective: to conduct a systematic, chorological analysis of ferns of the Southwestern Altai and to determine some aspects of their ecological and biological indicators to identify development trends and formation conditions.

Experimental

The study focuses on a set of fern species found in the flora of the Southwestern Altai, inhabiting all typical habitats within this mountainous region.

The mountain structure of the Southwestern Altai consists of a system of high ridges ranging from 1,500 to 2,800 meters above sea level, while low-mountain and foothill areas are situated at elevations of 500–700 meters. The climate is sharply continental, characterized by cold, long winters, hot summers, and significant temperature fluctuations throughout the day, seasons, and year. Annual precipitation varies from 400–550 mm in the western part to 1,500 mm at the upper forest line in the eastern and northeastern parts of the region [7].

To achieve the research objectives, we relied on the results of long-term field studies conducted in the Ivanovsky, Ubinsky, Ulbinsky, Koksinsky, Lineisky, and Kholzun ridges. Additionally, we examined herbarium collections housed in the herbarium fund of the RSE on the Right of Economic Management “Altai Botanical Garden” (acronym ABG) and utilized publications by the garden’s staff [8–11]. The floristic survey of the study area was conducted using the route-reconnaissance method [12], which provided data on fern species composition. The taxonomic analysis follows the classification of V.K. Nayar [13], with modifications based on A.I. Shmakov [14]. To study the natural-territorial distribution of the pteridoflora of the Southwestern Altai, a chorionomic approach was applied. This approach is based on the principle that each species is associated with a specific phytochorion (a unit of floristic zoning), such as a floristic kingdom or region. The alignment of a species’ distribution with particular phytochorions determines the classification of its range [15]. The type of range is established on a broad geographic scale, distinguishing species characteristic of an entire hemisphere (e.g., Holarctic) or specific geographic regions (Eurasian, North American-Asian, Asian). The range group further defines the species’ confinement to a specific zone or vegetation belt [16]. The classification of fern distribution patterns in the flora of the Western Altai follows the principles proposed by A.S. Mochalov et al. [2] in their analysis of Ural ferns. From an ecological perspective, ferns were analyzed based on their moisture requirements and preferred substrate type [15].

The nomenclature of genera and species primarily follows the Global Biodiversity Information Facility (GBIF) database [17].

Results and Discussion

A review of scientific publications established that the flora of the Kazakhstan Altai includes 41 species of ferns from the class Polypodiopsida, representing 14 genera and 10 families [18–22]. As a result of our research and a critical revision of the available literature data [9] on ferns (Polypodiopsida) in the Southwestern Altai, which is part of the Kazakhstan Altai, we identified a pteridoflora comprising 32 species from 12 genera and 9 families. This accounts for 78.05 % of the fern species diversity in the Kazakhstan Altai (Table).

Table

The composition of systematic groups of ferns (class Polypodiopsida) found in the South-West Altai

#	Family	Amount (count)		% of total species
		genera	species	
1	Polypodiacaceae–Polypody family	1	2	6.25
2	Hypolepidaceae — Hypolepis family	1	1	3.12
3	Aspleniaceae — Spleenwort family	1	2	6.25
4	Thelipteridacea–Marshfern family	2	2	6.25
5	Athyridaceae — Ladyfern family	1	4	12.50
6	Cystopteridaceae — Bladderfern family	2	6	18.75
7	Onocleodaceae — Sensitivefern family	1	1	3.12
8	Woodsiaceae — Clifffern family	1	7	21.88
9	Dryopteridaceae– Woodfern family	2	7	21.88
	TOTAL	12	32	100

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In the family-genus spectrum of ferns in the Southwestern Altai, three families contain two genera each (Dryopteridaceae, Cystopteridaceae, Thelypteridaceae), while the remaining six families each include a single genus. The family-genus coefficient of the pteridoflora is 0.75. Regarding the number of species composing the pteridoflora of the Southwestern Altai, the most species-rich families are Woodsiaceae, Dryopteridaceae, and Athyriaceae, each represented by seven species. The second-largest family is Cystopteridaceae, with six species, followed by Athyridaceae, which includes four species. The families Polypodiaceae, Aspleniaceae, and Thelypteridaceae each contain two species, while the remaining two families are represented by a single species. The family-species coefficient of the pteridoflora in the Southwestern Altai is 0.28. Thus, in taxonomic terms, the leading families with the highest number of species are Woodsiaceae, Dryopteridaceae, Cystopteridaceae, and Athyridaceae, accounting for 21.88 %, 21.88 %, 18.75 %, and 12.50 %, respectively, of the total species diversity. Together, these families comprise more than 75 % of the total fern species in the Southwestern Altai, while all other families collectively make up 25 % of the species composition.

The low saturation of families with genera and species indicates the ancient origin of ferns in the Southwestern Altai. It is well known that the older a florogenetic element is the fewer species it tends to contain [23]. The presence of many families and genera represented by only one or two species in the fern flora of the Southwestern Altai is characteristic of the flora of the northern regions of the Holarctic floristic kingdom as a whole [24].

The current distribution of these elements reflects the historical process of flora formation. In the chorological analysis, the ferns of the Southwestern Altai were classified into five chorological groups (Fig. 1).

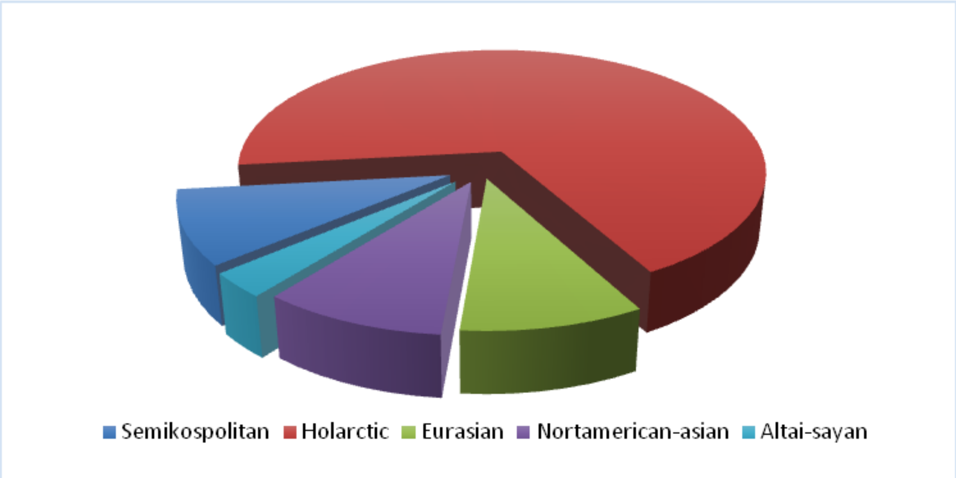

Figure 1. Fern habitats of the South-West Altai

1) Semicosmopolitan Group. This group is represented by three species (9.37 %) that are widely distributed in the Northern Hemisphere and extend into the Southern Hemisphere: *Pteridium aquilinum* (L.) Kuhn, *Asplenium trichomanes* L., *Cystopteris fragilis* (L.) Borb.;

2) Holarctic Group. This group includes 22 species (68.75 %) that are found across the Northern Hemisphere, specifically in Eurasia and North America: *Asplenium septentrionale* (L.) Hoffm., *A. ruta-muraria* L., *Athyrium filix-femina* (L.), *A. monomachii* (Kom.) Kom., *Cystopteris dickeana* R. Sim., *C. montana* (Lam.) Bernh., *Dryopteris carthusiana* (Vill.) H.P. Fuchs, *D. cristata* (L.) A. Gray, *D. expansa* (C. Presl) Fraser-Jenkins et Germy, *D. dilatata* (Hoffm.) A. Gray, *D. filix-mas* (L.) Schott, *D. fragrans* (L.) Schott, *Gymnocarpium continentale* (Petrov) Pojark., *G. dryopteris* (L.) Newman, *Phegopteris connectilis* (Michx.) Watt, Roth., *Polystichum braunii* (Spenn.) Fée, *P. lonchitis* (L.) Roth, *Polypodium vulgare* L., *Thelypteris palustris* Schott, *Woodsia alpina* (Bolton) Gray, *W. ilvensis* (L.) R. Br., *W. glabella* R. Br.;

3) North American-Asian Group. This group is represented by three species (9.37 %): *Athyrium sinense* Rupr., *Polypodium sibiricum* Sipliv., *Woodsia calcarea* (Fomin) Shmakov;

4) Eurasian Group. This group includes three species (9.37 %): *Athyrium distentifolium* Tausch ex Opiz, *Cystopteris sudetica* A. Braun & Milde, *Woodsia heterophylla* (Turcz. ex Fomin);

5) Altai-Sayan Group. This group is represented by a single species (3.14 %), an Altai-Sayan endemic, *Cystopteris altajensis* Gureeva. This species was described from Siberia (Altai); type locality: "Altai Krai, Turochaksky District, Lake Teletskoye, lower reaches of the Bolshie Chili River, shaded rock niches" [25].

Thus, the ferns of the Southwestern Altai are predominantly represented by Holarctic species (68.75 %). The high proportion of Holarctic ferns indicates extensive connections between the local flora of the Southwestern Altai and the floras of the Holarctic. Additionally, the presence of cosmopolitan species within the pteridoflora suggests its antiquity.

We identified zonal-altitudinal groups based on species distribution within specific ecological zones or altitudinal belts. Accordingly, the ferns of the Southwestern Altai were classified into three zonal-altitudinal groups: plain-mountain-forest, mountain-forest, and high-mountain. The high-mountain group comprises species growing above the forest line in subalpine meadows, rocky screes, and well-lit rock outcrops, with a vertical distribution range of 1,800–2,200 m above sea level. This group includes five species (15.65 %): *Athyrium distentifolium*, *Woodsia acuminata*, *W. asiatica*, *W. ilvensis*, and *W. heterophylla*. The mountain-forest group is the most species-rich, comprising 23 species (71.75 %) and encompassing a highly heterogeneous assemblage. Species within this group occur across the entire mountain-forest belt (900–1,700 m a.s.l.), predominantly in sparse coniferous and mixed forests. Representative species include *Athyrium filix-femina*, *A. monomachii*, *A. sinense*, *Botrychium lunaria*, *Dryopteris expansa*, *Matteuccia struthiopteris*, *Gymnocarpium dryopteris*, *Phegopteris connectilis*, *Polystichum braunii*, *P. lonchitis*, and *Pteridium aquilinum*. In the lower and middle mountain belts, *Dryopteris carthusiana* and *D. filix-mas* are found in shaded coniferous forests, whereas *Woodsia calcarea*, *Polypodium vulgare*, and *P. sibiricum* inhabit crevices of shaded, moss-covered, moist rock formations and granitoid outcrops. Meanwhile, *Asplenium septentrionale*, *A. trichomanes*, *Cystopteris altajensis*, *C. fragilis*, *C. dickeana*, *Dryopteris fragrans*, and *Gymnocarpium continentale* occur in illuminated rock crevices and rocky slopes. The plain-mountain-forest group is associated with both zonal vegetation (foothill coniferous and mixed forests) and intrazonal vegetation, including swamps, marshy meadows, riverbanks, and streams. This group comprises four species (12.5 %) distributed within an altitudinal range of 600–900 m a.s.l.: *Asplenium ruta-muraria*, *Cystopteris sudetica*, *Dryopteris cristata*, and *Thelypteris palustris*.

The observed zonal distribution of ferns in the study area aligns with the findings of A.I. Shmakov [26]. Analyzing the pteridoflora of the Altai, Tien Shan, and Semirechye, Shmakov demonstrated that most ferns are restricted to mountain systems, with only a few extending into lowland areas. This distribution pattern is closely linked to the evolutionary history of ferns, which were originally associated with forest vegetation. Over time, due to climatic shifts, certain species evolved adaptations that enabled them to colonize open, rocky environments. This explains the presence — albeit in limited numbers — of high-altitude species.

Ecological analysis of flora, including pteridoflora, involves assessing species' relationships with environmental conditions. Typically, this analysis examines species' affinity to factors such as moisture levels, rocky substrates, and calcium-rich soils [24].

The analysis of fern distribution in the Southwestern Altai revealed a distinct preference for rocky substrates, a pattern consistent with pteridofloras of other mountainous regions, particularly Southern Siberia [25]. Of the total species composition, 17 species (53.12 %) are confined to various rocky habitats and cliffs. As noted by I.I. Gureeva [25], small-sized species with compact rhizomes were commonly found in crevices, where microclimatic conditions — such as temperature and moisture regimes — resemble those of forest understories, while light spectra approximate those of open landscapes. In the Southwestern Altai, this group includes all species of the genus *Woodsia* (*W. acuminata*, *W. alpina*, *W. asiatica*, *W. calcarea*, *W. ilvensis*, *W. glabella*, *W. heterophylla*), as well as *Asplenium septentrionale* and *A. trichomanes*.

On flat surfaces of granitoid outcrops with minimal soil accumulation, we recorded the presence of *Cystopteris fragilis*, *C. dickeana*, *Polypodium sibiricum*, and *P. vulgare*. Additionally, *Athyrium distentifolium* and *Dryopteris fragrans* were observed on large Kurums (rock streams).

Based on moisture requirements, four major plant ecomorphs are traditionally distinguished concerning water regimes: xerophytes, mesophytes, hygrophytes, and hydrophytes. Intermediate groups that account for subtle variations in moisture availability are also recognized in floristic analyses [27].

The species of the studied pteridoflora were divided into 6 groups, which represent variations of 3 main ecomorphs (Fig. 2).

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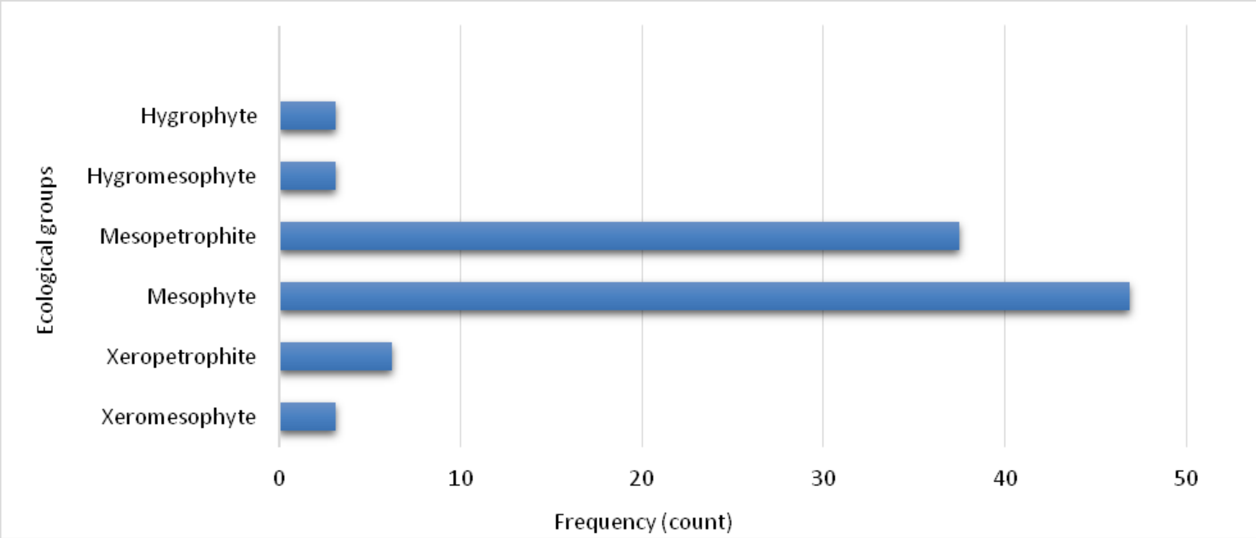

Figure 2. Distribution of the Southwestern Altai pteridoflora by moisture requirements

1. The xerophilicecomorph of ferns in the Southwestern Altai is scarce due to the biological and evolutionary characteristics of pteridophytes, represented by three species (9.37 %): *Woodsia asiatica* — a xeromesophyte (3.125 %), and *Asplenium septentrionale* and *Woodsia heterophylla* — xeropetrophytes (6.25 %). These species are confined to habitats with periodic or constant (but minor) moisture deficits, exhibiting high physiological drought tolerance yet responding positively to additional moisture under conditions of good drainage [28].

2. The mesophilic ecomorph occupies a dominant position in the studied flora and is represented by two groups: mesophytes and mesopetrophytes, demonstrating the prevalence of pteridophytes in moderately moist habitats. Some species exhibit tolerance to slightly drier conditions, while others prefer higher humidity levels. The mesophyte group is confined to moderately humid habitats in dark coniferous, broadleaf, mixed, and small-leaved forests, less frequently occurring in rocky forest glades covered with moss, wet forest meadows, and swamp edges. This group includes 15 species (46.87 %): *Athyrium distentifolium, A. filix-femina, A. monomachii, A. sinense, Cystopteris montana, C. sudetica, Dryopteris carthusiana, D. expansa, D. dilatata, D. filix-mas, Gymnocarpium dryopteris, Matteuccia struthiopteris, Phegopteris connectilis, Polystichum braunii, Pteridium aquilinum.* The mesopetrophyte group consists of ferns inhabiting shaded and humid environments in coniferous and mixed forests, on ledges beneath cliffs, and in rock crevices and scree habitats. In the Southwestern Altai, 12 species (37.5 %) are classified as typical mesopetrophytes: *Asplenium trichomanes, Cystopteris dickeana, C. fragilis, Gymnocarpium continentale, Polystichum lonchitis, Polypodium sibiricum, P. vulgaris, Woodsia acuminata, W. alpina, W. calcarea, W. ilvensis, W. glabella, Polystichum lonchitis.*

3. The hygrophilicecomorph of ferns in the Southwestern Altai is characterized by a high demand for soil moisture, preferring damp and wet habitats. This ecomorph includes two species: *Dryopteris cristata* (3.12 %) — a hygromesophyte, and *Thelypteris palustris* (3.12 %) — a true hygrophyte, growing in waterlogged meadows.

Thus, the ecological analysis demonstrated that ferns in the studied area are strictly confined to specific habitats and do not exhibit significant ecological diversity.

Conclusions

1 In the Southwestern Altai, 32 species from 12 genera and 9 families of ferns belonging to the class Polypodiopsida have been recorded. The dominant families are Woodsiaceae, Dryopteridaceae, Cystopteridaceae, and Athyriaceae, collectively comprising 75.0 % of the total pteridoflora species composition. The richest genera, accounting for 62.5 % of the species diversity, are Woodsia, Dryopteris, and Cystopteris.

2 The pteridoflora of the Southwestern Altai is predominantly formed by species with wide distribution ranges, particularly Holarctic species (22 species, 68.75 %), indicating a broad connection between the local

fern flora and the floras of the Holarctic region. The ancient origin of the pteridoflora in the Southwestern Altai is supported by the presence of genera represented by only one or two species.

3 The phytocoenotic confinement of the pteridoflora of the Southwestern Altai is categorized into three zonal-belt groups: plain-mountain-forest, mountain-forest, and high-mountain, ranging in elevation from 900 to 2200 m above sea level. Among these, the mountain-forest component is the most dominant, comprising 23 species (71.75 %).

4 The majority of pteridoflora species in the Southwestern Altai (53.12 %) are associated with various rocky habitats and cliffs. In terms of moisture preference, ferns are represented by three ecomorphs: xerophilic, mesophilic, and hygrophilic. Species growing under moderate moisture conditions prevail, with mesophytes accounting for 15 species (46.87 %) and mesopetrophytes for 12 species (37.5 %).

