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Species composition of vascular plants of Western Karatau gorges (Mangyshlak)

Analysis of flora and identification of important plant areas in Kazakhstan is an important task for the conservation of biological diversity. On the territory of Mangistau region an important object for identification is the vegetation of the Western Karatau ridge, where a large number of species grow, including species with conservation status. Analysis of species composition of vascular plants of 8 gorges (Samal, Akmysh, Kogez, Botakan, Zhemsemsay, Karasay, Kendirli, Shybyksay) allowed to determine 60 species from 53 genera and 26 families in the summer flora. The dominant families are Asteraceae, Fabaceae, Brassicaceae, Poaceae, Polygonaceae, Chenopodiaceae, Caryophyllaceae, Lamiaceae, and Rosaceae. By life forms, perennials and small perennials dominate, by ecological groups — xerophytes and xeromesophytes. The similarity between the floras of the gorges was established on the basis of Jaccard's coefficient, which varied from 0.26 to 0.58. The minimum similarity was observed between Zhemsemsay and Shybyksay gorges, the maximum — between Samal and Kogez gorges. Growth of 7 species classified as rare and endangered plants of Mangistau region, as well as 3 species listed in the Red Book of Kazakhstan was noted. On the basis of the performed research recommendations were given for inclusion of the gorges of the Western Karatau Ridge in the list of important plant areas.

Keywords: important botanical area, flora, vegetation, species composition, Western Karatau.

Introduction

Important plant areas (hereinafter IPAs) are natural areas of special importance for the conservation of flora and vegetation diversity [1]. A set of criteria for designating IPTs takes into account floristic richness, the number of rare and endemic species in need of protection, species listed in the Red Data Books, or species of great importance for the evolution and conservation of the biosphere [2].

Active isolation of IPT has been noted in the territory of European and CIS countries. Thus, IPAs have been described and isolated for the Murmansk and Kemerovo Regions, Altai-Sayan Range, in the Republic of Tyva, Khakassia [3–5], and IPAs in the Republic of Belarus have been well surveyed [6]. The isolation of IPAs for France and Germany has been carried out [7].

In Kazakhstan, these studies were conducted only for the territory of Almaty region [8]. Thus, 11 IPAs were identified for Zhetysu Alatau (Kapchagai Gorge; Itzhon Plateau; Karatas tract; Arkharly Pass; Ushkara tract; Lepsy River floodplain; Suleyman Creek; Seksenbai tract; Kyzkash Mountains; Arganaty Mountains; Zhanabulak, turang grove), with high floristic, mycobiotic and phytocenotic diversity. Similar studies have not been conducted in the rest of Kazakhstan.

Three main criteria are used to identify IPAs: 1) the presence of plant species listed as rare, endangered, or in the Red Books of different levels; 2) overall species richness, as IPAs are intended to identify and conserve areas with exceptional diversity of higher or lower plants; and 3) the presence of endangered habitats.

In Mangystau region (Western Kazakhstan), the gorges of the Western Karatau Range are unique areas with rich floristic diversity and a large number of rare species.

To identify sites that can be recognized as IPA, we evaluated the species composition of vascular plants in a number of gorges of the Western Karatau. The similarity of the flora was assessed using the Jaccard's coefficient.

Experimental

Expedition research of the site was carried out by the traditional route-reconnaissance method with coverage, if possible, of the most complete variety of biotopes (landscape-ecological conditions) and phytocenoses peculiar to them.

The materials were collected in 2023-2024. The vegetation cover of the studied gorges was studied using the traditional method of geobotanical research — description of plant communities [9, 10]. In this case, special attention was paid to the study of spatial distribution (structure) of vegetation and its relationship with other landscape components (relief, soils, etc.), species diversity and assessment of vegetation condition

Identification of the collected herbarium material was carried out using fundamental summaries: “Flora of Kazakhstan” [11], “Illustrated Identifier of Plants of Kazakhstan” [12]. The species composition is given taking into account modern nomenclatural changes [13].

Populations were analyzed in 8 gorges of the West Katarau Ridge (Table 1).

Table 1

Field survey routes in the territory of the Western Karatau Ridge

Study sites	Coordinates		Height, m above sea level
	Longitude	Latitude	
Akmysh Gorge	44°13'042"	51°58'346"	275
Samal Gorge	44°12'568"	51°59'370"	274
Kogez Gorge	44°17'178"	51°39'949"	253
Shybyksay Gorge	44°13'370"	51°58'46"	268
Jemsemsay Gorge	44°17'178"	51°39'949"	253
Karasay Gorge	44°12'341"	51°53'432"	367
Kendirli Gorge	44°13'138"	51°54'552"	376
Botakan Gorge	44°13'261"	51°54'144"	243

Results and Discussion

The Western Karatau Ridge is the highest massif of the Mangyshlak Mountains. Its altitude ranges from 380 to 480 meters above sea level. The highest point — Mount Beschoku — rises to 555 meters above sea level. The ridge stretches for 45 km with a width of about 10 km. Its summit is a peneplenized uvalist-hilly surface with ridges of dense rocks stretching parallel to each other and rising 5–10 m above the plain. Separate cone-shaped peaks rise 50–100 m above the peneplain (Djipakhchi, Beschoku and other mountains). Eastern Karatau has very steep slopes, in some places almost sheer. The slopes are strongly cut by deep ravines [14].

Akmysh Gorge. The area of the site is 1300x70 (30) m (Fig.). Akmysh is a stream with a small grove along its banks, fed by mountain springs, with a stream flowing through the center, which dries up in summer. The substrate is stony-rubble, sandy and clayey soils emerge at the foot of the ridge.

Samal Gorge. The area is 2500x100 meters. The site is a winding gorge, located on the slope of a ridge 500 m high, three kilometers from the Akmysh gorge. An abundant stream with fresh water flows along the bottom of the gorge for about a kilometer. The soils are brown, clayey, and strongly stony.

Kogez Gorge. Area 2000x50–100 m. Slopes are gentle, with small cluster of *Caragana grandiflora* (Bieb.) DC. bushes and wormwoods (*Artemisia austriaca, Artemisia santolina*). The habitat is occupied by little disturbed communities of lowland vegetation. Shrub thickets are natural undisturbed communities due to their inaccessibility. Total projective cover is 65–70 %.

Shybyksay Gorge. The area is 600x70 meters. The site is located in a mountain gorge with gentle rocky slopes of the ridge. The gorge is a winding form with steep slopes on all sides. The height of the slopes is not significant, up to 150 m, the slopes of the mountains are stony and rubbly, at the foot of the ridge sandy and clay soils emerge. The total projective cover formed by the community is 60–65 %. Community types are distributed in 3 tiers: woody (up to 350 cm high), formed by *Crataegus ambigua*; shrubby (120–150 cm high), formed by bushes *of Rhamnus sintenesii*, less frequently *Caragana grandiflora*, young

plants of hawthorn of doubtful, at springs single specimens of *Rubus caesius*; and herbaceous (up to 70 cm high). Due to inaccessibility and steepness of slopes, the plants are not used for livestock grazing.

Jemsemsay Gorge. The area is 800x100 m, the gorge is characterized by high slopes, cut through by numerous branches with very steep, stony slopes with a large number of bedrock outcrops and screes. Total projective cover is 50–60 %, hawthorn is the dominant species with abundance of sorghum$_2$. There are 3 tiers in the communities of the gorge: Woody (up to 500–550 cm high), consisting of white willow (*Salix alba*) and adult individuals of doubtful hawthorn (*Crataegus ambigua*) (according to Figure 10); shrubby (up to 160 cm high), formed of *Convolvulus fruticosus, Atraphaxis herliata, Caragana grandiflora, Rhamnus sintenisii*; herbaceous (up to 60 cm high). This habitat is not used for livestock grazing.

Karasay Gorge. The area is 2000x30–50 m. The gorge is small in size — its length is about 2 km, its width varies from 30 to 50 m, it is slightly winding. The height of the slopes is not significant, 20–25 m, some of them are precipitous, and most of them are gentle. The slopes are clayey-stony, and in the lower part there are rubbly scree slopes. There are no side branches or promontories in the gorge. A small stream with drinking water flows along the bottom of the gorge. Due to its easy accessibility, the site is actively used for watering and grazing of livestock, which explains a certain degree of degradation of vegetation cover (about 8–12 %).

Kendirli Gorge. The area is 5500x30–120 meters. The gorge is a deep, strongly winding gorge divided into 2 parts. The height of the slopes is from 60 to 200 m, the northern exposure is gentle, stony-clay. The slopes of the southern exposure are steep and precipitous, rubbly. A stream with fresh water flows along the bottom of the gorge. The length of the gorge exceeds 5.5 km and its width varies from 30 to 120 meters. There are 3 vertical tiers in the gorge communities: upper woody (250 to 350 cm in height), shrub (120–220 cm in height) and herbaceous with a sub-tier of tall grasses (60–80 cm in height) and a sub-tier of stunted grasses (10–30 cm in height). Due to the inaccessibility and steepness of the slopes, the gorge is not used for livestock grazing. No degradation of vegetation cover is observed.

Botakan Gorge. The area is 1500x30–100 m. The height of slopes ranges from 50 to 150 m, eastern exposure — gentle, stony-clay. The slopes of the western exposure are steep and precipitous, rubbly. The gorge is up to 1.5 km long and 30 to 100 m wide. There are 3 tiers in the community: woody (up to 300–350 cm high), consisting of adult specimens of doubtful hawthorn; shrubby (up to 160 cm high), formed by *Rhamnus sintenisii, Atraphaxis herliata,* rarely *Caragana grandiflora*, single specimens of *Rubus caesius* at springs, young specimens of hawthorn; herbaceous (up to 60 cm high), composed of other components of the community. Due to the inaccessibility and steepness of the slopes, the gorge is not used for livestock grazing. No degradation of the vegetation cover is observed.

The cumulative analysis of taxonomic composition of communities in the gorges of the Western Karatau showed that 60 species from 53 genera and 26 families (Table 2).

Table 2

Composition of plant communities in the Western Karatau gorges

№	Gorge	Number of species, pieces	Presence of rare and endangered species for Mangystau oblast, pieces	Presence of species listed in the Red Book of Kazakh-stan, pieces
1	Akmysh Gorge	60	2	2
2	Samal Gorge	55	3	3
3	Kogez Gorge	58	5	5
4	Shybyksay Gorge	35	5	2
5	Jemsemsay Gorge	53	7	2
6	Karasay Gorge	51	4	2
7	Kendirli Gorge	48	3	2
8	Botakan Gorge	39	6	2

Most species belong to the families Asteraceae, Fabaceae, Brassicaceae, Poaceae, Polygonaceae, Chenopodiaceae, Caryophyllaceae, Lamiaceae, and Rosaceae. Species from these nine leading families comprise 60.6 % of the total.

Of the rare, endangered and Red Book species, 10–21.3 % of those growing in the region were identified. *Crataegus ambigua* C.A. Mey., *Crambe edentula* Fisch., *Artemisia gurganica* (Krasch.) Filat., *Rubus caesius* L., included in the catalogue of rare and endangered plant species of Mangistau [15], are found in all

IPAs. Only in the Kogez gorge was the presence of the Red Book [16] species *Salix alba* L. and *Armeniaca vulgaris* Lam. and *Rhamnus sintenisii* Rech., *Capparis herbaceae* Sp., *Teucrium* polium L., included in the Red Book of Mangistau, revealed. Also, in the Kogez and Samal gorges, the Red Book species *Malus sieversii* (Ledeb.) M. Roem.

Analysis of life forms showed that herbaceous perennials dominate in the surveyed populations, 47.3 %; herbaceous minor perennials are in second place, 23.6 %; trees and shrubs are in third place, 18.2 % each, semi-shrubs, 5.5 %, semi-shrubs, 3.6 %, and shrubs 1.8 %.

Ecological analysis showed that a significant proportion of the flora of the studied IPAs consists of xerophytes (21 species or 35 %) and xeromesophytes (9 species or 15 %), which is associated with the severe aridity of the climate of Mangistau. The spectrum of ecological-phylogenetic groups confirmed the predominance of 501 desert and mountain-steppe species, which constitute the majority (53 %). A significant share falls to desert-steppe species (36.7 %). Meadow-steppe species make up 8 % of the total flora. Water-coastal species occupy 5.3 % of the total flora. 504 Weed species were identified, constituting 34.4 % of the total flora composition of the territory's studied areas. This indicates high anthropogenic load and cattle grazing in 506 all studied IPAs.

In the research process to assess the similarity of floras of different IPAs, the Jaccard coefficient was used, which is the ratio of the number of similar taxa for two communities to their sum for each list minus the number of common species. As we can see from the materials in Figure, the Jaccard coefficient for the Akmysh — Samal and Akmysh — Kogez, Akmysh — Karasay, Shybyksay — Zhemsemsay, Botakan — Karasay, Kendyrly — Kogez sites is almost the same, with relatively low values of 0.27–0.29. And vice versa — Samal — Kogez increases almost twice to 0.56 (56 %).