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А.Н. Данилова, Ю.А. Котухов, А.А. Сумбембаев, О.А. Ануфриева, А.А. Винокуров

Оңтүстік-Батыс Алтайдың папоротниктері қазақстандық Алтайдың птеридофлорасын (Polypodiopsida класы) зерттеудің нысаны ретінде

Мақалада қойылған мақсатқа сәйкес Оңтүстік-Батыс Алтайдағы қазақстандық Алтай папоротниктерінің жүйелік және хорологиялық талдау нәтижелері келтірілген, сондай-ақ птеридофлораның топырақ субстраттарына және ылғалмен қамтамасыз етілуіне байланысты таралу ерекшеліктері зерттелген. Зерттеу нәтижесінде птеридофлораның (Polypodiopsida класы) 32 түрден, 12 туыстан, 9 тұқымдастан тұратыны анықталды. Түр саны бойынша басым тұқымдастар — Woodsiaceae, Dryopteridaceae, Cystopteridaceae, Athyriaceae, олардың үлесі зерттелген аймақтағы жалпы түрлер санының 75 %-дан астамын құрайды. Оңтүстік-Батыс Алтай птеридофлорасының тұқымдас-түр коэффициенті 0,28 деңгейінде анықталып, оның түрлік құрамының тұқымдастарға қатысты аз қаныққандығын және көне флора екенін көрсетеді. Птеридофлора 5 таралу типіне жатқызылды, олардың ішінде голарктикалық түрлер (68,75 %) басым, бұл флораның Голарктика аймағымен байланысын айғақтайды. Өсу жағдайлары бойынша папоротниктер 3 биіктік-белдеу топтарына бөлінді: жазықтық-таулы-орманды, таулы-орманды және биік таулы. Оның ішінде таулы-орманды топ (23 түр, 71,75 %) басым, олар қылқан жапырақты, аралас және ұсақ жапырақты ормандарда, теңіз деңгейінен 900-1700 м биіктікте таралған. Сонымен қатар птеридофлораның әртүрлі тасты мекендер мен жартас субстраттарына ерекше бейімделуі анықталды. Ылғалмен қамтамасыз етілуіне байланысты папоротниктер 6 экологиялық топқа бөлінді, олардың ішінде мезофильді экоморфа басым: мезофиттер — 46,8 %, мезопетрофиттер — 37,5 %.

Кілт сөздер: таралу аймағы, түр, Оңтүстік-Батыс Алтай, птеридофлора, биіктік-белдеулік таралу, экоморфа.

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Папоротники Юго-Западного Алтая как объект изучения птеридофлоры (класс Polypodiopsida) Казахстанского Алтая

В статье, согласно поставленной цели, приведены результаты систематического и хорологического анализов папоротников Юго-Западного Алтая в пределах Казахстанского Алтая, а также проанализирована приуроченность птеридофлоры к почвенным субстратам и по отношению к увлажнению. Установлена птеридофлора (класс Polypodiopsida) в составе 32 видов, из 12 родов,9 семейств. По числу видов к ведущим семействам относятся Woodsiaceae, Dryopteridaceae, Cystopteridaceae, Athyridaceae, доля которых составляет свыше 75,0 % от общего числа видов исследуемой территории. Семейственно-видовой коэффициент птеридофлоры Юго-Западного Алтая равный 0,28 свидетельствует о низкой насыщенности семейств видами и указывает на ее древний возраст. Установлено, что птеридофлора относится к 5 типам ареалов, где доминирующую позицию занимают виды с голарктическим распространением — 68,75 %, что свидетельствует о связи с флорами Голарктики. По условиям произрастания папоротники распределились по 3 поясно-зональным группам: равнинно-горно-лесной, горно-лесной и высокогорной. Главенствующее положение занимает горно-лесная группа — 23 вида (71,75 %), произрастающие в хвойных, смешанных и мелколиственных лесах, приуроченных к горам в высотном пределе 900-1700 м н. у. м. Выявлена специфическая приуроченность птеридофлоры к разного рода каменистым местообитаниям и скалам. По требованию к влагообеспеченности экотопов папоротники распределились на 6 групп, где доминирующую позицию занимает мезофильная экоморфа, представленная мезофитами — 46,8 % и мезопетрофитами — 37,5 % от общего видового состава.

Ключевые слова: ареал, вид, Юго-Западный Алтай, птеридофлора, поясно-зональное распределение, экоморфа.

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New data on the distribution of the Caspian whipsnake *Dolichophis caspius* (Gmelin, 1789) in the West Kazakhstan region of the Republic of Kazakhstan

Information on the distribution of the Caspian whipsnake *Dolichophis caspius* (Gmelin, 1789) within the West Kazakhstan region of the Republic of Kazakhstan is summarized and possible reasons for its dispersal across the Bokeyorda district in recent decades are discussed. New discoveries of the species have allowed the northeastern boundary of its range to be pushed 20–30 km northward from the previously known habitats of the Caspian snake. The only protected natural area in Kazakhstan where the species is reliably present and, therefore, currently protected is the “Orda” State Nature Reserve of local significance. To ensure the conservation of the species in Kazakhstan, it is desirable to justify and create a new protected natural area — the regional nature monument “Mount Maloe Bogdo”.

Keywords: snakes, Colubridae, Red Book of the Republic of Kazakhstan, Bokeyorda district of West Kazakhstan Region, Maloe Bogdo, Khaki sor, specially protected natural areas, state nature reserve of local importance “Orda”.

Introduction

The Caspian whipsnake (= yellow-bellied whipsnake) is a monotypic species of the colubridae family, the modern scientific name of which is *Dolichophis caspius* (Gmelin, 1789) [1]. It is distributed in South-Eastern Europe and Asia Minor, the north-eastern border of the range passes through Western Kazakhstan (Fig. 1). The northern limit of distribution is located on the right bank of the Volga, in the Kamyshinsky district of the Volgograd region of Russia, on the territory of the Shcherbakovsky Nature Park [2, 3; 162-163].

Punder the name “Yellow-bellied snake *Coluber caspius*” with the status “IV category”. Unstudied species included in the latest edition of the Red Book of the Republic of Kazakhstan. In this edition, the authors of the species essay reported that measures to protect the yellow-bellied snake had not been taken or developed due to the lack of study of the species. As a proposal for its study, it was indicated that it was necessary to determine the boundaries of its distribution in Kazakhstan. The authors of the Red Book essay Z.K. Brushko and Yu.A. Zima [5; 78-79] knew of only one location on the territory of Kazakhstan from the article by Yu.M. Rall [6] — “in the relict steppe of Bes-Chokho in the Volga-Ural interfluve” (Kurmangazy district of Atyrau region). In fact, the *D. caspius* was recorded in Kazakhstan much earlier. The first published information about the *D. caspius* in what is now Atyrau Region dates back to the 18th century [7; 513-514, 8; 111-112, 8; 129], and in West Kazakhstan Region — to the 19th century [9; 73-74, 10; 24, 11; 123]. Our colleagues’ publications with new locations of the species’ occurrence in Kazakhstan mainly contain information territorially related to Atyrau Region [12–16], and information confirming its current habitat in West Kazakhstan Region, on Maloe Bogdo Mountain and its environs [12, 15, 17–19]. *D. caspius* was previously recorded on Maloe Bogdo: in 1854 by I.B. Auerbach; in 1887 by A.N. Kharuzin, in 2004 and 2008 by F.G. Bidashko. F.A. Saraev and co-authors [15; 223] reported a sighting in the interfluve of the Volga and Ural rivers — “Pomoshch settlement (48°08.583'N, 48°50.056'E), June 3, 2017 (Salahatov N.B., personal communication)”. The reference to the only sighting in the left bank of the Ural River, in the northern outskirts of the village of Inderborskiy [13, 15, 17], is based on an oral report by F.G. Bidashko about encountering the species there on June 29, 1998. It is worth noting that the presence of the *D. caspius* in the two latter locations, in the Akzhaik district of the West Kazakhstan region near the border with the Atyrau region, has not been confirmed later.

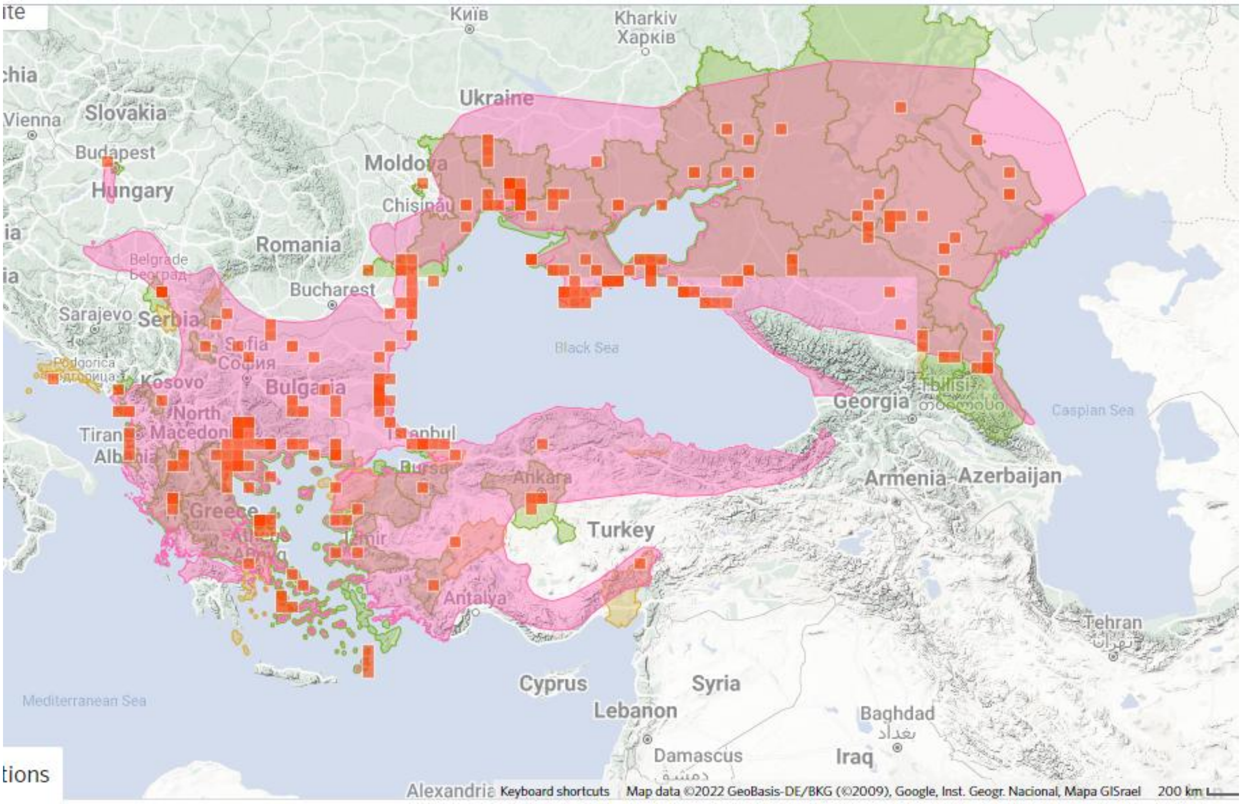

Figure 1. Sites of encounters [4] and range boundaries [1] of *Dolichophis caspius*

The objectives of this article are to clarify the current distribution, assess the state of protection and develop proposals for the protection of the species in the West Kazakhstan Region of the Republic of Kazakhstan (hereinafter WKR).

Experimental

The main material for the article was the authors' field research from 2017–2022 in the Bokeyorda District of the West Kazakhstan Region, partially published [20–25]. Literary sources and personal communications of colleagues related to encounters with the *D. caspius* in the West Kazakhstan region were analysed. Previously published and new data on recorded live and dead individuals, molted worms, were used to clarify the distribution of the species in the study region. Information on the current distribution of the Caspian whipsnake in the study region is presented as a range map with a cadastre including 11 locations. For uniformity, the coordinates of all species encounters are given in the format "DD°MM.mmm'". Geographic coordinates were determined using Garmin eTrex H GPS navigators (Garmin Ltd., Taiwan). Photographic surveys of snakes and biotopes were performed using a Nikon D500 digital SLR camera (Nikon, Japan) and a Fujifilm FinePix HS10 digital camera (Fujifilm, Japan). All our Caspian whipsnake locations have been uploaded as part of the West Kazakhstan snake dataset to the Global Biodiversity Information Facility (GBIF) portal [26].

To determine the reasons for the spread of the *D. caspius* in Kazakhstan, an analysis of the long-term dynamics of climate indicators was carried out at the Urda (Khan Ordasy) weather station, which is located closest to the sites of its new finds. The dynamics of air temperature and precipitation in the Bokeyorda district is given according to the data of the branch of the Republican state enterprise on the right of economic management "Kazhydromet" in the West Kazakhstan region.

A significant part of the study area is located below the altitude of 0 m above sea level and occupies a lowland plain freed from the Khvalynsk waters around the vast salt marsh lake Solyonye Gryazy (Sor Khaki), which remained as a closed salt water body after the sea waters retreated [27]. Sor Khaki is one of the largest salt marshes in the world, occupying an area of more than 1000 km^2. This salt marsh reaches 80 km in length, its width is 15–25 km, and the depth of the depression containing it is more than 15 m [28]. The eastern part is occupied by Naryn Sands, where hummocky and ridge-hummocky sands alternate with flat-plain depressions. In the southwest of the region is Mount Maloe Bogdo, which is the southern wing of the large Urpek salt uplift. On the surface it is a ridge stretching from west to east, reaching its highest point of 37 m on the eastern slope [29].

The climate is sharply continental. The saline depressions of Sor Khaki and Naryn-Peski are hotbeds of desertification [30].

Results and Discussion

Let's start with previously unpublished data on encounters in WKR. All meetings relate to its Bokeyorda district.

On July 25, 2019, we noted a dismembered carcass of a Caspian snake at the Babay-Sad cemetery near the village of Khan Ordasy (Fig. 2A; Fig. 3, point 1). On July 7, 2020, a 1.6-meter-long moulting snake was found there (Fig. 2B; Fig. 3, point 1).

At the end of March 2021, a *D. caspius* was found dead near a railway embankment near the Ravninny siding (15 km south of the village of Saikhin) of the Volga Railway (Urbach — Verkhniy Baskunchak Line) by a local resident, track fitter of JSC Russian Railways, Yuri Vladimirovich Berezin. The snake is about 1.8 m long (Fig. 2C; Fig. 3, point 3).

On April 19, 2022, during an ecological and local history expedition of the Bokeyorda Center for Tourism and Ecology with the participation of teachers and students of the M. Mametova and Zhangir Khan schools, four Caspian whipsnake were observed on Mount Maloe Bogdo. *D. caspius* were encountered at the southwestern foot of the mountain on the road leading to the quarry (Fig. 2D; Fig. 3, point 10) and at the eastern foot of Mount Maloe Bogdo (Fig. 3, point 11).

On June 12, 2022, in the extreme north-eastern part of the Khaki Sor, a *D. caspius* was observed crushed by a vehicle on a dirt road (Fig. 2E; Fig. 3, point 2).

Of the eleven locations of finds shown in Fig. 3, only one — point 1 — is located in a specially protected natural area (State Nature Reserve of Local Significance "Orda"). The remaining noted habitats do not have territorial protection.

Most of the meeting places of the species in recent years are in WKR (points 4–11 in Fig. 3) are confined to Mount Maloe Bogdo. This mountain, which was previously an island in the retreating Caspian Sea, was possibly a refugium for the Caspian whipsnake. In our opinion, by now it has become the centre of its distribution: the species is moving north in Kazakhstan from there. From Mount Maloe Bogdo, the *D. caspius* has spread more than 20 km to the northwest (point 3 in Fig. 3) and more than 30 km to the northeast (points 1 and 2, Fig. 3).

Let's dwell on the *anthropogenic factor*. At the "Zhaman-Tau" mineral deposit, located near Mount Maloe Bogdo, areas with deposits of sandstone, gypsum, limestone, and crushed stone suitable for construction work have been identified. The spread of the *D. caspius* north of Maloe Bogdo may be linked to the development of this non-metallic mineral deposit that began in 2020. First, snakes are migrating due to disturbance from the mining activities, and secondly, the snakes may be displaced during the transportation of sand-gravel mixtures and crushed stone from the deposit near Mount Maloe Bogdo to be used for the medium repairs of the national road R-56 (transported up to 100 km), as well as for the construction of roads in the villages of Khan Ordas, Shonay, and Saykhin. The presence of the *D. caspius* on Maloe Bogdo was noted as early as the 19th century, but its expansion to neighboring territories apparently began only at the end of the 20th century — beginning of the 21st century. Previously, researchers did not record it in areas north of Maloe Bogdo, which we now indicate.

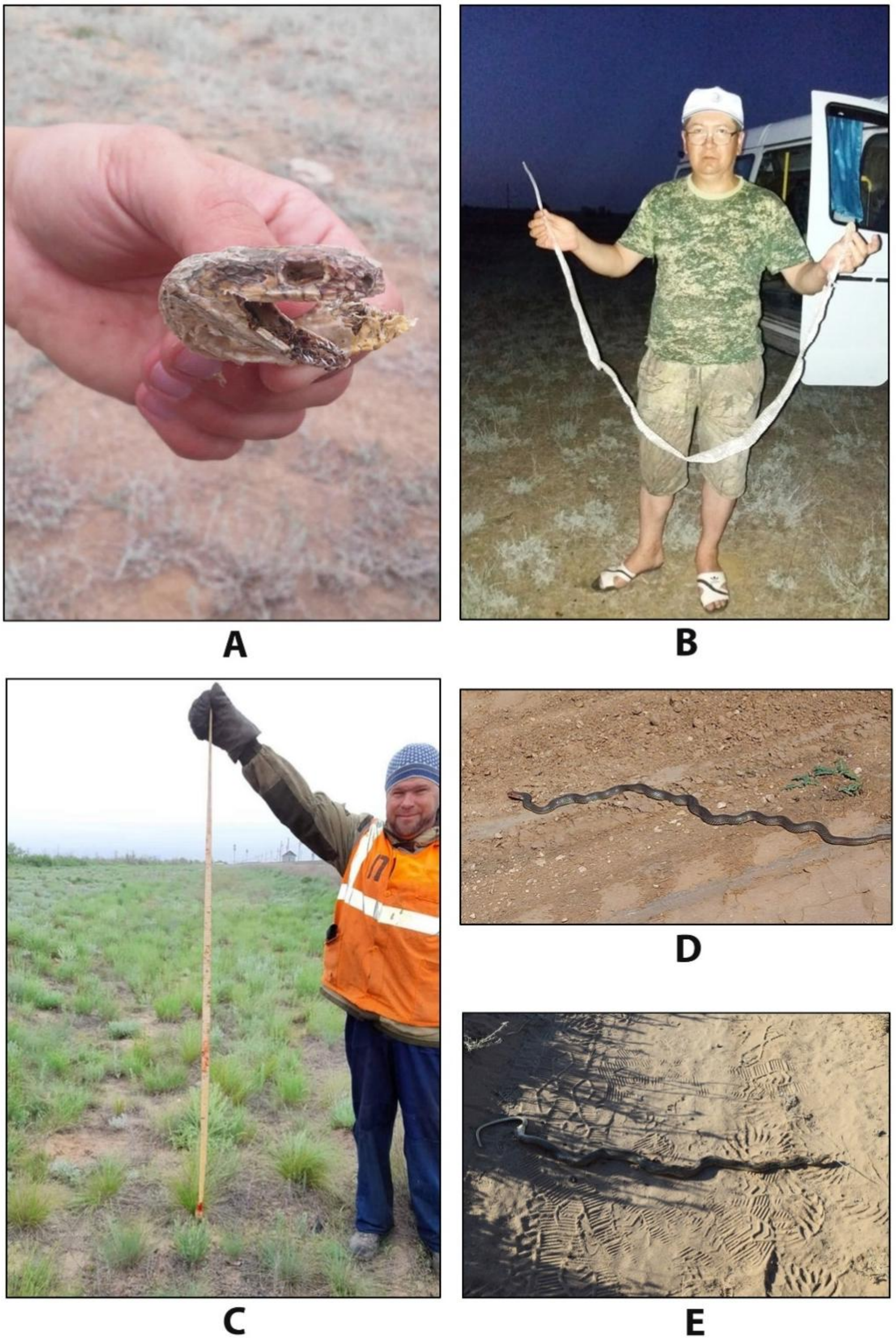

Figure 2. *Dolichophis caspius* encounters in the Bokeyorda
District of the West Kazakhstan Region of the Republic of Kazakhstan:
A — a dismembered Caspian whipsnake at the Babai-Sad cemetery in the vicinity of the village of Khan Ordasy;
B — a moulting worm, also there;
C — a crushed specimen at the Ravninny siding of the Privolzhskaya Railway;
D — a Caspian whipsnake at the south-western foot of the Maloe Bogdo Mountain;
E — a crushed specimen in the extreme north-eastern part of the Khaki Sor.