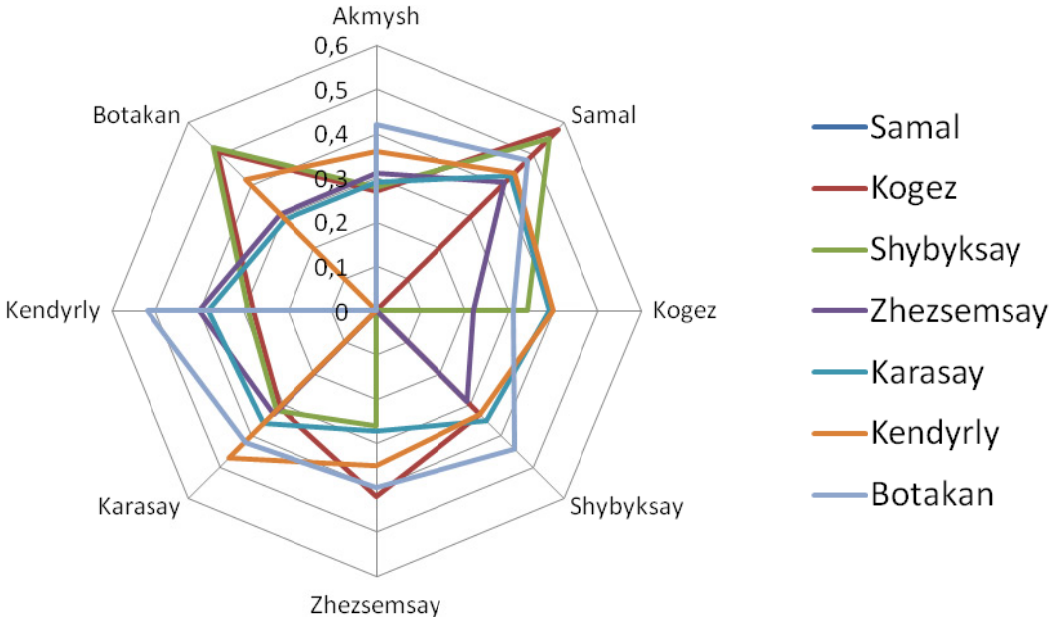

Figure. Similarity between the floras of the Western Karatau gorges based on the Jaccard index

The similarity of flora between the remaining plots ranged from 0.31 to 0.52. The differences can be explained by the presence of differences in soil conditions, anthropogenic load and moisture conditions.

It has been established that all areas are vulnerable due to a whole range of factors: location, intensive use in agriculture, increased anthropogenic load, etc. The most effective way to preserve rare plants is to maintain their natural populations. The allocation of the above areas to the category of critical botanical territories allows us to hope for the long- term existence of natural biocenoses without catastrophic changes. It is also essential to consider these areas with a high concentration of rare significant species when planning possible recreational and economic activities. Given the vulnerability of all three areas, it is proposed to use geographic data as an alternative or supplement when choosing new IPAs or specially protected natural areas.

Conclusion

Biodiversity analysis for the important plant areas — gorges of Westerm Karatau in the Mangistau region showed high species diversity and the presence of rare and endangered plant species, making these areas important for conservation and monitoring.

Based on the research results, allocating the 8 gorges, to the essential plant areas category are recommended to ensure the long-term existence of natural biocenoses and the conservation of rare plant species. This will allow for the establishment of a protection regime, the regulation of recreational load, and the limitation of grazing, which are necessary measures to maintain ecosystem stability.

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Батыс Қаратау (Маңғышлақ) шатқалындағы тамырлы өсімдіктердің түрлік құрамы

Қазақстандағы флораны талдау және негізгі ботаникалық аумақтарды анықтау биологиялық әртүрлілікті сақтаудың маңызды кепілі. Маңғыстау облысының Батыс Қаратау жотасы өсімдіктерді анықтау үшін маңызды объект болып табылады, оның аумағында табиғатты қорғау мәртебесі бар түрлерді қоса алғанда, көптеген түрлер өседі. 8 шатқалдағы тамырлы өсімдіктердің түрлік құрамын талдау (Самал, Ақмыш, Көгез, Ботақан, Жемсемсай, Қарасай, Кеңдірлі, Шыбықсай) жазғы флора құрамында 53 тұқымдас пен 26 туыстың 60 түрін анықтауға мүмкіндік берді. *Asteraceae, Fabaceae,*

Brassicaceae, Poaceae, Polygonaceae, Chenopodiaceae, Caryophyllaceae, Lamiaceae және *Rosaceae* сияқты түрлердің басым тұқымдастары анықталды. Тіршілік формаларында көпжылдық және жас көпжылдықтар, ал экологиялық топтарда ксерофиттер мен ксеромезофиттер басым. Шатқалдардың флорасы арасындағы ұқсастық 0,26-дан 0,58-ге дейін ауытқыған Жаккар коэффициенті негізінде белгіленді. Ең аз ұқсастық Жемсемсай мен Шыбықсай шатқалдары арасында, ең жоғарысы Самал мен Көгез шатқалдары арасында байқалды. Маңғыстау өңірінің сирек кездесетін және жойылып бара жатқан өсімдіктеріне жатқызылған 7 түрдің, сондай-ақ Қазақстанның Қызыл кітабына енгізілген 3 түрінің өсуі атап өтілді. Жүргізілген зерттеулер негізінде Батыс Қаратау жотасының шатқалдарын негізгі ботаникалық аймақтардың тізіміне енгізу бойынша ұсыныстар жасалды.

Кілт сөздер: негізгі ботаникалық аумақтары, флорасы, өсімдіктері, түр құрамы, Батыс Қаратау.

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Видовой состав сосудистых растений ущелий Западного Каратау (Мангышлак)

Анализ флоры и выделение ключевых ботанических территорий в Казахстане является важной задачей для сохранения биологического разнообразия. На территории Мангистауской области важным объектом для выделения является растительность хребта Западный Каратау, на территории которого произрастает большое число видов, включая виды с природоохранным статусом. Анализ видового состава сосудистых растений 8 ущелий (Самал, Акмыш, Когез, Ботакан, Жемсемсай, Карасай, Кендирли, Шыбыксай) позволил определить в составе летней флоры 60 видов из 53 родов и 26 семейств. Доминирующими семействами определены *Asteraceae, Fabaceae, Brassicaceae, Poaceae, Polygonaceae, Chenopodiaceae, Caryophyllaceae, Lamiaceae* и *Rosaceae.* По жизненным формам доминируют многолетники и малолетники, по экологическим группам — ксерофиты и ксеромезофиты. Установлено сходство между флорами ущелий на основании коэффициента Жаккара, который изменялся от 0,26 до 0,58. Минимальное сходство отмечено между ущельями Жемсемсай и Шыбыксай, максимальное — между ущельями Самал и Когез. Отмечено произрастание 7 видов, отнесенных к редким и исчезающим растениям Магистауской области, а также 3 видов, занесенных в Красную книгу Казахстана. На основании выполненных исследований даны рекомендации для включения ущелий хребта Западный Каратау в перечень ключевых ботанических территорий.

Ключевые слова: ключевые ботанические территории, флора, растительность, видовой состав, Западный Каратау.

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Main direction of optimization of agrotechnics of growing seedlings of woody plants with closed root system in Mangistau desert

The objective of this study is to optimize the agricultural technology of growing seedlings of woody plants with a closed root system in the arid conditions of Mangistau by conducting field experiments. Based on the dispersion and correlation analysis of the collected research material, it was concluded that the following agricultural practices are the most preferable in terms of biometric and physiological indicators of growth and development of woody plants: 1) Maintaining the pre-irrigation level of soil moisture within 70–80 % of the full field moisture capacity, 2) Mixing plant and peat soil in a ratio of 1: 1 and 3) Monthly fertilizing with mineral complex fertilizer at the rate of 75 g / m2. The most effective covering materials in the conditions of the Mangistau desert for preventing moisture evaporation under green spaces are such covering materials as Zeba super sorbent, sludge from treatment facilities and medium and fine gravel. The results of the research were successfully tested during mass propagation of 107 species, forms and varieties of the most promising introduced plants from 32 genera and 17 families (65,340 containers in total).

Keywords: optimization, agricultural technology, woody plants, seedlings, containers, field experiment, survival rate, growth.

Introduction

Despite significant successes of Mangyshlak Experimental Botanical Garden (MEBG) on introduction and acclimatization of plants in landscaping and horticultural practice of various organizations in Mangistau is widespread use of cheap imported planting material, which is obviously unpromising, poorly resistant and low-decorative in local conditions, while proven for decades species and varieties do not find widespread use despite all the advantages and economic effect of their introduction. At present, the network of tree and shrub nurseries in Mangistau oblast is poorly developed due to the shortage of irrigation water. The nurseries mainly grow a narrow assortment of trees and shrubs and sell their seedlings and seedlings with bare root system, which significantly reduces the level of rooting of plants.

In our opinion, the most promising way to solve the problem of reproduction of both widely used in landscaping and new species of fruit and berry and ornamental trees and shrubs in unfavorable climatic conditions of the Mangistau desert is the cultivation of their planting material with closed root system (CRS) — in containers, vases, briquettes, pots and others. This guarantees not only a very high survival rate of crops (up to 100 %), but also significantly lengthens the terms of planting works, reduces the consumption of scarce and very expensive (over 200 tg/m^3) irrigation water due to local moistening of soil and reducing losses from infiltration and evaporation.

Comparative analysis of domestic and world experience of growing seedlings and saplings of fruit and berry and ornamental plants with closed root system (CRS) on the basis of literature sources [1–7] has shown that in the practice of nursery farming for a fairly short period of time accumulated a fairly large research material, which is mainly aimed at solving the problems of forest growing and reforestation in forest and forest-steppe natural zones and are not quite suitable for extra-arid climate, saline and low-humus soils of Mangistau in terms of plant assortment, regular irrigation regime and, in general, agrotechnics of cultivation. In this regard, in the botanical garden within the framework of research work on the grant theme: “Development of scientific-methodological and practical bases of cultivation and creation of nursery of fruit and berry and tree ornamental plants with closed root system in the conditions of the Mangistau desert”, the task of clarification and optimization of basic agrotechnical methods in relation to the desert zone of the region was set on the basis of laying field experiments with variants of irrigation regime, methods of soil substrate preparation, doses of mineral fertilizers and types of moisture management.

Experimental

The objects of research were 9 botanical species and forms of different degree of stability, growth forms, systematic affiliation and geographical origin, for which biometric and physiological indicators of growth and development were determined in field experiments on the study of agrotechnics and variance analysis of collected materials was carried out: *Platycladusorientalis* (L.) Franco, *Ulmus pumila* L., *Ailanthus altissima* (Mill.) Swingle, *Armeniaca vulgaris* Lam., *Salix alba f. pendula*, *Populus bolleana* Lauche., *Fraxinus lanceolata* Borkh., *Ligustrum vulgare* L. and *Gleditsia triacanthos* L.

The aim of the research is to optimize agrotechnics of growing seedlings of woody plants with closed root system in arid conditions of Mangistau by means of field experiments.

Drawing up the schemes of field experiments was based on the methodology of experimental work of B.A. Dospekhov [8]. Taking into account the dominating in Mangistau conditions limit factors of soil moisture deficiency and soil poverty, as well as the special importance of substrate preparation quality in growing planting material, the main field experiment is laid out two-factor, including simultaneously the options of maintaining pre-watering soil moisture and mixing plant soil with peat substrate. Three variants were chosen for soil moisture: 1) Maintaining pre-watering soil moisture level during the growing season within 50–60 % of the lowest (full field) moisture capacity (MC); 2) 60–70 % of MC; and 3) 70–80 % of MC. On preparation of soil substrate 4 variants of mixing plant and peat soil were laid down: 1) 1: 2; 2) 1: 1; 3) 2: 1 and 4) control (without peat addition).

To study the reaction of plants to the application of complex mineral fertilizer, a separate one-factor experiment consisting of 5 variants was set up: 1) application of mineral complex fertilizer kemira "Spring-Summer" at the rate of 25, 2) 50, 3) 75; 4) 100 g/m^2 monthly for plant feeding; 5) control (without feeding).

Repetition of experiments is 4-fold. On each of them 5 specimens of trees and shrubs were placed. In total, 3060 units of planting material were planted in vases with a useful volume of 8 liters in the field experiments.

Standard peat lime peat substrate of "Suliflor SF0" brand with neutral medium reaction (pH — 5.5 — 6.0), fine fraction, with NPK content — 100-50-100, produced in Lithuania, was used as an organic fertilizer. Structurally, 80 % of it consists of organic matter, which is a mixture of lowland and upland peat. For plant feeding was chosen complex mineral granular fertilizer Kemira "Spring-Summer" prolonged action, containing all the necessary macro- and microelements in the optimal ratio (NPK — 11,3-12-28, S, Ca, Mn, Cu, Mo, Mo, B, Fe, Zn), produced by CJSC "KemiraAgro" (Russia).

In general, 16-17, 60–70 — 26-27 and 70–80 % of MC — 39-40 plant irrigations were carried out during the irrigation season on the experiment variant 50-60 % of MC. Inter-irrigation period averaged 10-11, 6-7 and 4-5 days, respectively.

At the end of the growing season, height, root neck diameter, length, width, leaf area and weight were determined in all experimental plants. The rooting ability of introducers was calculated based on the results of their fall inventory.