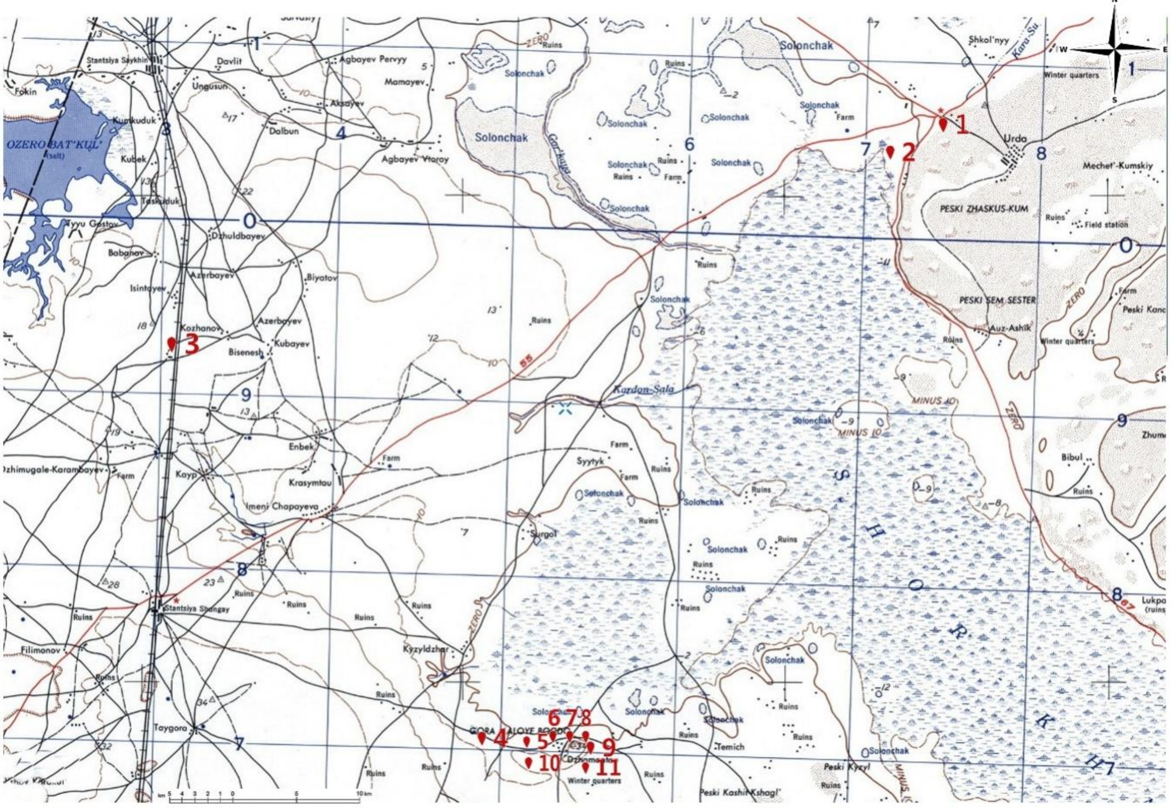

Figure 3. Meeting places with *Dolichophis caspius* in the Bokeyorda district of the West Kazakhstan region of the Republic of Kazakhstan in 2004–2022:
1 — the vicinity of the village of Khan Ordasy, the Babay-sad cemetery (48°47.305'N, 47°22.559'E), June 13–14, 2018 [25; 89]; July 25, 2019, July 7, 2020 [our data]; **2** — the extreme north-eastern part of the Khaki sor, on a dirt road (48°46.073'N, 47°20.542'E), June 12, 2022 [our data]; **3 —** surroundings Ravninny junction, at the railway embankment (48°40.240'N, 46°46.430'E), March 2021 [our data]; **4** — dirt road between Mount Maloe Bogdo and the village of Saykhin (48°28.392'N, 47°01.497'E), April 30, 2018 [20; 288–289]; **5** — Mount Maloe Bogdo (48°28.000'N, 47°03.000'E), April 21, 2004 and June 15, 2008 [17; 94, 13; 184]; **6** — plain adjacent to the southwestern slope of Mount Maloe Bogdo (48°28.035'N, 47°04.986'E), May 25, 2017 [21; 137]; **7** — Mount Maloe Bogdo (48°28.048'N, 47°05.326'E), May 23, 2012 [18; 213, 19; 71]; **8** — summit of Mount Maloe Bogdo, in a crevice (48°28.188'N, 47°05.548'E), April 29, 2018 [20; 288–289]; **9** — eastern foothill of Mount Maloe Bogdo (48°28.098'N, 47°05.591'E), May 25, 2017 [21; 137]; **10** — southwestern foothill of Mount Maloe Bogdo (48°27.309'N, 47°02.566'E), April 19, 2022 [our data]; **11** — eastern foothills of Maloe Bogdo Mountain (48°27.420'N, 47°05.323'E), April 19, 2022 [our data]

Moving on to *climate change*, climate change and global warming may also be the reason for the *D. caspius* northward expansion in WKR. An increase in climate aridity and an expansion of desertification were noted in the study area [30]. According to the results of studies in southwestern Bulgaria [31], the activity pattern of *D. caspius* shows its thermophilic nature: winter activity was not recorded, it emerges from hibernation relatively late, is active even in the hottest months and only during the day. According to the thermal adaptation index (the ratio of body temperature to external temperature), the Caspian snake is the most thermophilic (0.98 ± 0.03) in comparison with the other 13 studied reptile species of the Volga basin [32]. Ecological niche models predict that, as a result of global warming, the range of *D. caspius* will expand to the north, with a slight decrease in the range at its southern borders [33]. Studies with ecological niche modelling [34] have found a strong influence not only of temperature, but also, first of all, of precipitation on the distribution of the *D. caspius* as a xerophilic species.

The table shows the dynamics of two climate indicators for the Urda (Khan Ordasy) weather station for the period from 1986 to 2024, divided into three equal time intervals of 13 years each: 1986–1998, 1999–2011 and 2012–2024. The figures show that over the past 39 years, the general trend has been toward a decrease in average annual precipitation and an increase in average annual air temperature. The decrease in average annual precipitation in 2012–2024 compared to 1986–1998 was 40.7 mm, and 23.2 mm compared to 1999–2011. The increase in air temperature in 2012–2024 compared to 1986–1998 was 1.5 mm amounted to 1.9 °C, compared to 1999–2011 — 0.7 °C.

Table

Main climate indicators for a long-term period at the Urda (Khan Ordasy) weather station

Years	Average annual precipitation, mm	Average annual air temperature, °C
1986–1998	295.1	8.4
1999–2011	277.6	9.6
2012–2024	254.4	10.3
1986–2024	**275.7**	**9.4**

Feeding migrations. The diet of the species includes small mammals (gophers, jerboas, voles, gerbils, hamsters, etc.), birds, lizards and snakes, and less often amphibians, large spiders and insects [35–38].

The increased frequency of encounters in 2016–2018 in the Atyrau region may be explained by the increased activity of the Caspian whipsnake in search of prey against the background of the low numbers of midday and tamarisk sand eels in these years [16]. In the Bokeyorda district of WKR the same situation is noted with the small ground squirrel [39–41]. The movement of the Caspian snake north from the Maloe Bogdo Mountain may be associated with the snakes' search, with an insufficient food supply, for accumulations of rodents and other vertebrates of a size suitable for swallowing.

Recommendations for species conservation

The Malo-Bogdin salt-dome region is a key landscape and biological area that is insufficiently protected by territorial conservation measures. The justification and creation of a protected natural area, such as the regional nature monument "Mount Maloe Bogdo", has become an urgent issue. Such a protected area would contribute to the preservation not only of the karst formations of the area but also of the rare plant and animal species inhabiting it, including the *D. caspius*.

Direct destruction and mortality on roads are limiting factors for the Caspian snake, as confirmed by studies conducted outside the West Kazakhstan region [16, 24, 34, 42, 43]. Superstitions continue to be a reason for the destruction of rare non-venomous snakes such as *D. caspius*, so it is necessary to carry out educational work with the local population to eliminate false beliefs about snakes and their danger.

Conclusions

1. The northeastern boundary of the global range of the *D. caspius* — a species included in the Red Book of the Republic of Kazakhstan — passes through the territory of the West Kazakhstan region.

2. All sightings of the species in the West Kazakhstan region are geographically within its Bokeyordinsky district, where we define the boundary of its current distribution (from west to east) from the vicinity of the railway station Ravninsky through the northeastern edge of the Hakis sor to the northern outskirts of the village of Khan Ordas. According to the data obtained in 2018–2022, the previously known distribution of the Caspian snake in Kazakhstan has been extended more than 20 km northwest and more than 30 km northeast from Mount Maloe Bogdo.

3. In our opinion, the current distribution of the species was influenced by a complex of factors: global warming, forage migrations, and anthropogenic development of the territory.

4. The species is reliably present only in one protected natural area in Kazakhstan — the "Orda" State Nature Reserve of local significance (Bokeyordinsky district, West Kazakhstan region). To protect the species in Kazakhstan, it is promising to justify and create the regional nature monument "Mount Maloe Bogdo" in the Bokeyordinsky district.

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К.М. Ахмеденов, А.Г. Бакиев, А.Е. Кузовенко, А.А. Кленина

Қазақстан Республикасының Батыс Қазақстан облысында *Dolichophis caspius* (Gmelin, 1789) Каспий жыланының таралуы туралы жаңа деректер

Қазақстан Республикасының Батыс Қазақстан облысы шегінде Каспий жыланының таралуы туралы ақпарат жинақталды және оның соңғы онжылдықтарда Бөкей ордасы ауданы бойынша қоныстануының ықтимал себептері талқыланды. Түрдің жаңа табылғандары солтүстік-шығыс шекарасын түрдің ең жақын, бұрын белгілі болған мекендеу орындарынан солтүстікке қарай 20-30 км-ге жылжытуға мүмкіндік берді. Қазіргі уақытта Қазақстанның ерекше қорғалатын табиғи аумақтарында түр тек жергілікті маңызы бар «Орда» мемлекеттік табиғи қорығында ғана өмір сүреді, біз оны 2018-2022 жылдары кездестірдік. Қазақстанда түрді сақтау үшін ерекше қорғалатын табиғи аумақ — «Кіші Богдо тауы» Облыстық маңызы бар табиғат ескерткішін құру және құру перспективалы болып көрінеді. Бұл тауда және оның айналасында рудалы емес пайдалы қазбаларды өндіру басталған жерде өсімдіктер мен жануарлардың сирек кездесетін түрлері, соның ішінде салыстырмалы түрде көп кездесетін Каспий жыланы мекендейді.

Кілт сөздер: жыландар, Colubridae, Қазақстан Республикасының Қызыл кітабы, Батыс Қазақстан облысының Бөкей ордасы ауданы, Кіші Богдо, Хаки соры, ерекше қорғалатын табиғи аумақтар, жергілікті маңызы бар «Орда» мемлекеттік табиғи қорығы.

К.М. Ахмеденов, А.Г. Бакиев, А.Е. Кузовенко, А.А. Кленина

Новые данные о распространении каспийского полоза *Dolichophis caspius* (Gmelin, 1789) в Западно-Казахстанской области Республики Казахстан

Обобщена информация о распространении каспийского полоза в пределах Западно-Казахстанской области Республики Казахстан и обсуждены возможные причины его расселения по Бокейординскому району в последние десятилетия. Новые находки вида позволили отодвинуть северо-восточную границу ареала на 20–30 км к северу от ближайших, ранее известных, мест обитания вида. На особо охраняемых природных территориях Казахстана в настоящее время вид достоверно обитает только в государственном природном заказнике местного значения «Орда», где мы встретили его в 2018–2022 гг. Для сохранения вида в Казахстане перспективным представляется обоснование и создание особо охраняемой природной территории — памятника природы областного значения «Гора Малое Богдо». На этой горе и в ее окрестностях, где начата добыча нерудных полезных ископаемых, обитают редкие виды растений и животных, в том числе каспийский полоз с относительно высоким обилием.

Ключевые слова: змеи, Colubridae, Красная книга Республики Казахстан, Бокейординский район Западно-Казахстанской области, Малое Богдо, сор Хаки, особо охраняемые природные территории, государственный природный заказник местного значения «Орда».

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The results of the introduction into cultivation of a rare relict species *Allium hymenorhizum* Ledeb. in the Altai Botanical Garden

The article presents the results of an introductory study of three *Allium hymenorhizum* Ledeb. accessions from different ecological and geographical growth conditions in the Kazakhstan Altai of the East Kazakhstan region. Their phenology, biometric parameters, seed productivity, laboratory seed germination, and propagation methods were studied. According to seasonal development, *A. hymenorhizum* is a long-vegetating, summer-green species with forced winter dormancy. The duration of the flowering phase of individuals in the studied *A. hymenorhizum* accessions was 18.4–22.4 days with minor deviations from the average long-term indicator. According to flowering periods, the studied accessions belonged to summer-flowering plants. According to biomorphological characteristics, the accessions differed in the height of the generative shoot: the accession from subalpine South Altai was 92.45 ± 5.54 cm, the accession from mountain-forest West Altai was 85.46 ± 4.79 cm, and the accession from mountain-steppe Kalbinsky was 78.24 ± 10.52 cm. Variation in this trait was at a low and medium levels of 8.37 % — 15.69 %, which indicated the stability of the traitin accessions during growing period. Minor differences in the height and diameter of the inflorescence were also revealed; the form diversity of the inflorescence was found from spherical to oval-spherical. Seeds are formed in the accessions annually, ripen from mid-July to mid-August, and are characterized by morphological heterogeneity. Small seeds formed in the South Altai subalpine accession had the length of 3.3 ± 0.12 mm and the width of 1.4 ± 0.09 mm, large ones were found in the Kalbinsky mountain-steppe — 4.03 ± 0.09 mm and 1.84 ± 0.07 mm, respectively. The productivity coefficient of the inflorescence in *A. hymenorhizum* accessions introduced in the Altai Botanical Garden was from 29.56 % to 40.67 %, i.e. the potential for the formation of inflorescence seeds in the observed accessions was not fully realized. The mountain-forest accession from the Western Altai had the largest number of flowers, fruits, and seeds in the inflorescence. Accessions from the Southern and Kalbinsky Altai were similar to each other by these traits. Seeds of good quality were formed and demonstrated laboratory germination rates from 67.82 % to 76.52 % after six months of storage at the room temperature. The studied accessions of *A. hymenorhizum* were successfully reproduced vegetatively under introduction conditions. The species is promising for introduction into cultivation as an ornamental plant.

Keywords: *Allium hymenorhizum*, introduction, morphology, seed productivity.

Introduction

Currently, the preservation of biological diversity is one of the most important problems of the modern plant world. Rare and endangered plant species have less genetic diversity compared to widespread ones, so they are more susceptible to the threat of extinction due to changing environmental conditions and the influence of anthropogenic factors [1].

Mountain ecosystems of the Kazakhstan Altai of the East Kazakhstan region possess large botanical diversity. However, increasing anthropogenic pressure (development of natural areas, exploitation of industrial facilities, deforestation, mining, development of new lands for farms, increasing residential and recreational loads, use of chemicals) negatively affect natural ecosystems and, first of all, the plant component. At the same time, there is a simplification of the structure and composition of phytobiota, a reduction in the ranges of rare and endemic species, and the penetration and a spreading of alien plant species.

An effective way to conserve plant biodiversity is to protect individual species as part of communities. However, the level of anthropogenic destruction of habitats often leaves no opportunity for the *in situ* conservation, therefore, *ex situ* methods come to the fore, as it was mentioned in the “Global Strategy for Plant Conservation” adopted in 2002 at the VI Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) [2].

One of the species in the flora of the East Kazakhstan region that requires conservation by *ex situ* methods is *Allium hymenorhizum* Ledeb. — a Pleistocene relic onion species of Asian origin widespread in Western Siberia (Altai), Kazakhstan, Iran, and Mongolia [3]. In the East Kazakhstan region, Y.A. Kotukhov [4] lists the locations of the species in the floristic regions 22. Altai (Kazakhstan Altai, geographical regions:

Western, Southern, Kalbinsky Altai) and 12. Zaisan (Northern Zaisan region). The author notes that the species is found scattered and very limited in excessively moistened saline meadows of plains, grassy swamps, moist meadows, from the foothills to the middle mountain belt.

This article presents the results of a long-term introduction study in the Altai Botanical Garden (Ridder) of 3 accessions of *A.hymenorhizum*, brought into cultivation from different habitats in the flora of the Kazakhstan Altai of the East Kazakhstan region.

The aim of the study was the study of phenological, morphological, reproductive traits, reproductive biology, stability and prospects for the introduction into cultivation of three accessions of *A.hymenorhizum* from different ecological and geographical localities of the Kazakh Altai.

Experimental

The work was carried out on the collection site of the natural flora of the Altai Botanical Garden. Objects of study: 3 accessions of *A. hymenorhizum*, attracted to the introduction into the cultivation from geographically isolated regions of the Kazakhstan Altai. Planting material for the study was extracted from three geographical points in the form of living plants (Table).

Table

Ecological and geographical characteristics of the habitats of *Allium hymenorhizum* specimens attracted to the introduction from the natural populations of the Kazakh Altai

The place of collection of the accession	Coordinates of the main collection points			Area, ha	Spatial-structure	Accession ecotype, community
	width, N	longitude E	altitude a.s.l.			
Southern Altai, the southern slope of the ridge Kurchumsky, the neighborhood VerkhnyayaYelovka village, the coast of Lake Markakol	48.8164	85.6503	1513.0	85.0	diffuse-group	Subalpine; coasta wetmeadow
Western Altai, north-western slope, Ivanovsky district, Gray Meadow tract	50.3575	83.9047	1208.0	17.0	diffuse-group	Mountain forest; damp meadow
Kalbinsky Altai, Sibinskaya depression, lake Shybyndykol	49.40339	83.05461	823.0	12.0	distracted	Mountain-steppe, moderately moist meadow

The introduction area was the Altai Botanical Garden, located in the mountain-forest zone of the Kazakhstan Altai at 700–900 m above sea level. The distance from the oceans and the mountainous relief determine the continental climate, humidity and temperature conditions. According to the humidity coefficient, the Altai Botanical Garden is located in the region with Hydrothermal humidity coefficient (HHC) 1.2, which indicates moderately humid conditions [5]. According to the Ridder meteorological station, the winter period begins in the third ten days of October and continues until the beginning of April. The average height of snow cover in open spaces reaches 50–60 cm with a soil freezing depth of 40–119 cm. The average winter temperature is -12.6 °C with short-term frosts of -35 – -45 °C. According to the characteristics of the winter period, the length of forced dormancy of plants reaches from 5.9 to 6.4 months per year. Spring is late and long. Summer is short and humid. The air temperature of the warmest month of July is 16.6 °C. The average annual precipitation ranges from 432 to 937 mm with a summer maximum, which ensures good moisture throughout the growing season [6]. The soils where the introduction site is located are mountain black-soils. The humus content ranges from 6 % to 8 % (10 %) with a high percentage of nitrogen and potassium [7]. The experimental site where the test accessions were planted was flat and open; the plants on the plots were grown in monoculture without irrigation. Maintenance work during the growing season included removing weeds and soil loosening.