The following methods were used for physiological experiments and observations: chlorophyll content in plant leaves by T.N. Godnev on a spectrophotometer [9]; total water content of leaves — by drying leaves to constant weight at a temperature of 100–105°C; transpiration intensity by A.A. Ivanov [10] and leaf plate area — by specific area.

Statistical processing of the obtained results was carried out according to the method of G.F. Lakin [11] with the use of Statgraphics Centurion XVI.I (2011) statistical software package.

Results and Discussion

As the main evaluation indicators of success of agrotechnical variants of field experiments, we considered the rooting rate and annual height growth of woody plants, the values of which closely depend on both the yield of quality planting material per unit area and the growth energy of introducers.

In a single-factor field experiment to study the effect of mineral fertilizer application doses on the growth and development of seedlings with MC, only *Gleditsia triacanthos* L. took root at 100 % regardless of the variant values (Table 1). "Good" (80–100 %) on average in the field experiment it is estimated in *Ailanthus altissima* (Mill.) Swingle and *Fraxinus lanceolata* Borkh.

Ulmus pumila L., *Armeniaca vulgaris* Lam., *Platycladus orientalis* (L.) Franco and *Ligustrum vulgare* L. took root "satisfactorily" (50–80 %). "Unsatisfactory" (25–50 %) rooting was characterized by *Salix alba f. pendula* and *Populus bolleana* Lauche. that was due to very late planting of cuttings.

The difference between the variants of monthly feeding of plants with mineral complex fertilizer is absent ($F_f < F_{05}$) only in two tree species with a weak requirement for soil fertility — *Ulmus pumila* L. and *Ailanthus altissima* (Mill.) Swingle. In the other introducers, the difference is significant at 5 % significance level and there is a steady tendency of increasing the value of rooting as the doses of mineral fertilizers increase from 0 to 100 g/m^2. However, the difference between 75 and 100 g/m^2 variants is insignificant or not pronounced at all.

For the two-factor field experiment on the effect of irrigation regime and substrate preparation on seedling growth and development, the highest rooting rate (97.9 %) was also found for *Gleditsia triacanthos* L. (Table 2). "Good", by 80–100 %, took root *Ulmus pumila* L., *Ligustrum vulgare* L. and *Fraxinus lanceolata* Borkh. At *Ailanthus altissima* (Mill.) Swingle, *Armeniaca vulgaris* Lam., *Platycladus orientalis* (L.) Franco is estimated as "satisfactory" (50–80 %). Very low survival rate was observed in cuttings of *Salix alba f. pendula* (17.9 %) and *Populus bolleana* Lauche. (25.0 %).

Most plants showed a stable tendency of increasing the rooting rate with increasing soil moisture and peat percentage, but up to a certain level and with different degree of reliability. For factor A the difference between the variants is reliable ($F_f > F_{05}$) for *Ulmus pumila* L., *Platycladusorientalis* (L.) Franco, *Ligustrum vulgare* L., *Gleditsia triacanthos* L. and *Fraxinus lanceolata* Borkh. The other species react weakly to the increase in soil moisture and there is no statistically significant difference in rooting ($F_f < F_{05}$). Woody plants are more responsive to factor B (percentage of peat in the substrate) in terms of rooting. The difference is significant at 5 % significance level for 6 species out of 9: *Ulmus pumila* L., *Salix alba f. pendula*, *Populus bolleana Lauche.*, *Platycladusorientalis* (L.) Franco, *Ligustrum vulgare* L. and *Fraxinus lanceolata* Borkh. (Tab. 2).

Table 1

Adoption rate of woody plants in a one-factor field experiment on the effect of mineral fertilizer application doses on the growth and development of seedlings with CRS (in percent)

Plants	Variant of experiment					
	Norms of monthly fertilization of plants with mineral Kemira "Spring-Summer" complex fertilizer					
	control	25 g/m^2	50 g/m^2	75 g/m^2	100 g/m^2	Average:
Ulmus pumila L.	55	60	60	70	65	62,0
Statistics:	$F_ф = 1.13$. $F_{05} = 3.26$. $S_x = 5.3$. $S_d = 7.5$. $HCP_{05} = 23.8$.					
Ailanthus altissima (Mill.) Swingle	95	90	95	95	95	94,0
Statistics:	$F_ф = 0.62$. $F_{05} = 3.26$. $S_x = 2.8$. $S_d = 4.0$. $HCP_{05} = 12.7$.					
Armeniaca vulgaris Lam.	60	65	70	80	75	70,0
Statistics:	$F_ф = 4.54$. $F_{05} = 3.26$. $S_x = 3.7$. $S_d = 5.2$. $HCP_{05} = 16.5$.					
Salix alba f. pendula	25	40	40	45	60	42,0
Statistics:	$F_ф = 7.24$. $F_{05} = 3.26$. $S_x = 3.6$. $S_d = 6.5$. $HCP_{05} = 20.7$.					
Populus bolleana Lauche.	25	25	25	35	55	31,0
Statistics:	$F_ф = 13.91$. $F_{05} = 3.26$. $S_x = 2.4$. $S_d = 3.4$. $HCP_{05} = 10.8$.					
Platycladus orientalis (L.) Franco	50	55	55	60	65	57
Statistics:	$F_ф = 3.60$. $F_{05} = 3.26$. $S_x = 3.4$. $S_d = 4.9$. $HCP_{05} = 15.6$.					
Ligustrum vulgare L.	60	60	75	75	70	68,0
Statistics:	$F_ф = 10.96$. $F_{05} = 3.26$. $S_x = 2.6$. $S_d = 3.7$. $HCP_{05} = 11.9$.					
Gleditsia triacanthos L.	100	100	100	100	100	100,0
Statistics:	$F_ф = 0.00$. $F_{05} = 3.26$. $S_x = 0.0$. $S_d = 0.0$. $HCP_{05} = 0.0$.					
Fraxinus lanceolata Borkh.	70	80	80	85	85	80,0
Statistics:	$F_ф = 6.80$. $F_{05} = 3.26$. $S_x = 3.3$. $S_d = 4.7$. $HCP_{05} = 14.9$.					
Average:	59,4	65,0	63,3	67,2	69,4	64,8
Statistics:	$F_ф = 5.42$. $F_{05} = 3.26$. $S_x = 3.0$. $S_d = 4.4$. $HCP_{05} = 14.0$.					

Note. F_f — actual difference significance criterion; F_{05} — Fisher's criterion at the significance level of 5 %; S_x — generalized mean error; S_d — mean difference error; HCP_{05} — smallest significant difference at the significance level of 5 %.