The limiting factors for the introduction into the Altai Botanical Garden were large amplitudes of daily and annual temperatures, humidity, limited frost-free and vegetation periods. That is why the most important characteristics for the selection of introduced accessions were high winter- and frost-resistance, shortened growth and development rhythm that allows them to pass the main phases of seasonal development [8].

The rhythm of plant development is the main indicator of their adaptability to new growth conditions. An important method of its studying was phenological observation, which was carried out starting from the second year after planting up to five years. During active growth, the frequency of observations was three times per week, during the rest of the period — once a week. Phenological observations were carried out using a methodology developed in the Main Botanical Garden of the Russian Academy of Sciences [9], classification of phenorhythmotype was carried out according to the methods of E.S. Fomin et al. [10]. Seed productivity and sowing qualities of seeds were studied using the method of I.V. Vainagiy [11]. The assessment of the success of the introduction of the species into cultivation and its prospects as a cultural plant was carried out according to a set of biological and economic characteristics [12].

Statistical analysis was performed using the Excel. The average values of the indicators, the coefficient of variation, and the accuracy of the experiment were determined.

Results and Discussion

A. hymenorhizum holds practical value as both a food source and an ornamental plant. The study of the biology, resource qualities, and reproduction of A. hymenorhizum at the South Ural Botanical Garden-Institute led to its recommendation for use as both an ornamental and food plant [13]. Introduction trials at the Kuzbass Botanical Garden demonstrated its potential for landscaping, owing to its adaptability to open-ground conditions, effective seed and vegetative reproduction, and contributions to the conservation of rare and endangered species [14]. Additionally, N.G. Gemedzhieva et al. [15], in a review on the prospects of Kazakhstani *Allium* L. species, highlighted *A. hymenorhizum* as a promising ornamental and honey plant based on cultivation tests.

A. hymenorhizum is a perennial bulbous plant. Bulbs are attached one or more to a short rhizome, forming a dense turf. The bulbs are cylindrical, with leathery brown shells, up to 2 cm thick. The stem is almost half covered with leaf sheaths. The umbel is usually spherical, multi-flowered, the sheath is persistent. The perianth leaflets are pink-purple, 4–6 mm long, the style protrudes from the perianth. The capsule is equal to the perianth [16]. According to its life form, it belongs to the loose-tussock rhizome-bulbous monocentric biomorph, the habitats of which are confined to sparse phytocenoses [17]. Studies of morphological variability and molecular genetic features have established the dependence of *A. hymenorhizum* on its geographical origin [18–22].

When introducing plants, one of the key indicators is their progression through phenological phases and growth dynamics, as these reflect the species' adaptation to local conditions. Long-term phenological observations show that all three A. hymenorhizum accessions consistently emerge after winter without signs of under snow growth, overwinter successfully without losses, and remain unaffected by spring frosts. Regardless of origin, they complete a full development cycle during the growing season, culminating in seed production. Their phenological rhythm is stable, characterized by a long-vegetating, summer-green, summer-flowering phenorhythmotype with enforced winter dormancy. Table 2 summarizes the average annual phenological data for A. hymenorhizum accessions over a 5-year period (2020–2024).

The plants of the subalpine accession, brought from the Southern Altai, were the first to start growing in the first ten days of April. In the mountain-forest and mountain-steppe accessions, vegetation began in mid-April. The budding phase of the generative shoot in the subalpine accession started at the end of the first ten days of June, while in the accessions from the Kalbinsky and Western Altai, it began 6–10 days later, in mid-June. The subalpine meadow accession bloomed en masse at the end of June, while the mountain-forest and subalpine accessions started mass flowering in the first ten days of July. The seed ripening periods were extended, with the subalpine accession beginning seed ripening in the second ten days of July, and the mountain-steppe and mountain-forest accessions starting in the third ten days of July and completing in August.

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T a b l e 2

Average annual phenodates of *Allium hymenorhizum* accessions in the exposition of the Altai Botanical Garden

Name of the phenodate	Statistical indicators	Origin of the accessions		
		Kalbinsky Altai, Sibinskaya depression, swampy meadow, Shybyndykol lake, mountain steppe accession	Western Altai, Ivanovsky district, Gray Meadow tract, damp meadows, mountain and forest accession	Southern Altai, Kurchumsky district, coastal damp meadow, Markakol Lake, subalpine accession
The beginning of spring regrowth	(M±m) C% P%	18.04±7.07 18.22 6.89	18.04±3.03 7.82 2.95	07.04±5.07 16.77 6.34
The beginning of budding	(M±m) C% P%	13.06±2.73 3.28 1.24	12.06±9.84 13.15 4.97	03.06±9.34 11.34 4.29
The beginning of flowering	(M±m) C% P%	30.06±4.80 4.97 1.88	29.06±6.59 7.49 2.83	19.06±6.85 7.57 2.86
Mass flowering	(M±m) C% P%	10.07±2.27 2.17 1.82	10.07±2.27 2.17 1.82	30.06±3.75 3.89 1.47
The end of flowering	(M±m) P%	18.07±4.51 4.07 1.54	19.07±3.80 3.40 1.29	10.07±7.34 6.31 2.38
The beginning of seed maturation	(M±m) C% P%	27.07±1.76 1.49 1.56	23.07±10.69 9.34 3.53	19.07±9.52 7.14 2.70
The end of seed maturation	(M±m) C% P%	13.08 ±1.36 1.03 1.39	08.08±5.69 4.46 1.68	14.08±11.61 8.56 3.23
The end of the growing season	(M±m) C% P%	18.09±4.62 2.93 1.11	09.09±8.86 5.75 2.17	09.09±6.55 4.28 1.62
Note – M is the average value of the indicator; C% is the coefficient of variation; P% is the accuracy of the experiment				

In statistics, when the variation coefficient is less than 12 %, the degree of variability of a trait is considered low; from 13 % to 20 % — average; from 21 % to 40 % — high; more than 40 % — very high [23]. In our studies, the level of variability of the studied indicators of average annual phenodates was established in all three accessions at a low level of variability, and only one at an average level. Such indicators of phenodate variability confirm the good adaptation of the three studied accessions as cultivated plants.

Based on the analysis of the onset of phenodates, the duration of each phase of seasonal development was determined (Table 3). The plant had one generation of leaves, after the seeds ripen, the leaves began to turn yellow and gradually died off. Vegetation ended at the end of August or in the first or second decade of September after the onset of autumn frosts on the soil. Formation of the autumn generation of leaves did not occur.

The duration of the seasonal development phases was experimentally determined for all three accessions. The period from the beginning of vegetation to the end of vegetation for the subalpine and mountain-forest accessions was, with slight deviations from the long-term average, 144.3±6.54 days and 144.9±4.58 days, respectively, for the mountain-steppe accession — 164.4±7.24 days; the duration of flowering for *A. hymenorhizum*accession from Southern Altai was 18.40±2.77 days, for the mountain-forest accession from Western Altai — 20.90±2.63 days, and for the mountain-steppe accession from Kalbinsky Altai — 22.40±2.44 days. The seeds ripened within 14–15 days in the subalpine and mountain-forest accessions with minor deviations from the average long-term indicator; in the mountain-steppe accession this period was 25.83±1.91 days.

Table 3

The duration of the phases of seasonal development of *Allium hymenorhizum* accessions of different ecological and geographical origin in the exposition of the Altai Botanical Garden

a) Name of the seasonal development phase	b) The duration of the seasonal development period, in days		
	c) Southern Altai, subalpine accession	d) Western Altai, mountain-forest accession	e) Kalbinsky Altai, mountain-steppe accession
f) The beginning of the growing season– the end of the growing season	g) 144.3±6.54 h) 7.58 i) 2.39	j) 144.9±4.58 k) 3.33 l) 0.96	m) 164.4±7.24 n) 7.46 o) 2.36
p) The beginning of flowering is the end of flowering	q) 18.40±2.77 r) 10.96 s) 3.47	t) 20.90±2.63 u) 19.07 v) 5.03	w) 22.40±2.44 x) 18.08 y) 4.72
z) The beginning of seed maturation is the end of seed maturation	aa) 14.70±3.50 bb) 13.30 cc) 4.95	dd) 15.92±2.08 ee) 20.13 ff) 3.67	gg) 25.83±1.91 hh) 21.29 ii) 5.14

Note – M is the average value of the indicator; C% is the coefficient of variation; P% is the accuracy of the experiment

The studied *A. hymenorhizum* accessions differed in biomorphological parameters. In terms of generative shoot height, the subalpine accession from the Southern Altai stood out at 92.45 ± 5.54 cm, with a variation coefficient of 8.37 %. The generative shoot height of the mountain forest accession was 85.46 ± 4.79 cm, with a variation coefficient of 15.69 %, and for the mountain steppe accession, it was 78.24 ± 10.52 cm, with a coefficient of 11.27 %. The low to medium variation in plant height indicated the stability of this trait in cultivation over a prolonged period of introduction.

The inflorescence of *A. hymenorhizum*, like other species in the genus *Allium*, was a spherical, multi-flowered, dense umbel [24], though other sources describe it as oval-spherical [25]. Measurements of the experimental accessions grown at the Altai Botanical Garden revealed the following inflorescence parameters: subalpine accession — height 1.7 ± 0.4 cm, diameter 2.1 ± 0.4 cm, and index (height-to-diameter ratio) 0.81; mountain forest accession — 2.2 ± 0.4 cm, 2.0 ± 0.09 cm, and 0.11, respectively; mountain steppe accession — 1.8 ± 0.2 cm, 2.3 ± 0.04 cm, and 0.78, respectively. Thus, based on the inflorescence index, the accessions exhibited both spherical and oval-spherical inflorescences (Fig. 1).

ii) kk) 11)

Figure 1. The form diversity of *Allium hymenorhizum* inflorescences in introduction

When studying the morphological parameters of freshly collected seeds in the observed accessions, differences in size were found depending on the ecological and geographical origin of the accession. According to measurements, the smallest seeds were produced by the South Altai subalpine accession: length — 3.3 ± 0.12 mm, width — 1.4 ± 0.09 mm; the mountain-forest accession measured 3.79 ± 0.03 mm and 1.68 ± 0.04 mm, respectively; and the mountain-steppe accession measured 4.03 ± 0.09 mm and 1.84 ± 0.07 mm, respectively. The morphological heterogeneity of seeds, preserved during introduction, was undoubtedly associated with adaptations to different environmental conditions. Meanwhile, the morphological characteristics of the seeds from the studied *A. hymenorhizum* accessions aligned with previously reported data obtained during introduction [13; 25-26].

The seeds fell from the capsules as they ripened, and self-seeding was observed in all three accessions. The first individual shoots of self-seeding appeared after seed dispersal in late August to early September.

However, the autumn self-seeding did not survive the winter, with 100 % mortality during the overwintering period. In the spring, self-seeding produced uniform shoots in late May to early June. Counts showed that 50 to 80 seeds germinated near the parent sod on the plot, but without supplemental watering, the shoots dried up at the cotyledon stage by mid-June, preventing natural rejuvenation of the original plantings through self-seeding.

To predict the success of introduction, the reproductive indicators were analyzed in the experimental accessions of *A. hymenorhizum* (Table 4). As noted by O.A. Elizarieva et al. [27], seed productivity (SP) was challenging to predict and could only be determined empirically.

Table 4

Reproductive indicators of *Allium hymenorhizum* of different ecological and geographical origin in the exposition of the Altai Botanical Garden

jj) Indicators	kk) Origin of the accession		
	ll) Southern Altai, subalpine accession	mm) Western Altai, mountain-forest accession	nn) Kalbinsky Altai, mountain-steppe accession
oo) The number of flowers in the inflorescence, count.	pp) 74.31±1.69	qq) 87.47±6.15	rr) 75.2±3.82
ss) The number of fruits with seeds in the inflorescence, count.	tt) 41.2±1.36	uu) 59.29±6.15	vv) 48.05±6.26
ww) Fruit formation of the inflorescence, %	xx) 55.4	yy) 67.7	zz) 63.8
aaa) The number of seeds in the fruit, count.	bbb) 3.2±0.40	ccc) 3.6±0.22	ddd) 3.5±0.63
eee) Potential seed productivity of the inflorescence, count.	fff) 445.86±22.64	ggg) 524.82±26.22	hhh) 451.2±31.33
iii) The actual seed productivity of the inflorescence, count.	jjj) 131.84±8.58	kkk) 213.44±21.24	lll) 168.17±16.32
mmm) Seed productivity coefficient, %	nnn) 29.56	ooo) 40.67	ppp) 37.27
qqq) Weight of 1000 seeds, g	rrr) 1.40±0.08	sss) 1.59±0.04	ttt) 1.71±0.06

Table 4 showed that the potential for seed formation in the observed accessions was not fully realized under cultivation. The potential seed productivity of the inflorescence ranged from 445.86 ± 22.64 to 524.82 ± 26.22 ovules, while the actual seed productivity varied from 131.84 ± 8.58 to 213.44 ± 21.24 seeds, resulting in a seed productivity coefficient of 29.56 % — 40.67 %. Seeds were produced annually, but during dry and hot summers (2021–2022), the inflorescences achieved only 5.6–8.7 % of their potential.

The mountain-forest accession from the Western Altai had the highest number of flowers, fruits, and seeds per inflorescence. The accessions from the Southern and Kalbinsky Altai did not differ significantly in these indicators. Seed setting per fruit was average across all accessions, ranging from 3.2 ± 0.40 to 3.6 ± 0.22 pcs. The reduction of ovules at the fruit level was 53.3 % for the subalpine accession from the Southern Altai, 60.0 % for the mountain-forest accession from the Western Altai, and 58.3 % for the mountain-steppe accession from the Kalbinsky Altai.

The experimental introduction demonstrated that high-quality seeds were formed in all test accessions. Laboratory seed germination after six months of storage at room temperature (18–24 °C) was above average for all three accessions: 68.53 % for the subalpine accession from the Southern Altai, 76.52 % for the mountain-forest accession from the Western Altai, and 67.82 % for the mountain-steppe accession from the Kalbinsky Altai. However, soil germination was consistently lower across all accessions, with values reduced by more than 2.0–2.8 times compared to laboratory germination. After six months of storage, the soil germination rate was 39.62 % for the subalpine accession, 28.52 % for the mountain-forest accession, and 23.64 % for the mountain-steppe accession (Fig. 2). The observed seed productivity indicators of the studied species aligned with the findings of O.A. Elizareva [28].

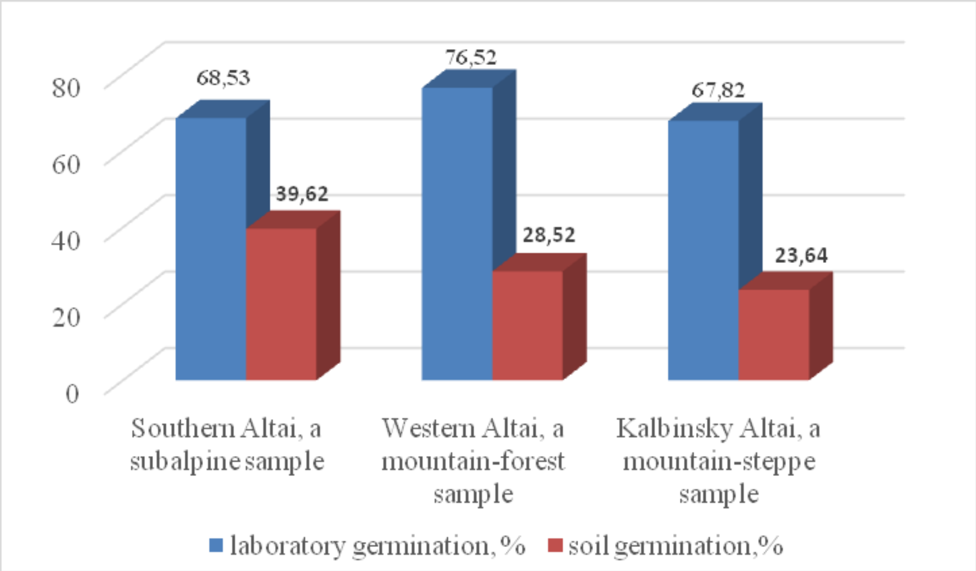

Figure 2. Laboratory and soil germination of seeds in the introduction of 3 accessions of *Allium hymenorhizum* of different ecological and geographical origin

The studied accessions of *A. hymenorhizum* were well propagated vegetatively by dividing the bush into turfs, each containing 3–5 bulbs. When planted in spring during the second ten days of May and watered daily in the morning at a rate of 10 L/m^2, the survival rate of the seedlings was 100 %

Conclusion

The *Allium hymenorhizum* accessions tested in the introduction into the cultivation, sourced from subalpine, mountain-forest, and mountain-steppe meadows with varying moisture levels, successfully adapted to the new growing conditions at the Altai Botanical Garden. These accessions demonstrated winter hardiness and a consistent seasonal development rhythm, aligning with the phenorhythmotype of long-vegetating, summer-green, summer-flowering plants with enforced winter dormancy. Having completed a full development cycle over an extended introduction period while maintaining morphometric parameters and exhibiting good reproductive indicators, these accessions showed promise for inclusion in landscaping assortments. The introduction study of *A. hymenorhizum* accessions from diverse ecological and geographical origins facilitated a more comprehensive and rational approach to utilizing the species' resource potential. This approach aimed to enrich the cultural flora of the East Kazakhstan region and safeguard the rare species. Cultivating intraspecific taxa of *A. hymenorhizum* under introduction conditions served as an additional conservation measure. It also established a reserve fund for conducting breeding work on this species as an ornamental plant.

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Алтай ботаникалық бағында *Allium hymenorhizum* Ledeb. сирек реликті түрін жерсіндірудің нәтижелері

Мақалада Шығыс Қазақстан облысындағы қазақстандық Алтайдың экологиялық-географиялық әртүрлі жағдайлардан алынған *Allium hymenorhizum* Ledeb. 3 үлгісін жерсіндіру нәтижелері ұсынылған. Олардың фенологиясы, биометриялық параметрлері, тұқымдық өнімділігі, зертханалық өну қабілеті, көбею тәсілдері зерттелді. Маусымдық даму бойынша A. *hymenorhizum* — ұзақ вегетацияланатын, жазда жасыл болып тұратын, мәжбүрлі қысқы тыныштық кезеңі бар түр. Зерттелген *A.hymenorhizum* үлгілерінің гүлдеу фазасының ұзақтығы — 18,4–22,4 күн аралығында, орташа көпжылдық көрсеткіштен шамалы ауытқулары бар. Гүлдеу мерзіміне байланысты зерттелген үлгілер жазда гүлдейтін өсімдіктерге жатады. Биоморфологиялық сипаттамалары бойынша үлгілер генеративті өскіннің биіктігі бойынша ерекшеленеді: Оңтүстік Алтайдың субальпілік үлгісі — 92,45±5,54 см, Батыс Алтайдың таулы-орманды үлгісі — 85,46±4,79 см, Қалба таулы-далалы үлгісі — 78,24±10,52 см. Бұл белгінің өзгергіштігі төмен және орта деңгейде 8,37 %-15,69 % аралығында, бұл жасанды өсіру жағдайларында осы көрсеткіштің тұрақтылығын көрсетеді. Сонымен қатар, гүлшоғырдың биіктігі мен диаметрінде де кішігірім айырмашылықтар байқалды; гүлшоғырлар формасының әртүрлілігі анықталды, яғни шар тәрізділен доғал-шар тәрізділге дейін. Үлгілерде тұқымдар жыл сайын қалыптасып, шілде айының ортасынан тамыз айының ортасына дейін піседі және морфологиялық әртүрлілікпен ерекшеленеді. Оңтүстік Алтайдың субальпілік үлгісінде кішкентай тұқымдар қалыптасады (мм): ұзындығы — 3,3±0,12, ені — 1,4±0,09, ал Қалба таулы-далалы үлгісінде тұқымдар ірі — сәйкесінше 4,03±0,09 және 1,84±0,07. A. *hymenorhizum* үлгілерінде зонт өнімділігі коэффициенті 29,56 %-40,67 % аралығында болды, яғни бақылаудағы үлгілерде тұқымдар мен гүлдер қалыптасу мүмкіндігі толық жүзеге аспайды. Ең көп гүл, жеміс және тұқым саны Батыс Алтайдан алынған таулы-орманды үлгіде байқалды. Оңтүстік және Қалба Алтайынан алынған үлгілердің бұл көрсеткіштері арасында айтарлықтай айырмашылық жоқ. Тұқымдар жақсы сапалы болып қалыптасады, зертханалық өну қабілеті — алты ай бойы бөлме температурасында сақталғаннан кейін 67,82 %-76,52 % аралығында. Зерттелген A. *hymenorhizum* үлгілері жерсіндіру жағдайында вегетативті түрде сәтті көбейтіледі. Түрді әсемдік өсімдік ретінде қолдан өсірудің болашағы бар.

Кілт сөздер: *Allium hymenorhizum,* жерсіндіру, морфология, тұқымдық өнімділік.

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Результаты интродукции редкого реликтового вида *Alliumhymenorhizum* Ledeb. — в Алтайском ботаническом саду

Представлены результаты интродукционного изучения 3-х образцов *Allium hymenorhizum* Ledeb. из разных эколого-географических условий произрастания в Казахстанском Алтае Восточно-Казахстанской области. Изучены их фенология, биометрические параметры, семенная продуктивность, лабораторная всхожесть семян, способы размножения. По сезонному развитию A. *hymenorhizum* — длительновегетирующий, летнезеленый вид с вынужденным зимним покоем. Длительность фазы цветения особей у исследованных образцов *A.hymenorhizum* составляет 18,4– 22,4 дня с незначительными отклонениями от среднего многолетнего показателя. По срокам цветения изученные образцы относятся к летнецветущим растениям. По биоморфологическим характеристикам образцы различаются по высоте генеративного побега: субальпийский южноалтайский образец — 92,45±5,54 см, горно-лесной западноалтайский — 85,46±4,79 см, горно-степной калбинский — 78,24±10,52 см. Установлено варьирование этого признака на низком и среднем уровне 8,37 % – 15,69 %, что указывает на стабильность показателя при культивировании образцов. Также выявлены незначительные различия по высоте и диаметру соцветия; установлено формовое разнообразие соцветия от шаровидной до овально-шаровидной. Семена у образцов завязываются ежегодно, созревают с середины июля до середины августа, характеризуются морфологической разнородностью. Мелкие семена формируются у южноалтайского субальпийского образца(мм): длина–3,3±0,12, ширина 1,4±0,09, крупные у калбинскогогорно-степного –4,03±0,09 и 1,84±0,07 соответственно. Коэффициент продуктивности зонта у образцов A. *hymenorhizum* в интродукции составил 29,56 %–40,67 %, т.е. потенциальные возможности образования семян соцветий у наблюдаемых образцов реализуются не полностью. Наибольшим количеством цветков, плодов, семян в соцветии выделяется горно-лесной образец с Западного Алтая. Образцы с Южного и Калбинского Алтая по этим показателям между собой практически не отличаются. Семена формируются хорошего качества с показателями лабораторной всхожести на уровне 67,82 % –76,52 % после шести месяцев хранения при комнатной температуре. Изученные образцы A. *hymenorhizum* в условиях интродукции успешно размножаются вегетативно. Вид перспективен для введения в культуру в качестве декоративного растения.

Ключевые слова: *Allium hymenorhizum*, интродукция, морфология, семенная продуктивность.

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New species for the lichen biota of Kazakhstan from the western part of the Chulak ridge

This article presents information on two newly identified lichen species in Kazakhstan: *Scytinium palmatum* (Huds.) Gray and *Anaptychia roemeri* Poelt. Both species were located on the Chulak (Sholak) ridge, the southern extension of the Dzhungar Alatau. Both species are accompanied by synonyms, nomenclatural citations of primary sources, original anatomical and morphological descriptions, specific location points (including coordinates, collection date, and collector's name), environmental characteristics, and general distribution (including adjacent territories). The original descriptions document noted the life form, coloration, and characteristics of the upper and lower surfaces of the thallus; the presence, nature, and positioning of attachment organs; and the type, dimensions, and location of soredia, isidia, and pycnidia on the thallus. Additionally, they specify the type of thallus, the shape and size of asci, the presence and structure of paraphyses, and the type, color, size, and quantity of ascospores within each ascus. The outcomes of chemical staining are also shown. *Scytinium palmatum* is observed to be sterile throughout Kazakhstan and the majority of Europe. The species is uncommon in southeastern Kazakhstan and is included in the Catalog of rare and endangered flora of the Almaty area. No apothecia were seen in the thalli of *Anaptychiaroemeri*. The origin of the *Protoanaptychia* section, to which this species belongs, is presumed to be linked to the hilly areas of Central Asia. Moreover, there exist strong correlations between the lichen floras of the Caucasus and Central Asia, since all four kinds of the section are documented in these areas.

Keywords: apothecium, ascospore, ascus, epithecium, hymenial layer, hypothecium, paraphysis, thallus.

Introduction

In 1821, the lichen genus *Scytinium* (Ach.) Gray (Collemataceae Zenker, Peltigerales Walt. Watson, Lecanoromycetes O.E. Erikss. & Winka, Ascomycota Caval. -Sm.) was introduced under the name "Scytenium". Subsequently, the species of this genus were reclassified as *Leptogium* (Ach.) Gray. The taxonomic status of these exceedingly heterogeneous genera can now be accurately determined through the application of contemporary molecular genetics research methodology [1, 2]. The genus *Scytinium*, which presently comprises 51 species (as per the Mycobank database [3], has been confirmed by M.A. Otálora and coworkers [2]. It is the third most diverse genus in the Collemataceae family, following the genera *Leptogium* and *Collema* Weber ex F.H. Wigg.

In 1848, the genus *Anaptychia* Körb. (Physciaceae Körb., Caliciales Nannf., Lecanoromycetes, Ascomycota) was first described. The genus *Anaptychia* was comprised of over 450 taxa, as indicated by the Mycobank database [3]. However, a significant number of these taxa were subsequently transferred to the genera *Leucodermia* Kalb, *Heterodermia* Trevis., *Seirophora* Poelt, *Poeltonia* S.Y. Kondr., Lőkös & Hur, *Physciella* Essl., *Phaeophyscia* Moberg, *Physconia* Poelt, *Xanthoparmelia* (Vain.) Hale, *Tornabea* Østh., *Teloschistes* Norman, *Klauskalbia* S.Y. Kondr., Lőkös, E. Farkas & Hur, *Physcia* (Schreb.) Michx., *Kurokawia* S.Y. Kondr., Lőkös & Hur, *Dirinaria* (Tuck.) Clem., and *Polyblastidium* Kalb.

At present, Russia is across to eight species of the *Anaptychia s. s.* genus [4–6].

Our objective was to provide morphological descriptions, ecological and geographical data, and illustrations of lichen species that are novel to Kazakhstan and originating from the western region of the Chulak ridge.

Experimental

The samples were collected in the central and western regions of the Chulak ridge from 2022 to 2023. The GPS (Germin) was employed to register the geographical coordinates of the sample collection sites. The majority of the samples were obtained from boulders and mountain outcrops, while a significantly smaller number were collected from branches of shrubs and semi-shrubs.

The morphological and anatomical characteristics, as well as the chemical reactions that are characteristic of lichens, were used to identify the species. The subsequent morphological characteristics were assessed: life form; color and character of the upper and lower surfaces of the stratum; presence, nature, and location of attachment structures; type, size, and location of fruit bodies on the stratum, or soredia, isidium, pycnidium, etc. [7]. The microscopic examination of narrow sections of thallus and fruiting bodies was employed to identify anatomical features. The following characteristics were assessed in these sections: the thallus type, the structure and systematic position of the photobiont, the type and features of the internal structure of the fruiting bodies, the shape and size of the asci, the presence of paraphyses and their structure, the type, color, and size of the spores, as well as their quantity within the asci. Utilizing a Levenhuk MED D45T LSD light microscope, the anatomical and morphological characteristics of lichens were investigated.

Biochemical characteristics have been identified, which are essential diagnostic indicators. A saturated aqueous solution of calcium hypochlorite, an alcoholic solution of iodine, and a 10 % aqueous solution of potassium hydroxide were employed to conduct the staining. The species was identified by employing specific criteria [4, 8]. The species inventory has been verified and is organized in accordance with the Mycobank Database's system [3]. The following are provided for both species: anatomical-morphological original descriptions, synonyms, nomenclatural citations from primary sources, specific locality data (including coordinates, collection dates, and collector's surname), ecological characteristics, and general distribution (including neighboring territories). Literary sources are employed to extract data regarding the species' ecology and distribution.

Results and Discussion

Scytinium palmatum(Huds.) Gray [as "Scytenium"], in Natural Arrangement of British Plants, 1821, (London) 1: 398.

*Examined Specimens. "*Kazakhstan, Almaty Region, Kerbulak District, Chulak Ridge, expansive gorge leading to the plateau, on soil and rocks, p. 466, 778 m a.s.l., N43°55′22.9″, EO77°48′35.4″, 27.05.2022. Collected and identified by Y.V. Rakhimova".

Description. The thallus of *Scytinium palmatum* is medium-sized, lobed, and forms thick turf (Fig. 1–3), reaching heights of 1-1.5 cm, with a somewhat glossy, chestnut-brown appearance, paler on the underside. The blades are broad, deeply notched, with edges curved downward, and horn-shaped tips at the ends (Fig. 1–3).

Apothecia are absent in our samples; literature indicates [9] they can reach up to 0.5 mm in diameter and are either sessile or adnate to the bottom surface. The disk is often concave, sometimes flat, reddish-brown, with a smooth edge. The excipule is paraplectenchymatous, transparent, and is 12–65 μm in thickness. The hypothecium is whitish and measures 25–50 μm in thickness. The hymenial layer is transparent and is 125–300 μm in thickness. The epithecium has a brownish hue. Paraphyses are uncomplicated and measure 1 μm in diameter. Asci are club-shaped, measuring 130–185 x 16–25 μm, containing 8 spores. Ascospores are ellipsoidal, smooth, featuring 5–9 transverse and 1–2 longitudinal septa, with dimensions of 27–56 × 10–20 μm. The hymenial layer exhibits a blue coloration with the application of an alcoholic iodine solution.

Ecological characteristics and distribution. On soil and moss-covered rocks, infrequently on tree bark. In the plains and mountains of Ukraine, Western Siberia, Europe, Asia, North Africa, the Canary Islands, North America, South America, and Australia. *Scytinium palmatum* is exclusively documented along the Black Sea coast of the Krasnodar territory in the Caucasus and has not been identified in other areas [10]. Formerly recognized in Russia from the Kaliningrad oblast [11], it has been documented in the Krasnoyarsk krai, as well as the Altai, Tuva, and Khakassia Republics [12]. In the Crimean Reserve, only four specimens of the closely related genus *Leptogium* have been documented: *L. gelatinosum* (With.) J.R. Laundon, *L. lichenoides* (L.) Zahlbr., *L. schraderi* (Ach.) Nyl. And *L. tenuissimum* (Dicks.) Körber [13]. Five species of the genus *Leptogium* are emblematic of the Altai Krai [14, 15]. Five species of the genus *Scytinium* have been identified in Belarus; however, *S. palmatum* has not been recorded [16].

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Figure 1. The thallus of *Scytinium palmatum* on rocks

Figure 2. Fragment of the thallus *Scytinium palmatum*

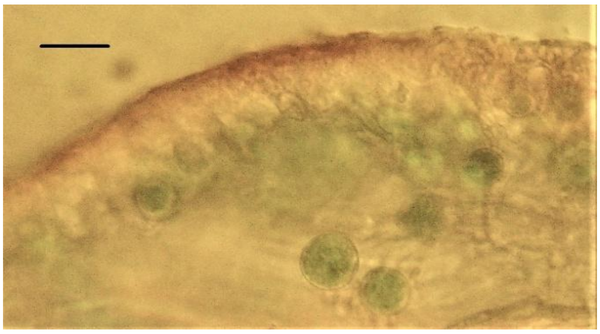

Figure 3. Upon sectioning the thallus of *S. palmatum*, algal cells become discernible. The measurement is 10 microns

Seven species of the genus Scytinium are present in Albania: *Scytinium imbricatum* (P.M. Jørg.) Otálora, P.M. Jørg. & Wedin (*Leptogium imbricatum* P.M. Jørg.), *S. gelatinosum* (With.) Otálora, P.M. Jørg. & Wedin (*L. gelatinosum* (With.) J.R. Laundon), *S. lichenoides* (L.) Otálora, P.M. Jørg. & Wedin (*L. lichenoides* (L.) Zahlbr.), *S. palmatum* (Huds.) Gray (*L. palmatum* (Huds.) Mont.), *S. pulvinatum* (Hoffm.) Otálora, P.M. Jørg. & Wedin (*L. pulvinatum* (Hoffm.) Otálora), *S. schraderi* (Ach.) Otálora, P.M. Jørg. & Wedin (*L. schraderi* (Bernh.) Nyl.) and *S. tenuissimum* (Dicks.) Otálora, P.M. Jørg. & Wedin (*L. tenuissimum* (Dicks.) Körb.) [17]. *Scytinium palmatum* has been identified in Southern Albania National Park, among a mixed forest of spruce, fir, and oak, on soil atop limestone formations, at an elevation of 1200 meters above sea level [17]. Seven species of the genus *Scytinium* have been documented in Montenegro: *S. gelatinosum, S. lichenoides*, *S. magnussonii* (Degel. & P.M. Jørg.) Otálora, P.M. Jørg. & Wedin, *S. massiliense* (Nyl.) Otálora, P.M. Jørg. & Wedin, *S. plicatile* (Ach.) Otálora, P.M. Jørg. & Wedin (*L. plicatile* (Ach.) Leight.), *S. schraderi, S. tenuissimum* [18]. Only four species are prevalent in Albania. In Sweden, five species have been recorded: *S. gelatinosum*, *S. lichenoides, S. magnussonii, S. palmatum, S. teretiusculum* (Wallr.) Otálora, P.M. Jørg. & Wedin [19]. In Fennoscandia, there are 19 species of the genus *Scytinium*, with *S. palmatum* being found in Sweden and Norway [20]. The lichen biota of Portugal includes a significant representation of the genera *Scytinium* and *Leptogium*, comprising 13 species of *Scytinium* (*S. aragonii* (Otálora) Otálora, P.M. Jørg. & Wedin (*L. aragonii* Otálora), *S. biatorinum* (Nyl.) Otálora, P.M. Jørg. & Wedin (*L. biatorinum* (Nyl.) Leight.), *S. ferax* (Durieu & Mont.) Otálora, P.M. Jørg. & Wedin (*L. ferax* (Durieu & Mont.) Rabenh.), *S. gelatinosum*, *S. lichenoides*, *S. magnussonii*, *S. palmatum*, *S. plicatile*, *S. pulvinatum, S. rivale* (Tuck.) Otálora, P.M. Jørg. & Wedin (*L. rivale* Tuck.), *S. schraderi, S. subtile* (Schrad.) Otálora, P.M. Jørg. & Wedin (*L. subtile* (Schrad.) Torss.), *S. tenuissimum*) and 12 species of *Leptogium* [21]. Twenty species of the genus *Scytinium* have been documented in Britain and Ireland: *S. biatorinum*, *S. callopismum* (A. Massal.) Otálora, P.M. Jørg. & Wedin, *S. fragile* (Taylor) Otálora, P.M. Jørg. & Wedin, *S. fragrans* (Sm.) Otálora, P.M. Jørg. & Wedin, *S. gelatinosum*, *S.imbricatum* (P.M. Jørg.) Otálora, P.M. Jørg. & Wedin, *S. intermedium* (Arnold) Otálora, P.M. Jørg. & Wedin, *S. lichenoides*, *S. magnussonii*, *S. massiliense* (Nyl.) Otálora, P.M. Jørg. & Wedin, *S. palmatum*, *S. parvum* (Degel.) Otálora, P.M. Jørg. & Wedin, *S. plicatile, S. pulvinatum, S. schraderi, S. subtile, S. subtorulosum* (Nyl. ex Stizenb.) Otálora, P.M. Jørg. & Wedin, *S. tenuissimum*, *S. teretiusculum*, *S. turgidum*; along with 10 species of the genus *Leptogium*. The species *S. Palmatum* predominantly inhabits Western and Northern Britain, typically located on moss amid stones, on the ground in ancient dunes, along pathways in wastelands, on derelict airfields, and post-industrial areas, and infrequently on tree trunks. The species is dispersed and deemed uncommon [22]. Bulgaria hosts 12 species of the genus *Scytinium*, including *S. palmatum*linked to hilly areas such as the Balkan Mountains, the Rhodope Mountains, and Strandzha Mountain [23]. This species is found in soil, rocks, and moss throughout much of France, including Corsica [24]. The northern distribution boundary of the species *Scytinium fragile* extends across Estonia [25]. One species of the genus *Leptogium* has been identified in Gauja National Park, Latvia [26]. In Majella National Park (Central Italy), two species of the genus *Leptogium* (*L. hildenbrandii* (Garov.) Nyl. and *L. saturninum* (Dicks.) Nyl.) and four species of the genus *Scytinium* (*S. gelatinosum* (With.) Otálora, P.M. Jørg. & Wedin, *S. imbricatum* (P.M. Jørg.) Otálora, P.M. Jørg. & Wedin, *S. lichenoides* and *S. schraderi* (Ach.) Otálora, P.M. Jørg. & Wedin) have been documented [27].

Scytinium lichenoides, S. pulvinatum, S. turgidum (Ach.) Otálora, P.M. Jørg. & Wedin (*L. turgidum* (Ach.) Cromb.), together with five species of the genus *Leptogium*, have been identified in Iran [28]. *S. lichenoides* and *S. plicatile* have been observed in China [29]. Seven species of the genus *Scytinium* have been identified in Turkey, including *Scytinium palmatum* documented in the province of Bitlis [30].

The lichen biota of the United States and Canada includes 39 species of the genus *Leptogium* and 33 species of the genus *Scytinium*, with *S. palmatum* being documented [31].