Table 2

Adoption rate of woody plants in a two-factor field experiment on the influence of irrigation regime and substrate preparation on the growth and development of seedlings with MC (in percent)

Plant, Variant of experiment – Factor A	Variant meaning, % from NV	Variant of experience — factor B				
		Ratio of plant and peat soil in substrate preparation				
		Control	2: 1	1: 1	1: 2	Average
Ulmus pumila L.						
Pre-watering soil moisture	50-60	85	90	85	90	87,5
	60-70	60	75	80	95	77,5
	70-80	80	90	95	100	91,3
Average:		75,0	85,0	86,7	95,0	85,4
Statistics: $F_{\phi A} = 44.40$. $F_{05A} = 3.23$. $F_{\phi B} = 39.50$. $F_{05B} = 2.79$. $S_x = 4.4$. $S_d = 6.3$. $HCP_{05} = 12.6$.						
Ailanthus altissima (Mill.) Swingle						
Pre-watering soil moisture	50-60	65	60	80	75	70,0
	60-70	75	70	75	70	72,5
	70-80	60	80	85	75	75,0
Average:		66,7	70,0	80,0	73,3	72,5
Statistics: $F_{\phi A} = 0.14$. $F_{05A} = 3.23$. $F_{\phi B} = 0.17$. $F_{05B} = 2.79$. $S_x = 234$. $S_d = 33.1$. $HCP_{05} = 66.6$.						
Armeniaca vulgaris Lam.						
Pre-watering soil moisture	50-60	70	75	65	100	77,5
	60-70	75	70	70	100	78,8
	70-80	75	80	70	100	81,2
Average:		73,3	75,0	68,3	100,0	79,2
Statistics: $F_{\phi A} = 186$. $F_{05A} = 3.23$. $F_{\phi B} = 0.17$. $F_{05B} = 2.79$. $S_x = 2.3$. $S_d = 3.2$. $HCP_{05} = 6.4$.						
Salix alba f. pendula						
Pre-watering soil moisture	50-60	0	0	35	45	20,0
	60-70	0	0	40	45	21,2
	70-80	0	0	15	35	12,5
Average:		0,0	0,0	30,0	41,7	17,9
Statistics: $F_{\phi A} = 1.83$. $F_{05A} = 3.23$. $F_{\phi B} = 11.49$. $F_{05B} = 2.79$. $S_x = 7.0$. $S_d = 9.9$. $HCP_{05} = 19.9$.						
Populus bolleana Lauche.						
Pre-watering soil moisture	50-60	0	45	50	0	23,8
	60-70	0	40	55	0	23,8
	70-80	0	35	75	0	27,5
Average:		0,0	40,0	60,0	0,0	25,0
Statistics: $F_{\phi A} = 2.85$. $F_{05A} = 3.23$. $F_{\phi B} = 9.57$. $F_{05B} = 2.79$. $S_x = 7.0$. $S_d = 9.9$. $HCP_{05} = 19.9$.						
Platycladus orientalis (L.) Franco						
Pre-watering soil moisture	50-60	55	70	70	95	72,5
	60-70	65	75	80	90	77,5
	70-80	80	85	85	100	87,5
Average:		66,7	76,7	78,3	95,0	79,2
Statistics: $F_{\phi A} = 55.90$. $F_{05A} = 3.23$. $F_{\phi B} = 187.50$. $F_{05B} = 2.79$. $S_x = 1.6$. $S_d = 2.2$. $HCP_{05} = 4.4$.						
Ligustrum vulgare L.						
Pre-watering soil moisture	50-60	75	85	85	90	83,8
	60-70	65	80	80	90	78,8
	70-80	80	90	90	100	90,0
Average:		73,3	85,0	85,0	93,3	84,2
Statistics: $F_{\phi A} = 19.56$. $F_{05A} = 3.23$. $F_{\phi B} = 46.81$. $F_{05B} = 2.79$. $S_x = 3.6$. $S_d = 5.1$. $HCP_{05} = 10.2$.						

Continuation of Table 2

Plant, Variant of experiment – Factor A	Variant meaning, % from NV	Variant of experience — factor B				
		Ratio of plant and peat soil in substrate preparation				
		Control	2: 1	1: 1	1: 2	Average
Gleditsia triacanthos L.						
Pre-watering soil moisture	50-60	100	95	95	95	96,2
	60-70	95	95	100	100	97,5
	70-80	100	100	100	100	100,0
Average:		98,3	96,7	98,3	98,3	97,9
Statistics: $F_{\phi A} = 4.10$. $F_{05A} = 3.23$. $F_{\phi B} = 0.57$. $F_{05B} = 2.79$. $S_x = 1.9$. $S_d = 2.6$. $HCP_{05} = 5.2$.						

The value of rooting rate in nursery practice depends very much on the quality of planting material and observance of optimal planting dates. Therefore, its correlation coefficients with the rate of monthly feeding of plants with mineral complex fertilizer, pre-watering soil moisture and peat-soil content in the substrate do not look as convincing as expected, respectively — 0.49; 0.27 and 0.60 (Table 3), which is associated with the relatively cool and wet summer period of recent years. The same reason can be explained by too complicated derived formulaic relationships of rooting percentage with agrotechnical parameters — exponential, steppe and multiplicative types.

Table 3

Correlation of woody plant establishment with pre-watering soil moisture, peat-soil content in soil substrate and rate of monthly feeding with mineral complex fertilizer

Plants	Pre-watering soil moisture		The content of peat in the soil substrate		Feeding rate mineral fertilizer	
	Coefficient					
	Correlation	Determination	Correlation	Determination	Correlation	Determination
Ulmus pumila L.	0.41	0.17	0.47	0.22	0.51	0.26
Ailanthus altissima (Mill.) Swingle	0.14	0.02	0.14	0.02	0.33	0.11
Armeniaca vulgaris Lam.	0.01	0.00	0.92	0.85	0.76	0.57
Salix alba f. pendula	0.22	0.05	0.67	0.45	0.22	0.05
Populus bolleana Lauche.	026	0.07	0.62	0.38	0.90	0.81
Platycladus orientalis (L.) Franco	046	0.21	0.80	0.64	0.62	0.38
Ligustrum vulgare L.	043	0.18	0.67	0.45	0.45	0.20
Gleditsia triacanthos L.	0.39	0.15	0.17	0.03	0.00	0.00
Fraxinus lanceolata Borkh.	0.14	0.02	0.91	0.83	0.61	0.38
Average:	0.27	0.07	0.60	0.36	0.49	0.24
Critical value of the correlation coefficient at the significance level of 5 %	0.27	-	0.27	-	0.44	-

Judging by the graphical representation of the derived regression equations, the increase in rooting rate with the growth of the selected agrotechnical factors is clearly visible. However, at detailed analysis of research materials it can be stated that the most preferable for its value are the following variants of field experiments: maintenance of pre-watering level of soil moisture within 70–80 % of CM, mixing of vegetable and peat soil in the ratio of 1: 1 and monthly feeding with mineral complex fertilizer at the rate of 75 g/m^2.

According to the value of height increment, the difference between the variants in the single-factor field experiment is significant at 5 % significance ($F_f > F_{05}$) for all species of woody plants (Table 4). According to the reaction of height increment to the increase in doses of mineral fertilizer feeding, the introducers are divided into two types:

- "increasing" (from 0 to 100 g/m^2) — *Ailanthus altissima* (Mill.) Swingle, *Armeniaca vulgaris* Lam., *Salix alba f. pendula*, *Populus bolleana* Lauche., *Ligustrum vulgare* L., *Gleditsia triacanthos* L.; and
- "variable" (with a maximum at the variant 75 g/m^2) — *Ulmus pumila* L., *Platycladus orientalis* (L.) Franco and *Fraxinus lanceolata* Borkh.

Table 4

Height increment of woody plants in a one-factor field experiment on studying the effect of mineral fertilizer application doses on the growth and development of Seedlings with CRS (in cm)

Plants	Variant of experiment					
	Norms of monthly fertilization of plants with mineral Kemira "Spring-Summer" complex fertilizer					
	control	control	control	control	control	control
Ulmus pumila L.	18.5	30.4	27.3	41.2	39.9	31.5
Statistics:	$F_ф$ = 350.00. F_{05} = 3.26. S_x = 1.6. S_d= 2.2. HCP_{05} = 7.0.					
Ailanthus altissima (Mill.) Swingle	9.0	10.4	13.3	14.7	15.9	12.7
Statistics:	$F_ф$ = 45.00. F_{05} = 3.26. S_x = 1.1. S_d= 1.6. HCP_{05} = 5.1.					
Armeniaca vulgaris Lam.	3.0	15.0	23.0	23.9	30.9	19.2
Statistics:	$F_ф$ = 113.75. F_{05} = 3.26. S_x = 1.0. S_d= 1.4. HCP_{05} = 4.5.					
Salix alba f. pendula	39.7	65.4	68.1	90.5	100.8	72.9
Statistics:	$F_ф$ = 27.52. F_{05} = 3.26. S_x = 4.1. S_d= 5.8. HCP_{05} = 18.4.					
Populus bolleana Lauche.	9.0	23.9	47.9	45.4	46.0	34.4
Statistics:	$F_ф$ = 26.60. F_{05} = 3.26. S_x = 3.2. S_d= 4.5. HCP_{05} = 14.2.					
Platycladus orientalis (L.) Franco	10.4	10.4	11.8	20.4	20.0	14.6
Statistics:	$F_ф$ = 21.62. F_{05} = 3.26. S_x = 1.4. S_d= 2.0. HCP_{05} = 6.4.					
Ligustrum vulgare L.	7.9	15.7	29.0	30.0	38.1	24.1
Statistics:	$F_ф$ = 10.78. F_{05} = 3.26. S_x = 2.8. S_d = 3.9. HCP_{05} = 12.4.					
Gleditsia triacanthos L.	20.9	26.2	31.4	40.5	45.2	32.8
Statistics:	$F_ф$ = 6.32. F_{05} = 3.26. S_x = 3.2. S_d= 4.5. HCP_{05} = 14.2.					
Fraxinus lanceolata Borkh.	15.5	15.4	15.2	18.8	18.6	16.7
Statistics:	$F_ф$ = 4.67. F_{05} = 3.26. S_x = 0.9. S_d = 1.2. HCP_{05} = 3.8.					
Average:	14.9	23.6	29.7	36.2	39.5	28.8
Statistics:	$F_ф$ = 6.74. F_{05} = 3.26. S_x = 2.1. S_d= 3.0. HCP_{05} = 9.5.					

In the two-factor experiment, the combination of soil moisture and the percentage of peat in the substrate also had a statistically significant effect on the growth of the overwhelming majority of taxa, except for *Armeniaca vulgaris* Lam. (factors A and B) and *Populus bolleana* Lauche (factor B). However, different variants are optimal for their growth vigor (Table 5):

- For *Ulmus pumila* L. (29.7 cm), *Salix alba f. pendula* (66.4 cm) — pre-watering moisture threshold of 60–70 % of MC and ratio of ratite and peat soil in the substrate 1: 1;

- *Ailanthus altissima* (Mill.) Swingle (26.9 cm) and *Gleditsia triacanthos* L. — 70–80 and 1: 2, respectively;

- *Ligustrum vulgare* L. (23.3 cm) and *Fraxinus lanceolata* Borkh. (42.8 cm) — 60–70 and 1: 2;

- *Armeniaca vulgaris* Lam. (20.9 cm), *Platycladus orientalis* (L.) Franco (21.7 cm) and *Populus bolleana* Lauche. (40.7 cm) — 70–80 and 1: 1.

Annual height growth is characterized by a more pronounced variation (up to 47.7–94.1 %) in the variants of the experiment compared to the rooting rate, and its dependence on agrotechnical variants looks much tighter. Thus, if the correlation coefficient of rooting percentage with the rate of monthly feeding of woody plants with mineral complex fertilizer is 0.49, pre-watering soil moisture — 0.27 and the content of peat in the soil substrate — 0.60, then the height increment — respectively: 0.84; 0.35 and 0.62 (Table 6). These agrotechnical factors, judging by the value of the coefficient of determination, determine up to 69–95 % of all changes in growth energy by height.

Table 5

Height increment of woody plants in a two-factor field experiment on the influence of irrigation regime and substrate preparation on the growth of seedlings of CRS (in centimeters)