Scytinium lichenoides and kindred species *Leptogium cyanescens* (Ach.) Körb. and *Leptogium saturninum* (Dicks.) Nyl. have been seen in the southeastern mountainous regions of Kazakhstan, namely in the Ile Alatau and Kungey Alatau [7]. In eastern Kazakhstan, namely in the Altai area, four species of the genus *Scytinium* have been identified: *S. lichenoides, S. plicatile, S. subtile* (Schrad.) Otálora, P.M. Jørg. & Wedin (*L. subtile* (Schrad.) Torss.) and *S. tenuissimum* [12]. Species prevalent in Kazakhstan and Kyrgyzstan encompass *Scytinium lichenoides*, *Leptogium saturninum* and *S. tenuissimum* [32].

*Endnotes***.** The species has resemblance to *S. gelatinosum*, however, the lobes are bigger, and their margins distinctly curve inward, becoming tubular, particularly at the tips [22].

Scytinium palmatum is sterile not just in Kazakhstan but also over a broader region of Europe [33], nevertheless, Portugal is an exception, where some specimens produce a considerable quantity of apothecia [21]. Apothecia are nonexistent in Great Britain and Ireland; their presence is recorded just in Morea [22].

Scytinium palmatum is an uncommon species found in southeastern Kazakhstan and is documented in the Catalog of rare and endangered flora of the Almaty area [34].

Anaptychia roemeri Poelt., Mitteilungen aus der Botanischen Staatssammlung München 7: 228 (1968)

Examined Specimens. "Kazakhstan, Almaty Region, within the jurisdiction of the akimat of Konaev city, northeast of Chingeldy village, Chulak Ridge, near the pond, riverside, p. 29, 961 m a.s.l., N44°04'56.7″, EO77°52'22.0″, 23.05.2023. Collected by Y.V. Rakhimova and identified by I.V. Evdokimov".

Description. The thallus is foliose, rosette-shaped, and sometimes uneven in our specimens (Fig. 4), measuring 2×4 mm, generally loosely attached to the substrate; devoid of soredia and isidia. Lobes are profoundly incised and thin, measuring up to 0.6 mm in width (Fig. 4). Frequently marginally enlarged and segmented into diminutive sections (lobules) near the extremities, elevated. Prominent short spines are seen near the apices of the lobules. The thallus's top surface is irregular owing to the fissured epinecral layer, exhibiting dark gray-brown or light brown hues. The medulla is characterized by the presence of calcium oxalate crystals and exhibits a bright appearance. The inferior surface of the thallus is pale, featuring uncomplicated rhizines. Apothecia absent, pycnidia submerged, conidia cylindrical, measuring 5-6 µm in length.

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Figure 4. The thallus of *Anaptychia roemeri* on rocks

Ecological characteristics and distribution. It is located on the surface of boulders in high-altitude arid regions, where it is found on a scant layer of sediment or moss. Considered a cryophyte species. The Vakhan Range, located in northeastern Afghanistan, is described at an elevation of approximately 3200 meters above sea level. It is found in the Caucasus (Georgia, Armenia, North Ossetia, Dagestan) and Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Mongolia, Syria, Iran, Afghanistan) at elevations exceeding 3000 meters above sea level [5, 6, 35–39].

Tree bark, boulders, and soil are the habitats of species of the genus, which are found in all natural zones of the Northern Hemisphere but are uncommon in the Arctic. They are commonly found in association with mosses and lichens. The Crimea Nature Reserve is home to only two members of the *Anaptychia* genus: *A. ciliaris* (L.) Körb. and *A. setifera* (Mereschk.) Räs. [13]. The most extensively distributed species in Belarus is *Anaptychia ciliaris*, while the same two species of the genus *Anaptychia* have been recorded [16, 26]. Two members of the *Anaptychia* genus are distinctive to the Altai region: *Anaptychia bryorum* Poelt and *A. setifera* [14].

Anaptychia ciliaris is the most extensively distributed of the seven species of the genus *Anaptychia* that are encountered in France [24]. This species is also prevalent in Poland [40] and Bulgaria, however, only four species are documented in this location [23]. Two species of the *Anaptychia* genus are present in Sweden, Norway, and Finland within Fennoscandia [20]. *A. ciliaris*is the sole species identified in the Majella National Park (Central Italy) [27]. In Afghanistan, 4 species of the genus *Anaptychia* were found, of which *Anaptychia roemeri* was recorded in only one province Badakshan [39].

The genus *Anaptychia* is represented by five species in the lichen biota of the United States and Canada: *Anaptychia bryorum*, *A. crinalis* (Schlich. ex Schaer.) Vzda ex J. Nawak, *A. elbursiana* (Szatala) Poelt, *A. palmulata* (Michaux) Vain. and *A.ulothricoides* (Vain.) Vain. [31].

A. ulothricoides is also documented in the mid-mountain and high-mountain steppes of Uzbekistan, Tajikistan, and Turkmenistan [32].

Upon examining the distribution of species in the *Protoanaptychia* section of the genus *Anaptychia*, certain authors [5] propose that the group's origin is linked to the mountainous regions of Central Asia (including the territories of Tajikistan and Afghanistan). It is precisely in these regions (as well as the Caucasus) that all four species of the section are observed. This phenomenon, in conjunction with the presence of species such as *Anaptychia elbursiana* and *A. roemeri* in the Caucasus, may suggest a close relationship between the lichen flora of the Caucasus and Central Asia [5].

Endnotes. The foliose thallus of *A. roemeri* is characterized by the uplifted ends of the lobes, which are profoundly divided into terminal lobules. The most closely related species are *A. elbursiana* (Szatala) Poelt, *A. mereschkowskii* (Tomin) Kulakov (which is distinguished by the presence of soredia), and *A. Desertorum* (Rupr.) Poelt (which has lobe tips that are faintly divided into tiny lobules).

In the Red Book of the Republic of Dagestan [41], *A. roemeri* is classified as a 3 (VU) (vulnerable species) species and is included in the inventory of plant, animal, and parasitic species.

Conclusion

This study focuses on the lichens of the arid lowlands in southeastern Kazakhstan. The article's content was derived from the authors' personal collections; literature data was utilized to compare and evaluate species traits and distribution. Two lichen species, *Scytinium palmatum* (Huds.) Gray and *Anaptychia roemeri* Poelt, were identified on the Chulak Ridge, a southwestern extension of the Dzhungar Alatau, both of which are new to Kazakhstan. Both species are accompanied by synonyms, nomenclatural citations of primary sources, original anatomical-morphological descriptions, specific location points (including coordinates, collection date, and collector's name), ecological characteristics, and general distribution (encompassing adjacent territories). The initial descriptions detail the organism's life form, coloration, and attributes of the thallus's upper and lower surfaces, the existence, nature, and positioning of attachment organs, the classification, dimensions, and configuration of soredia, isidia, and pycnidia on the thallus, thallus type, morphology, and size of the ascus, the presence and structure of paraphyses, as well as the type, coloration, and dimensions of spores, their quantity within the ascus, and the outcomes of chemical staining. The outcomes of chemical staining are also shown. *Scytinium palmatum* and *Anaptychia roemeri* are observed to be infertile in Kazakhstan. *Scytinium palmatum* is an uncommon plant in southeastern Kazakhstan and is included in the Catalog of rare and endangered flora of the Almaty area. The *Protoanaptychia* section, which includes the *Anaptychiaroemeri* species, is linked to the hilly areas of Central Asia, including Tajikistan and Afghanistan. The acquired data are crucial for evaluating biodiversity within Kazakhstan's region.

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Шолақ жотасының батыс бөлігінен Қазақстан лихенобиотасына арналған жаңа түрлер

Мақалада Қазақстан үшін қынаның екі жаңа түрі: *Scytinium palmatum* (Huds.) Gray және *Anaptychia roemeri* Poelt туралы мәліметтер берілген. Түрлердің екеуі де Жоңғар Алатауының оңтүстік-батыс сілемінің Шолақ жотасының аумағынан табылды. Екі түр үшін де синонимдер, бастапқы дереккөздердің номенклатуралық дәйексөздері, анатомиялық және морфологиялық түпнұсқа сипаттамасы, нақты орналасқан жерлердің нүктелері (координаталары, жиналған күні және коллектордың атауы көрсетілген), экологиялық сипаттамалары, жалпы таралуы (соның ішінде іргелес аумақтар бойынша) берілген. Түпнұсқа сипаттамаларда талломның жоғарғы және төменгі беттерінің тіршілік формасы, түсі мен сипаты, бекіну органдарының болуы, сипаты мен орналасуы, талломдағы соредиялардың, изидиялардың, пикнидтердің түрі, мөлшері мен орналасуы, талломның түрі, қалталардың пішіні мен өлшемдері, парафиздер және олардың құрылымы, спoctaлардың түрі, түсі мен мөлшері, олардың қалталарының саны көрсетілген. Сонымен қатар, химиялық бояудың нәтижелері берілген. *Scytinium palmatum* тек Қазақстанда ғана емес, сонымен қатар кейбір үлгілері апотецияның айтарлықтай санын құрайтын Португалияны қоспағанда, Европаның басым бөлігінде стерильді екендігі атап өтілген. Түр Қазақстанның оңтүстік-шығысында сирек кездеседі және Алматы облысының Қызыл кітабына енгізілген. *Anaptychia roemeri*-ге келетін болсақ, оның талломында апотеция табылған жоқ. Бұл түрге жататын *Protoanaptychia* бөлімінің шығу тегі Орталық Азияның таулы аймақтарымен (Тәжікстан мен Ауғанстан аумақтары) байланысты деген болжам бар. Сонымен қатар, Кавказ бен Орталық Азияның лихенофлоралары арасында тығыз байланыс бар, өйткені дәл осы аймақтарда бөлімнің барлық 4 түрі байқалған.

Кілт сөздер: апотеция, аскоспора, гипотеция, парафиздер, балдыр, қалта, таллом, эпитеция.

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Новые виды для лихенобиоты Казахстана из западной части хребта Чулак

В предлагаемой статье приводятся данные о двух новых для Казахстана видах лишайников *Scytinium palmatum* (Huds.) Gray и *Anaptychia roemeri* Poelt. Оба вида обнаружены на территории хр. Чулак (Шолак), являющегося юго-западным отрогом Джунгарского Алатау. Для обоих видов приведены синонимы, номенклатурные цитаты первоисточников, анатомо-морфологическое оригинальное описание, точки конкретных местонахождений (с указанием координат, даты сбора и фамилии коллектора), экологическая характеристика, общее распространение (в том числе на сопредельных территориях). В оргигинальных описаниях отмечены жизненная форма, цвет и характер верхней и нижней поверхности таллома, наличие, характер и расположение органов прикрепления, тип, размер и расположение на талломе соредий, изидий, пикнид, тип таллома, форма и размеры сумок, наличие парафиз и их строение, тип, цвет и размеры спор, их количество в сумках. Кроме того, приведены результаты химического окрашивания. Отмечено, что *Scytinium palmatum* стерилен не только в Казахстане, но и на большей территории Европы, исключение составляет Португалия, где некоторые образцы формируют значительное количество апотециев. Вид является редким на юго-востоке Казахстана и занесен в Красную книгу Алматинской области. Что касается *Anaptychia roemeri,* то апотеции в его талломах не обнаружены. Имеется предположение, что происхождение секции *Protoanaptychia,* куда относится этот вид, связано с горными регионами Центральной Азии (территории Таджикистана и Афганистана). Кроме того, существуют тесные связи лихенофлор Кавказа и Центральной Азии, поскольку именно в этих регионах отмечены все 4 вида секции.

Ключевые слова: апотеций, аскоспора, гипотеций, парафиза, слоевище, сумка, таллом, эпитеций.

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Structural features of the leaf in some cultivated species of the genus Citrus

This article discusses the significance and relevance of studying the vegetative organ of the leaf in addressing various fundamental questions. *Citrus* crops cultivated worldwide are representatives of the genus Citrus L. This genus, along with its wild and semi-wild relatives (*C. trifoliata* L. and *C. ichangensis* Sw.), belongs to the subfamily Aurantioideae Eng. of the family Rutaceae Juss. Almost all are evergreen plants and are considered important fruit crops in tropical and subtropical regions of the world. The classification and systematics of citrus are quite problematic. To this day, there is no universally accepted botanical classification, likely due to the extreme polymorphism of the genus *Citrus*. The three botanical genera of the most economic and practical significance are *Citrus, Fortunella,* and *Poncirus*. The fruits, flowers, and leaves contain a wide range of biologically active substances (organic acids, bioflavonoids, essential oils, and 12 vitamins). Citrus essential oils are widely used to produce natural perfumes and as flavoring ingredients in food, pharmaceutical, and cosmetic products. Leaves from plants such as pomelo, orange variety Uzbekistan, and mandarin variety Medovka were studied. A single leaf type was established — hypostomatic. The mesophyll type of the leaf contains various inclusions, with the presence of water-storing cells and a large number of intercellular spaces. It was found that pomelo has the largest leaf blade height, while mandarin Medovka has the smallest one. The presence of trichomes and glandular hairs was noted in the pomelo representative. The smallest number of stomata was observed in mandarin Medovka, while the largest one was found in orange Uzbekistan.

Keywords: leaf structure, pomelo, orange, mandarin, stomata, epidermis, trichomes, mesophyll.

Introduction

Currently cultivated citrus crops worldwide are representatives of the genus *Citrus* L. This genus, along with its wild and semi-wild relatives (C. trifoliata L. and C. ichangensis Sw.), belongs to the subfamily Aurantioideae Eng. of the family Rutaceae Juss. [1-2]. Citrus species, with the exception of C. trifoliata, are evergreen plants and are considered to be among the most important fruit crops in tropical and subtropical regions of the world [3–5].

The systematics and classification of citrus crops are quite problematic and controversial [6]. There is still no universally accepted botanical classification, which is related to the extraordinary polymorphism of the genus Citrus. According to V.P. Alekseev (1955) [7], the family Rutaceae includes 7 subfamilies, 150 genera, and approximately 1600 species. The three botanical genera of the greatest economic and practical significance are Citrus, Fortunella, and Poncirus. Currently, two main classifications of the subfamily Aurantioideae have been developed, created by W.T. Swingle (1967) [8] and T.A. Tanaka (1966) [9], each of which has its advantages and disadvantages. Among citrus cultivation specialists, the classification by W.T. Swingle has gained the most recognition. It is widely accepted in many countries, especially in England and the USA, and includes two subgenera represented by 16 species of the genus *Citrus*, eight of which produce edible fruits and have commercial importance*: C. reticulata* (mandarins), *C. medica* (citron), *C. sinensis* (L.) Osb. (sweet oranges), *C. paradisi* Macf. (grapefruits), *C. maxima* (pummelo), *C. limon* (L.) Burm. (lemon), *C. aurantifolia* (Christm.) Swing. (lime), and *C. aurantium* L. (bitter orange) [8, 10, 11]. T.A. Tanaka's classification encompasses more than 147 species of the genus *Citrus* [12]. In distinguishing species, he considered the morphological characteristics of the plants, their ecology, and fruit structure. However, some citrus taxonomists disagree with the existence of such a large number of distinct species, as the differences between some are very minor [11]. The systematics of the genus *Citrus* has also been studied by R.W. Hodgson (1961) [13], P.M. Zhukovsky (1971) [14], and others.

The numerous beneficial properties and qualities of citrus fruits that positively impact human health have contributed to their cultivation and spread worldwide. In terms of distribution among fruit crops, they rank third globally, with an annual production exceeding 137 million tons and an area under cultivation of over 14 million hectares. Currently, citrus cultivation is of industrial significance in more than 142 countries.

The highest gross yields are reported from countries such as China (over 39.3 million tons), Brazil (19.7 million tons), India (11.4 million tons), Mexico, the USA, Spain, Turkey, and Egypt (FAO, 2023).

Citrus plants have the ability to purify indoor air from harmful microorganisms through phytoncides [15]. Currently, there is a growing social demand for environmental improvement technologies that promote active longevity, which were first developed in Russia by A.T. Bolotov in the 18th and 19th centuries [16]. Citrus species are particularly popular in ornamental horticulture. They easily adapt to new growing conditions, have decorative foliage, and are visually striking during flowering [17–20]. Citrus crops are characterized by longevity and high yield, which contribute to rapid cost recovery on an industrial scale. Some citrus species are remarkable for their longevity. For instance, in Rome, there is a bitter orange tree in the grounds of a monastery that is approximately 600 years old [21]. However, the most famous and oldest orange tree grows near the Palace of Versailles in the suburbs of Paris, having been planted around 1421. Due to such longevity and favorable soil-climatic conditions, individual trees can yield exceptionally high harvests, often surpassing the yields of other fruit crops by several times. For example, on the island of Malta and in the vicinity of Naples, trees can produce up to 30,000 fruits [22].

The leaves are simple, thick, leathery, and vary in shape from oval to lanceolate, with varying degrees of serration. The upper side is covered with a cuticle, while the abaxial (lower) side has numerous stomata and cavities containing essential oils. The color of the leaves depends on their age: light green in young leaves and dark green in mature ones, with a lifespan of 2-3 years. Young leaves perform the primary functions necessary for sustaining life, while older leaves accumulate nutrients for the formation of new vegetative and generative organs. Depending on the species, the petioles may have various wing-like structures, ranging from weakly winged (in mandarins) to strongly winged (in pummelos and grapefruits). In citrons, these wings are completely absent, while in plants of the subgenus Papeda, they can be comparable in size to the leaf blade. Thorns of various sizes may be present in the leaf axils or on the branches, or they may be completely absent [23, 24].

Uzbekistan, located in Central Asia, boasts a rich agricultural heritage deeply rooted in its warm climate, which fosters the cultivation of a diverse range of species and varieties. This favorable environment allows for the production of numerous fruit crops with exceptional quality and yield. Traditionally, Uzbekistan has relied on conventional methods of cultivation and processing these crops, with a particular focus on local markets. However, against the backdrop of a rapidly changing landscape, the country is poised for significant growth and global recognition, especially in the export of products such as cherries, apricots, and grapes. The shift towards modern farming methods marks a turning point for Uzbekistan’s agricultural sector. This transition not only positions the country as a reliable exporter of fruits but also provides lucrative opportunities for nurserymen, including various varieties and rootstocks, as well as for companies engaged in greenhouse technologies worldwide. Furthermore, in regions where agricultural mechanization is underdeveloped, Uzbekistan has significant potential for the implementation of advanced technologies in both cultivation and post-harvest processes. In this context, various international players, including companies from Turkey, the Netherlands, China, and the USA, have begun to capitalize on Uzbekistan’s growing agricultural landscape. Thus, Uzbekistan is becoming a beacon of opportunities on the global stage, fostering collaboration and innovation in the field of fruit science.

Citrus fruits primarily grow in countries with a subtropical climate. These bright, juicy fruits are valued for their tangy “sourness”, refreshing aroma, and numerous health benefits.

Many citrus fruits positively influence the functioning of the digestive tract. Citrus juice disinfects mucous membranes and gradually forms a reliable defense against infectious diseases of the upper respiratory tract. In light of the above, the trend of growing these plants in greenhouse conditions has increased recently.

Today, fundamental research on citrus fruits is relevant not only in Uzbekistan but also worldwide for addressing phylogenetic issues and systematic problems. Additionally, leaves are the organs most susceptible to various damages, which are exacerbated by the active spread of various insect pests.

Thus, the aim of our research is to conduct a structural study of the vegetative organ, specifically the leaf, in plants such as orange (Uzbekistan variety), mandarin (Medovka variety), and pomelo.

Experimental

Experimental studies were conducted from 2023 to 2024. The leaves of pomelo, orange (Uzbekistan variety), and mandarin (Medovka variety) were collected from 5–8 sympodial branches for the research. For anatomical analysis, the fresh leaves were fixed in 96 % ethanol. Measurements were taken, and preparations of cross-sections and paradermal sections of the fresh leaves were made. For the analysis of the paradermal

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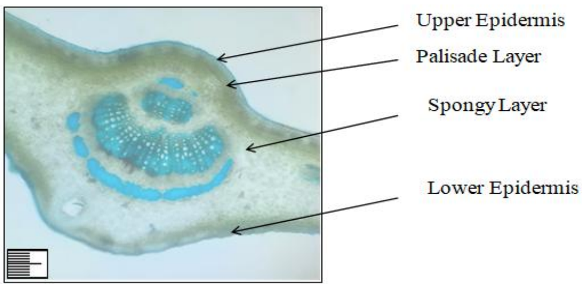
and cross-sections of the leaf, samples with an area of 1 cm² were taken from the central zone (on both sides of the main vein of leaves of medium formation).

Young leaves in the phase of most vigorous growth were fixed. The material was washed and preserved in a 70 % alcohol solution. Leaf cuttings of 1x1 cm were placed in a mixture of 23 cm³ of 96 % alcohol and 2 cm³ of chloroform for 1-2 days. After rinsing in distilled water, they were placed in an 18 % KOH solution for clarification for 4–6 days. They were then rinsed again and placed on a glass slide. Staining of the epidermal cell walls was performed with methylene blue.

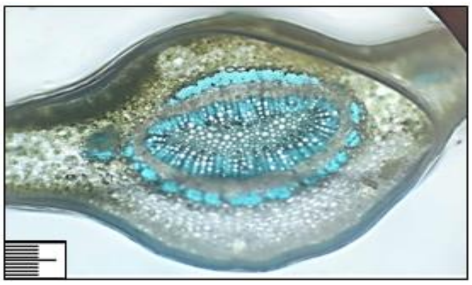
Morphometric processing of the collected material was carried out, photographs were taken, and tables were compiled. A trinocular microscope XSP-500SM (with a 7-inch screen and the ability to connect to a PC) was used for the research. Statistical processing of quantitative data was performed using standard criteria with the help of a personal computer (MS Excel).

Results and Discussion

Analyzing the obtained data, it was found that the mesophyll of the pomelo leaf is dorsiventral, with two layers of palisade parenchyma. The spongy parenchyma contains from 14 to 18 layers of cells, and in the middle of the mesophyll, there is a presence of water-storing parenchyma. The cells of the water-storing tissue are somewhat larger than those of the spongy parenchyma. Additionally, the spongy parenchyma contains a large number of intercellular spaces. The mesophyll is also rich in lysigenous cavities filled with various essential oils (Fig. 1). The adaxial epidermis is covered with a waxy coating, and no trichomes or glandular hairs were observed on the leaf. The height of the pomelo leaf blade differs from those studied, measuring the largest size at 224.4 ± 12.6 μm (Tab. 1, Fig. 2, 3). The cells of the palisade mesophyll are elongated-oval in shape. The palisade coefficient is very low at 21 % (according to the scale of B.R. Vasiliev, 1988) (Fig. 4). The spongy mesophyll consists of round-shaped cells. The vascular bundles are of a concentric nature, surrounded by periodic layers.



Orange Uzbekistan



Mandarin Medovka

Pomelo

Figure 1. Structure of the leaf blade of some representatives of *Citrus*

Table 1

Structural indicators of the cross-section of the leaf of some representatives of *Citrus* (in µm)

Types	Upper Epidermis	Palisade Parenchyma	Spongy Parenchyma	Lower Epidermis	Total Leaf Height
Pomelo	28,4±3,7	47,1±5,1	112,7±12,1	34,3±4,8	222,4±12,2
Mandarin Medovka	11,7±1,7	13,7±2,1	38,2±41	10,8±0,9	74,5±6,1
Orange Uzbekistan	10,7±0,9	20,5±2,2	50,9±4,1	15,7±2,0	98,0±2,7

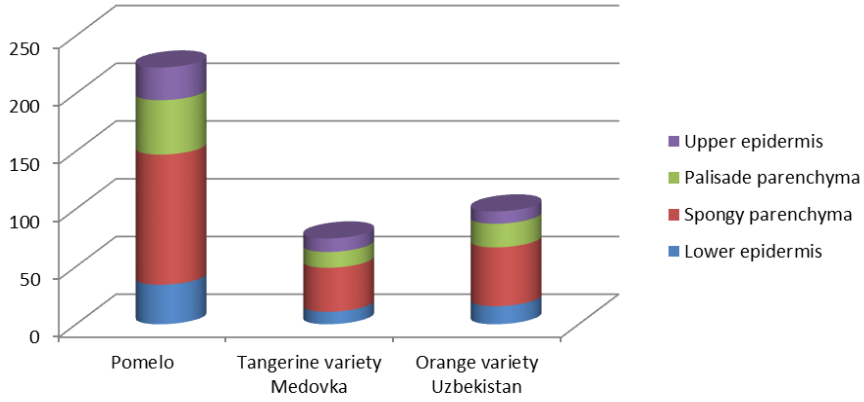


Figure 2. Height of individual layers of the leaves of the studied representatives of the genus *Citrus*

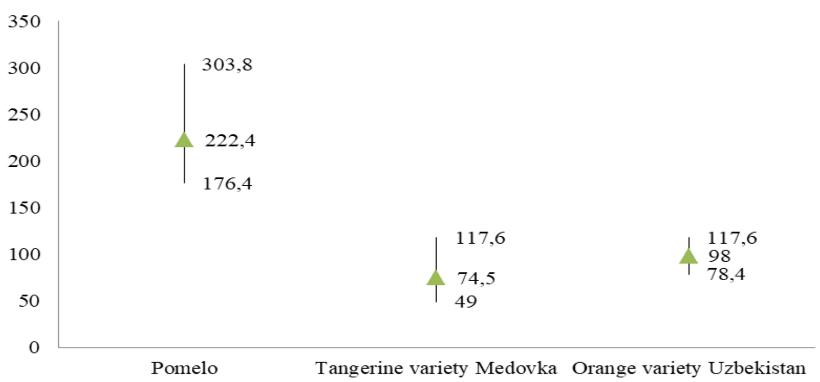


Figure 3. Indicators of total leaf height and its error in the studied representatives of the genus Citrus

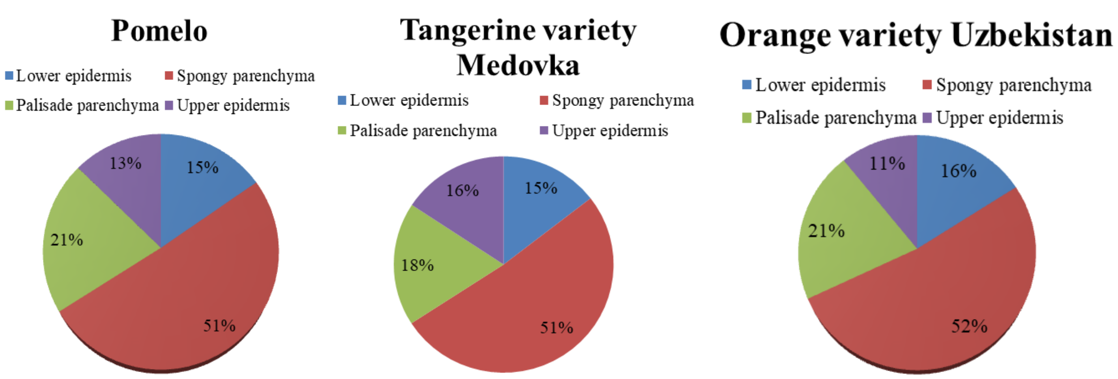


Figure 4. Indicators of the percentage ratio of leaf tissues in the studied representatives of the genus *Citrus*

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When comparing the number of epidermal cells on the adaxial side of the leaf, it was established that the projection of the epidermal cells is flattened, the wall outlines are straight, and the cells are very small, with those on the abaxial epidermis being somewhat larger than those on the adaxial side (Fig. 5, 6). The stomata are slightly sunken, oval in shape, numerous, of the anomocytic type, and randomly oriented. Unicellular trichomes are preferentially located on the leaf veins. In this representative, the adaxial epidermis is the most finely cellular, containing 7551.3±14.9 cells per 1 mm² (Tab. 2). Additionally, the stomatal apparatus is absent on the adaxial side of the leaf. On the abaxial side of the pomelo leaf, the number of epidermal cells is somewhat less compared to the adaxial side, containing 5443.4±63.5 cells per 1 mm², indicating larger cell sizes. This side also has an anomocytic stomatal apparatus, making the leaf hypostomatic. The size of the stomata varies slightly from one another, with a count of 802.5±18.6 stomata per 1 mm². Furthermore, on the abaxial side of the pomelo leaf, there are multicellular trichomes (89.9±9.7 per 1 mm²) and glandular hairs (13.3±4.6 per 1 mm²).

Table 2

Quantitative indicators of paradermal analysis of the leaf in the studied representatives of the genus Citrus, per 1 mm^2

Species	Upper Epidermis			Lower Epidermis			
	Number of Epidermal Cells	Number of Stomata	Number of Trichomes	Number of Epidermal Cells	Number of Stomata	Number of Trichomes	Number of Glandular Hairs
Pomelo	7551,3±14,9	-	-	5443,4±63,5	802,5±18,6	89,9±9,7	13,3±4,6
Mandarin Medovka	3598,6±267,6	-	-	1811,5±87,7	741,5±62,0	-	-
Orange Uzbekistan	2011,3±63,9	-	-	1741,6±52,8	1111,1±64,4	-	-

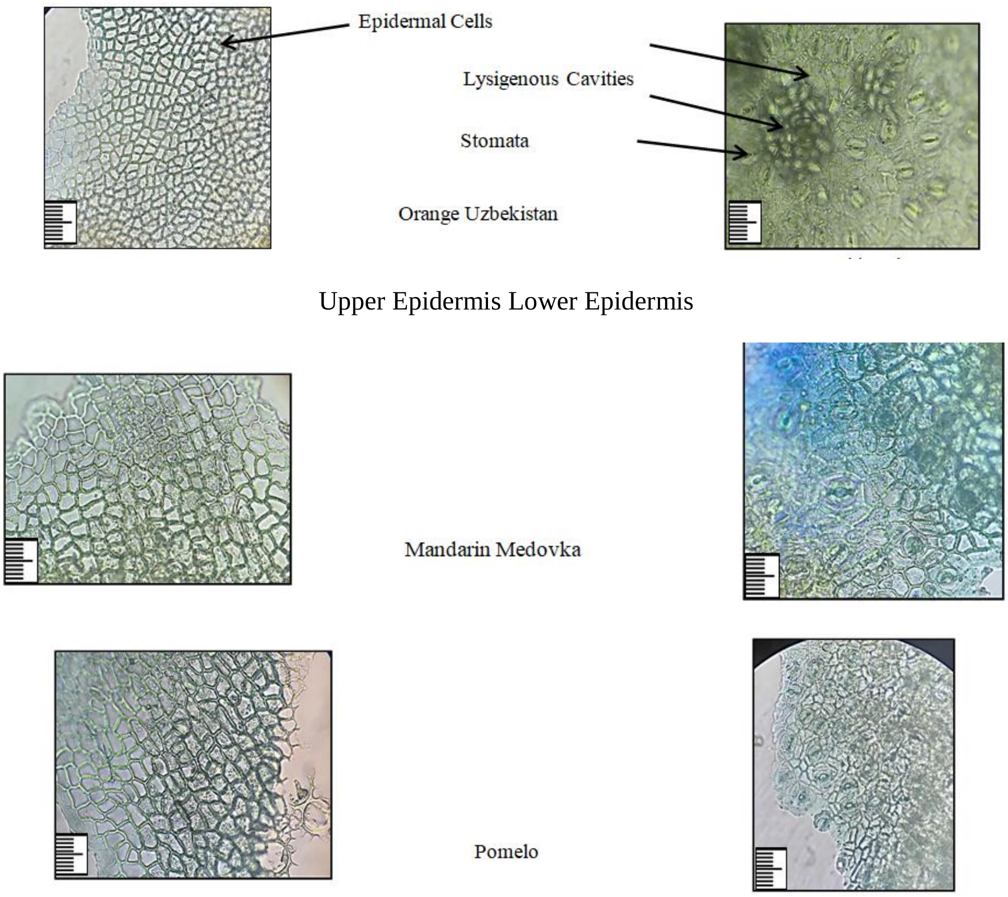

Figure 5. Structure of the paradermal analysis of the leaf in the studied representatives of the genus *Citrus*

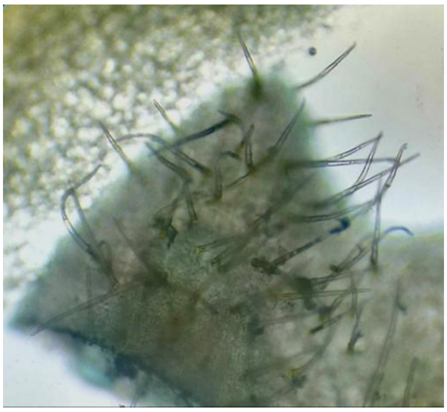

Figure 6. Epidermal Trichomes and Glandular Hairs on the Leaf of Pomelo

The analysis of the structural indicators of the leaf of the Mandarin Medovka showed that the mesophyll of the leaf is dorsiventral (Fig. 1). The total height of the leaf blade is the smallest compared to the studied representatives (74.5 ± 6.1 µm), but the epidermis on the adaxial side of the leaf is somewhat larger compared to the studied representative — the orange variety Uzbekistan (Tab. 1, Fig. 2). All other height indicators of various leaf tissues are significantly lower, practically 2–4 times less than those of other studied representatives, except for the height of the central vein. Its measurements are average among the studied representatives, reaching 454.7 ± 15.4 µm. Additionally, the mesophyll contains lysigenous cavities. Among the spongy parenchyma, there is a large number of intercellular spaces and water-storing cells.

Upon examining the cells of both epidermal layers, it was found that the cells of the adaxial epidermis are almost twice as small as those of the abaxial epidermis (3598.6 ± 267.7 per 1 mm² and 1811.5 ± 87.7 per 1 mm², respectively). The wall contours are somewhat wavy, and the outline of the epidermal cells is polygonal, with 3–5 sides. The stomata are slightly sunken, oval in shape, numerous, of the anomocytic type, and are oriented randomly. The number of stomata is recorded only on the abaxial side of the leaf, indicating that the leaf is hypostomatic. The number of stomata on the abaxial side of the leaf is the lowest compared to the studied representatives (741.5±62.0 per 1 mm²).

The obtained data on the structure of the leaf of the orange variety Uzbekistan show that the wall contours of both epidermis layers are straight and polygonal (4-5 sides), and the cells are larger than those of the studied representatives, with the abaxial epidermis being somewhat larger than the adaxial (1741.6±52.8 per 1 mm² and 2011.3±63.9 per 1 mm², respectively). The mesophyll of the leaf has a dorsiventral structure, with the palisade layer consisting of 2 rows and the spongy layer being multi-layered (8–10 layers). Lysigenous cavities and water-storing cells are also present in the mesophyll, and calcium oxalates are found in the parenchyma cells. The height of the adaxial epidermal cell in the orange variety Uzbekistan is the smallest among the studied representatives (10.7±0.9 µm). The other indicators are average between the two studied representatives, with the height of the leaf blade reaching 98.0 ± 2.7 µm. However, the height of the central vein is the maximum among the studied species (597.8±17.1 µm).

When counting the stomata on both sides of the leaf, it was found that stomata are present only on the lower side of the leaf; therefore, the orange variety Uzbekistan, like all studied representatives, has a hypostomatic type of leaf. The number of stomata on the abaxial side of the leaf reaches 1111.1±64.4 per 1 mm², which is the highest indicator among the studied representatives.

The mesophyll is penetrated by veins, which consist of bundles of conducting tissues made up of primary xylem and phloem. Citrus plants exhibit pinnate venation. In pinnate venation, the main vein and secondary veins are well developed. In the Mandarin Medovka and Pomelo, the vascular bundle has a concentric structure. The central vein of the leaf contains xylem and phloem and is connected to the conducting system of the stem.

It has been identified as belonging to the hygrophytic group of plants, as indicated by the very thin dorsiventral structure of the leaf, the unilayered epidermis, the positioning of the stomata at the same level as the epidermis, and their absence on the upper side of the leaf.

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Conclusions

In Mandarin Medovka and Pomelo, the vascular bundle has a concentric structure, indicating a greater primitiveness compared to the orange variety Uzbekistan. In all studied representatives, there are no stomata and trichomes on the upper epidermis, which is evidence of the hypostomatic nature of the leaf. The leaf blade of Pomelo has the greatest thickness, which contributes to biological protection against insect pests.

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Н.В. Тутушкина, К. Уразбаева, А.Чатченко

Citrus тұқымдасының кейбір түрлерін жасанды жағдайда өсіруде жапырақтың құрылымдық ерекшеліктері

Мақалада әртүрлі іргелі мәселелерді шешу үшін жапырақтың вегетативті мүшесін зерттеудің маңыздылығы мен өзектілігі қарастырылған. Бүкіл әлемде жасанды жағдайда өсірілетін цитрус дақылдары *Citrus* L. туысына жатады. Бұл тұқымның жабайы және жартылай жабайы туыстары (*C. trifoliata* L. және *C. ichangensis* Sw.) Rutaceae Juss тұқымдасының Aurantioideae Eng тұқымдас тармағына жатады. Олардың барлығы дерлік мәңгі жасыл және әлемнің тропикалық және субтропикалық аймақтарында маңызды жеміс дақылдары болып саналады. Цитрус жемістерінің жіктелуі мен систематикасы өте өзекті. Бүгінгі күнге дейін жалпы қабылданған ботаникалық классификация жоқ, бұл Citrus туысының арнайы полиморфизміне байланысты болуы мүмкін. *Citrus, Fortunella* және *Poncirus* — ең үлкен экономикалық және практикалық маңызы бар үш ботаникалық тұқымдастар. Жемістер, гүлдер мен жапырақтарда биологиялық белсенді заттардың кең спектрі бар (органикалық қышқылдар, биофлавоноидтар, эфир майлары және 12 витамин). Цитрустық эфир майлары табиғи парфюмерия өндіру үшін және тамақ, фармацевтика және косметикалық өнімдерде хош иістендіргіш ретінде кеңінен қолданылады. Помело, Өзбекстан апельсині, «Медовка» мандарині сұрыптары өсімдіктерінің жапырақтары зерттелді. Жапырақтардың бірыңғай түрі анықталды, яғни гипостоматикалық. Жапырақ мезофилінде әртүрлі қосындылар бар; оның құрамында су сақтайтын жасушалар және көптеген жасушааралық кеңістіктер бар. Помелода жапырақ алақанының (тақтасы) ең үлкен биіктігі бар екендігі, ал «Медовка» мандаринінде ең кішкентай екені анықталды. Помелолар өкілінде трихомалар мен безді түктердің болуы кездеседі. «Медовка» мандаринінде аз, ал Өзбекстан апельсинінде көп мөлшерде екендігі байқалды.

Кілт сөздер: жапырақ құрылымы, помело, апельсин, мандарин, саңылау, эпидермис, трихома, мезофилл.

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Структурные особенности листа у некоторых культивируемых видов рода *Citrus*

В данной статье рассматривается значение и актуальность изучения вегетативного органа листа для решения различных фундаментальных вопросов. Цитрусовые культуры, культивируемые во всем мире, являются представителями рода *Citrus* L. Этот род, наряду с его дикими и полудикими родственниками (*C. trifoliata* L. и *C. ichangensis* Sw.), относится к подсемейству Aurantioideae Eng. семейства Rutaceae Juss. Почти все они являются вечнозелеными растениями и считаются важными плодовыми культурами в тропических и субтропических регионах мира. Классификация и систематика цитрусовых весьма проблематичны. По сей день не существует общепринятой ботанической классификации, что, вероятно, связано с чрезвычайным полиморфизмом рода *Citrus*. Три ботанических рода, имеющие наибольшее экономическое и практическое значение, — это *Citrus, Fortunella* и *Poncirus*. Плоды, цветки и листья содержат широкий спектр биологически активных веществ (органические кислоты, биофлавоноиды, эфирные масла и 12 витаминов). Эфирные масла цитрусовых широко используются для производства натуральных духов и в качестве ароматизаторов в пищевой, фармацевтической и косметической продукции. Были изучены листья таких растений, как помело, апельсин сорта Узбекистан и мандарин сорта Медовка. Установлен единый тип листьев — гипостоматический. Мезофилл листа содержит различные включения, в нем присутствуют водозапасающие клетки и большое количество межклеточных пространств. Установлено, что у помело наибольшая высота листовой пластинки, а у мандарина Медовка — наименьшая. У представителя помело отмечено наличие трихом и железистых волосков. Наименьшее количеством было отмечено у мандарина Медовка, а наибольшее — у апельсина Узбекистан.

Ключевые слова: структура листа, помело, апельсин, мандарин, устьице, эпидермис, трихома, мезофилл.

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Study of anatomical structure of *Dactylorhiza fuchsii* (Orchidaceae) growing in the Karkaraly Mountains (Central Kazakhstan)

The study of plant structure peculiarities plays an important role in understanding the ecology and habitat conditions of species, as well as for the identification of characteristic features in confirming the species identity of plant raw materials. This article presented the results of microscopic structure of above-ground and underground organs of *Dactylorhiza fuchsii* growing in the Karkaraly Mountains (Central Kazakhstan). The results showed that the leaf preparation is characterized by the presence of polygonal epidermal cells, stomata of tetracytic type, predominantly localized on the lower side of the leaf. Mesophyll is of homogeneous type, bundles are collateral, cranium-lined, and usually oval in shape. The stem on transverse section is characterized by a well-defined epidermis and cortex, numerous conductive bundles, collateral type, and several lacunae are presented. The transverse section of the root is characterized by the presence of starch grains and fungal peletons, indicating the symbiosis of this species with fungi under natural conditions. In general, the features of the anatomical structure confirm the mesophytic character of *Dactylorhiza fuchsii* habitat, in particular, the absence of velamen in the root and adaptations in the leaves for water absorption. The results obtained contribute to the assessment of ecological and biological peculiarities of the species and allow us to use the obtained characters for taxon identification at the microscopic level.

Keywords: *Dactylorhiza fuchsii*, anatomical structure, Karkaraly Mountains, leaf, stem, root, mesophytic signs.

Introduction

Orchids are among the most vulnerable plants protected internationally. All species of the Orchidaceae family are listed in the Annex of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). *Dactylorhiza fuchsii* (Druce) Soo is protected at the national level in Belgium and Luxembourg, and at the regional level in France [1]. In the Russian Federation, this species is included in the Red Data Books of most regions. In Kazakhstan, *Dactylorhiza fuchsii* is included in the Red Data Book [2] as the only representative of the genus *Dactylorhiza*. In the Central and Northern Kazakhstan it is found in such protected areas as Kokshetau, Karkaraly, and Burabai national parks [3, 4].

Like many representatives of the family Orchidaceae, the abundance of *Dactylorhiza fuchsii* in nature is decreasing due to anthropogenic impacts, including habitat destruction, climate change and plant harvesting. In this regard, study of the anatomical features of this species become relevant, as they allow us to understand the mechanisms of its adaptation to different environmental conditions. It is worth noting that the roots and rhizomes of *Dactylorhiza fuchsii* contain biologically valuable substances and can be active against infectious agents [5].

International studies of morphology and micromorphology of orchids are actively conducted in Europe [6]. However, the anatomy of *Dactylorhiza fuchsii* remains insufficiently studied [7, 8], and in Kazakhstan, this kind of research is generally not conducted.

Anatomical studies cover such aspects as root system structure, stem morphology, leaf composition and features of floral structures. Root tubers play an important role in nutrient accumulation, the stem provides support and transport of water and minerals, and leaves are adapted for optimal photosynthesis. Specialized floral structures indicate complex relationships with pollinators [9–11].

The aim of this study is to investigate the anatomical features of *Dactylorhiza fuchsii* to understand the mechanisms of its adaptation to the environment. The results of the study can be used to develop strategies for the conservation of the species, effective management of its populations and restoration of natural habitats. In addition, the study of the anatomy of *Dactylorhiza fuchsii* contributes to the expansion of scientific knowledge in the field of botany and plant physiology, and can also be used to clarify the diagnostic features of medicinal plant raw materials.

Experimental

The object of the study were aboveground and underground organs of *Dactylorhiza fuchsii* (root tubers, leaves, shoots) collected in the 2nd decade of July 2024 in the Karkaraly Mountains (Karkaraly district, Karaganda region) in the flowering phase (Fig. 1). Sampling coordinates for the study: N49°19'54.174604“, E75°33'11.665018”, 893 m above sea level.

Figure 1. Flowering samples of *Dactylorhiza fuchsii* in Karkaraly Mountains (2024)

Fresh plants were fixed in a mixture of ethyl alcohol 96 % — distilled water — aqueous glycerol 40 % (1:1:1 ratio, Strauss-Fleming reagent). Transverse sections and surface preparations were made manually using a blade [12–14]. The middle part of the shoot was used for the stem, the central vein for the leaf, and the central part for the petiole. The obtained micro specimens were viewed through a binocular microscope NINGBOSUNNY Instruments CoEX30 (China) with a digital camera Altami 8.5 Mpix (Russian Federation). AltamiStudio software was used for photo processing. When describing the anatomical structure we used the principles outlined in the works of L.I. Lotova [15] and P.J. Rudall [16].

Results and Discussion

Dactylorrhiza fuchsii is a perennial herbaceous plant, 15–25 cm tall; tubers are rounded or turnip-shaped, palmate. Shoots are solitary, dense, 5–7 mm in diameter. Leaves are few, 2 to 5 in number, slightly deviated from the stem, almost flat or folded along the central vein, oblong-lanceolated in the lower part and awl-shaped-linear and slightly sinuous in the upper part of the stem; color is green with rounded purple spots of different sizes. Flowers are gathered in spike-like inflorescences, up to 8-9 cm long and 3-4 cm in diameter. The color of flowers varies widely, from white to purplish-red.

Microscopic examination of the leaf (Fig. 2) showed that differences in the structure of the upper and lower sides of the plate were observed.

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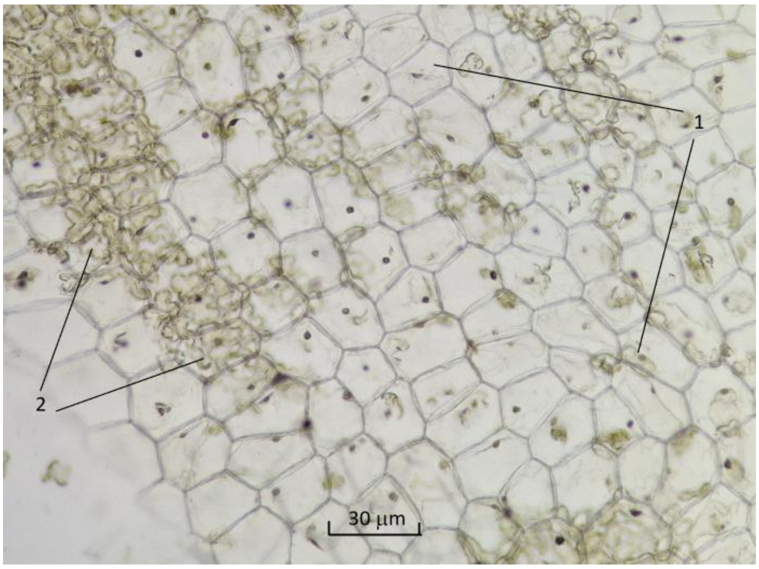


A

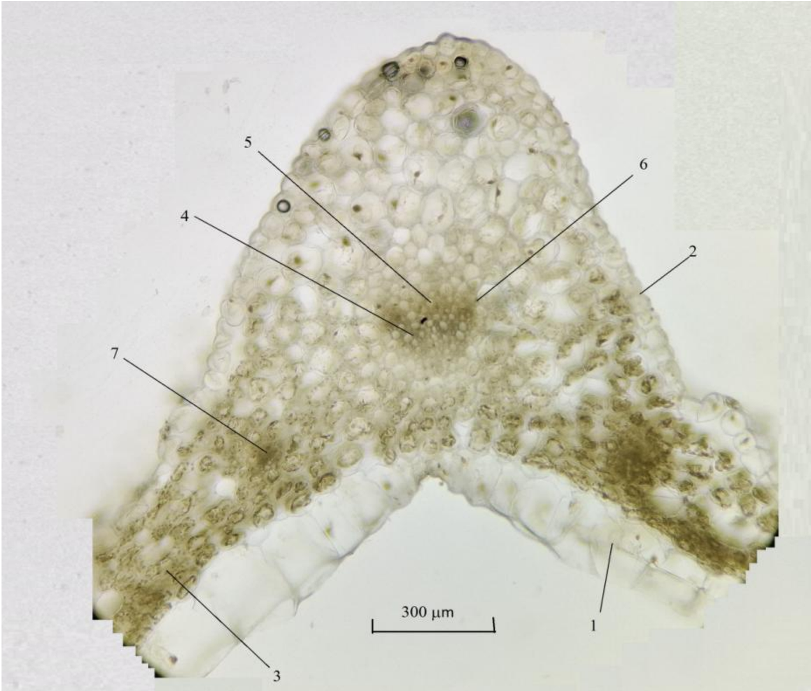
B

1 — basic cells of epidermis, 2 — leaf mesophyll cells, 3 — stomata; A — upper epidermis, B — lower epidermis

Figure 2. Preparation of *Dactylorhiza fuchsii* leaf from surface

The epidermis of the upper side consists of thin-walled polygonal cells, rounded or slightly oval in shape, through which the polygonal cells of the mesophyll are well translucent. The size of the cells ranges from 20 to 35 μm. Cells of the lower epidermis are smaller in size, 20–30 μm, with weakly curved walls, slightly elongated along the central vein. Nuclei are well expressed in the epidermal cells of both sides of the leaf. Stomata are identified only on the lower side (hypostomal type). Stomata are rounded, 15–20 μm in diameter, tetracytic type. Such features of the structure were confirmed in the works of L.V. Averyanov [17].

The internal structure of the leaf (Fig. 3, 4) is characterized by a homogeneous type of mesophyll structure, which is reflected in the absence of its differentiation into palisade and spongy tissues; leaf thickness in the lateral part is 250–305 μm, in the region of the central vein — up to 400 μm.



1 — upper epidermis, 2 — lower epidermis, 3 — mesophyll, 4 — xylem,
5 — phloem, 6 — cranial lining, 7 — lateral vascular bundle

Figure 3. Leaf preparation of *Dactylorhiza fuchsii*, transverse section, fragment in the area of the central vein

1 — upper epidermis, 2 — lower epidermis, 3 — mesophyll, 4 — lateral vascular bundle

Figure 4. Leaf preparation of *Dactylorhiza fuchsii*, transverse section,
fragment in the area of the lateral part of the leaf lamina

The total number of cell layers ranges from 7 to 9. This structure is typical for many species of Orchidaceae [18, 19]. The epidermis is single-layered, consisting of isodiametric and almost square cells with a small amount of intercellular space; the cuticle is absent on both sides. The cells of the upper side are larger in size than those of the upper side; the shape on the transverse section is similar. Leaves have collateral vascular bundles; phloem is oriented toward the abaxial side, xylem toward the adaxial side. The xylem is poorly differentiated. A cranial lining is formed around the bundles. Sclerenchyma fibers are almost not observed.

On anatomical sections of the stem, a rounded or ovoid shape with remnants of adjacent leaves can be observed (Fig. 5). The perimeter of the stem is covered with one-layer epidermis with a thin cuticular layer; the shape of cells is oval.

1 — leaf area adjacent to the stem, 2 — epidermis, 3 — cortex,
4 — medullary parenchyma, 5 — xylem, 6 — lacuna

Figure 5. Cross section of leaf of *Dactylorhiza fuchsii*

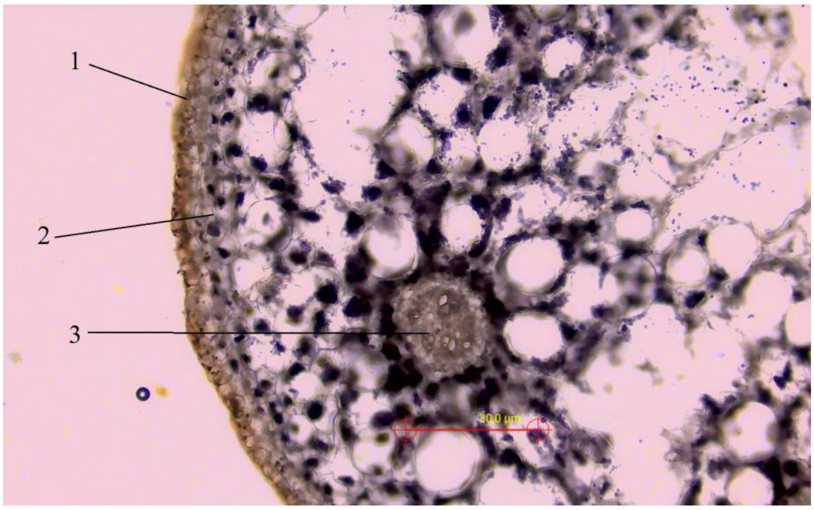
The epidermis is followed by the cortex, consisting of parenchymatous cells, in 10–15 layers. Part of the cells is filled with starch granules. The central part of the stem is filled with medullary cells. Vascular bundles are collateral, reminiscent of dicotyledonous plants and arranged at regular intervals. Elements of xylem are well visible; elements of phloem are almost invisible due to thin cell walls. There are several lacunae in the stem due to the core being broken into parts. These features are also characteristic of other Orchid species *like Ophyslutea* and *Orchismascula* [20, 21].

Examination of root anatomy showed that the outer layer consists of 1-2 layers of rhizoderm, the cells of which do not have a stable shape. The cells can be elongated in longitudinal or transverse direction, sometimes rounded in shape. The cells of the cortex consists of 5–8 layers, usually rounded, their size decreases towards the central part. Remains of fungal peletons can be noted on the outside [22]. The central part of the stem is occupied by a vascular bundle with sclerenchyma lining.

1 — rhizoderm, 2 — cortex, 3 — fungal peletons, 4 — vascular bubdle

Figure 6. Cross section of *Dactylorhiza fuchsia* root

Transverse section of root tuber anatomy showed the presence of starch grains in cells when stained with Lugol's solution (Fig. 7). The endoderm is 1-layered, completely surrounding the meristem periphery. Vascular bundles are several in number; arranged in a circle, as in dicotyledonous plants. The bundles consist of xylem, sieve tubes, phloem parenchyma, cambium is absent; there are some areas of pericycle.



1 — rhizoderm, 2 — endoderm, 3 — vascular bundle

Figure 7. Cross section of root tuber of *Dactylorhiza fuchsii*. Fragment

Conclusion

Thus, according to the peculiarities of structure, *Dactylorhiza fuchsii* belongs to mesophytic tuberous-rooted species forming symbiosis with fungi. In general, the structure of above-ground and underground organs shows the presence of adaptations for water absorption and retention as a system of bark parenchyma (cortex). The absence of the velamen which is formed in many genera of Orchidaceae is noted. Leaves of the plant do not have adaptations for water retention, which indicates growth in conditions of sufficient moisture without the test of constant hydric stress.

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Қарқаралы (Орталық Қазақстан) тауларында өсетін *Dactylorhiza fuchsii* (Orchidaceae) анатомиялық құрылымын зерттеу

Өсімдіктер құрылымының ерекшеліктерін зерттеу түрдің экологиясы мен тіршілік ету ортасын түсінуде, сондай-ақ өсімдік шикізатының түрлерін растау кезінде тән белгілерді анықтауда маңызды рөл атқарады. Мақалада Қарқаралы (Орталық Қазақстан) тауларында өсетін *Dactylorhiza fuchsii* жерүсті және жерасты органдарының микроскопиялық құрылысының нәтижелері келтірілген. Нәтижелер жапырақ препараты негізінен жапырақтың төменгі жағында локализацияланған эпидермистің көпбұрышты жасушаларының, тетрацит типті саңылауларының болуымен сипатталатынын көрсетті. Мезофилл біртекті типтес, шоғырлары бүйірлі, сақина тәріздес, сопақша пішінді. Көлденең кесілген сабақ айқын анықталған эпидермис және қыртыспен сипатталады; коллатеральды типтегі көптеген өткізгіш шоқтарымен, сонымен қатар бірнеше қуыстары бар. Көлденең кесілген тамыр крахмал дәндері мен саңырауқұлақ пелетондарының болуымен сипатталады, бұл табиғи жағдайда саңырауқұлақтармен осы түрдің симбиозын көрсетеді. Тұтастай алғанда, анатомиялық құрылымның ерекшеліктері *Dactylorhiza fuchsii* тіршілік етуінің мезофиттік сипатын растайды, атап айтқанда, бұл тамырда веламеннің болмауы және суды сіңіру үшін жапырақтардың бейімделуі. Алынған нәтижелер түрдің экологиялық-билогиялық ерекшеліктерін бағалауға ықпал етеді және алынған белгілерді таксонды микроскопиялық деңгейде анықтау үшін пайдалануға мүмкіндік береді.

Кілт сөздер: *Dactylorhiza fuchsii*, анатомиялық құрылымы, Қарқаралы таулары, жапырақ, сабақ, тамыр, мезофиттік белгілері.

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Изучение анатомической структуры *Dactylorhiza fuchsii* (Orchidaceae) произрастающей в горах Каркаралы (Центральный Казахстан)

Изучение особенностей строения растений играет важную роль для понимания экологии и условий обитания вида, а также для выделения характерных признаков при подтверждении видовой принадлежности растительного сырья. В настоящей статье приведены результаты микроскопического строения надземных и подземных органов *Dactylorhiza fuchsii*, произрастающей в горах Каркаралы (Центральный Казахстан). Результаты показали, что препарат листа характеризуется присутствием многоугольных клеток эпидермиса, устьица тетрацитного типа, преимущественно локализованы с нижней стороны листа. Мезофилл гомогенного типа, пучки — коллатеральные, с кранц-обкладкой, обычно овальной формы. Стебель на поперечном срезе характеризуется четко выраженным эпидермисом и кортексом, присутствуют многочисленные проводящие пучки, коллатерального типа, а также несколько лакун. Поперечный срез корня характеризуется присутствием крахмальных зерен и грибных пелетонов, что свидетельствует о симбиозе данного вида с грибами в природных условиях. В целом, особенности анатомического строения подтверждают мезофитный характер обитания *Dactylorhiza fuchsii*, в частности, это отсутствие веламена у корня и приспособлений у листьев для поглощения воды. Полученные результаты вносят вклад в оценку эколого-билогических особенностей вида и позволяют использовать полученные признаки для идентификации таксона на микроскопическом уровне.

Ключевые слова: *Dactylorhiza fuchsii*, анатомическое строение, горы Каркаралы, лист, стебель, корень, мезофитные признаки.

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