Plant, variant of experiment – factor A	Variant values, %	Variants of experiments — factor B				
		Ratio of plant and peat soil for substrate preparation				
		Control	2: 1	1: 1	1: 2	Average
Ulmus pumila L.						
Pre-irrigation soil humidity	50-60	15.5	13.5	19.7	16.7	16.4
	60-70	20.4	29.3	29.7	25.0	26.1
	70-80	11.4	11.7	19.7	16.9	14.9
Average:		15.8	18.2	23.0	19.5	19.1
Statistics: $F_{\phi A} = 197.00$. $F_{05A} = 3.23$. $F_{\phi B} = 36.67$. $F_{05B} = 2.79$. $S_x = 0.8$. $S_d = 1.2$. $HCP_{05} = 2.4$.						
Ailanthus altissima (Mill.) Swingle						
Pre-irrigation soil humidity	50-60	11.2	11.1	17.1	18.6	14.5
	60-70	11.9	7.3	17.9	20.7	14.5
	70-80	13.6	12.7	17.9	26.9	17.8
Average:		12.2	10.4	17.6	22.1	15.6
Statistics: $F_{\phi A} = 3.47$. $F_{05A} = 3.23$. $F_{\phi B} = 22.27$. $F_{05B} = 2.79$. $S_x = 1.9$. $S_d = 2.7$. $HCP_{05} = 5.4$.						
Armeniaca vulgaris Lam.						
Pre-irrigation soil humidity	50-60	9.8	9.4	18.3	16.0	13.4
	60-70	3.8	8.8	14.5	10.8	9.5
	70-80	6.1	10.6	20.9	15.3	13.2
Average:		6.6	9.6	17.9	14.0	12.0
Statistics: $F_{\phi A} = 1.86$. $F_{05A} = 3.23$. $F_{\phi B} = 0.17$. $F_{05B} = 2.79$. $S_x = 2.3$. $S_d = 3.2$. $HCP_{05} = 6.4$.						
Salix alba f. pendula						
Pre-irrigation soil humidity	50-60	-	-	24.4	63.8	44.1
	60-70	-	-	33.5	65.6	49.6
	70-80	-	-	31.5	66.4	49.0
Average:		-	-	29.8	65.3	47.5
Statistics: $F_{\phi A} = 449.26$. $F_{05A} = 3.23$. $F_{\phi B} = 309.84$. $F_{05B} = 2.79$. $S_x = 2.1$. $S_d = 3.1$. $HCP_{05} = 6.2$.						
Populus bolleana Lauche.						
Pre-irrigation soil humidity	50-60	-	31.4	37.9	-	34.7
	60-70	-	34.3	37.7	-	36.0
	70-80	-	33.9	46.6	-	40.3
Average:		-	33.2	40.7	-	37.0
Statistics: $F_{\phi A} = 5.38$. $F_{05A} = 3.23$. $F_{\phi B} = 1.19$. $F_{05B} = 2.79$. $S_x = 15.2$. $S_d = 21.6$. $HCP_{05} = 43.4$.						
Platycladusorientalis (L.) Franco						
Pre-irrigation soil humidity	50-60	9.1	12.5	8.7	12.4	10.7
	60-70	9.7	12.7	12.1	14.1	12.2
	70-80	19.1	12.2	21.7	16.5	15.9
Average:		10.6	12.5	14.2	14.3	12.9
Statistics: $F_{\phi A} = 48.00$. $F_{05A} = 3.23$. $F_{\phi B} = 21.60$. $F_{05B} = 2.79$. $S_x = 1.1$. $S_d = 1.6$. $HCP_{05} = 3.2$.						
Ligustrum vulgare L.						
Pre-irrigation soil humidity	50-60	6.0	10.7	14.0	14.8	11.4
	60-70	11.1	13.8	30.5	42.8	24.6
	70-80	11.2	13.9	33.1	36.3	23.6
Statistics: $F_{\phi A} = 432.50$. $F_{05A} = 3.23$. $F_{\phi B} = 651.00$. $F_{05B} = 2.79$. $S_x = 0.7$. $S_d = 1.0$. $HCP_{05} = 2.0$.						
Average:		9.4	12.8	25.9	31.3	19.9
Gleditsia triacanthos L.						
Pre-irrigation soil humidity	50-60	18.5	26.7	28.8	41.9	29.0
	60-70	15.6	19.3	27.8	58.6	30.3
	70-80	19.7	23.3	30.0	69.2	35.6
Average:		17.9	23.1	28.9	56.6	31.6
Statistics: $F_{\phi A} = 299.20$. $F_{05A} = 3.23$. $F_{\phi B} = 284.33$. $F_{05B} = 2.79$. $S_x = 1.5$. $S_d = 2.1$. $HCP_{05} = 4.2$.						

Continuation of Table 5

Plant, variant of experiment – factor A	Variant values, %	Variants of experiments — factor B				
		Ratio of plant and peat soil for substrate preparation				
		Control	2: 1	1: 1	1: 2	Average
Fraxinus lanceolata Borkh.						
Pre-irrigation soil humidity	50-60	2.2	20.8	15.0	16.0	13.5
	60-70	2.1	16.1	15.7	25.4	14.8
	70-80	5.5	18.8	19.6	23.3	16.8
Average:		3.3	18.6	16.8	21.6	15.0
Statistics: $F_{\phi A}$ = 3.38. F_{05A} = 3.23. $F_{\phi B}$ = 60.54. F_{05B} = 279. S_x = 1.8. S_d = 2.5. HCP_{05} = 5.0.						
Average for all plant species:		10.8	17.3	23.9	30.6	20.6
Statistics: $F_{\phi A}$ = 44.40. F_{05A} = 3.23. $F_{\phi B}$ = 39.50. F_{05B} = 2.79. S_x = 4.4. S_d = 6.3. HCP_{05} = 126.						

Table 6

Correlation of height increment of woody plants with pre-watering soil moisture, peat-soil content in soil substrate and rate of monthly feeding with mineral complex fertilizer

Plants	Pre-irrigation soil humidity		The content of peat in the soil substrate		Rate of fertilization with mineral fertilizer	
	Coefficient					
	Correlation	Determination	Correlation	Determination	Correlation	Determination
Ulmus pumila L.	0.81	0.66	0.43	0.18	0.97	0.94
Ailanthus altissima (Mill.) Swingle	0.24	0.06	0.75	0.56	0.79	0.62
Armeniaca vulgaris Lam.	0.10	0.01	0.92	0.85	0.97	0.94
Salix alba f. pendula	0.69	0.48	0.71	0.50	0.90	0.81
Populus bolleana Lauche.	0.45	0.20	0.37	0.12	0.94	0.88
Platycladus orientalis (L.) Franco	0.77	0.59	0.36	0.13	0.80	0.64
Ligustrum vulgare L.	0.51	0.26	0.77	0.59	0.74	0.55
Gleditsia triacanthos L.	0,.52	0.27	0.38	0.14	0.81	0.66
Fraxinus lanceolata Borkh.	0.17	0.03	0.87	0.76	0.63	0.40
Average:	0.35	0.12	0.62	0.38	0.84	0.70
Critical value of the correlation coefficient at the significance level 5 %	0.27	-	0.27	-	0.44	-

The graphs constructed according to the derived formulas on the data averaged for all experimental plants reflect only a general trend of growth increase with increasing values of the selected agrotechnical parameters. At the same time, taking into account the need to save organic and mineral fertilizers, we conclude that the most favorable conditions for the growth of introducers in height are created by combining such variants of field experiments as: mixing vegetable and peat soil in the ratio of 1:1, monthly feeding with mineral complex fertilizer at the rate of 75 g/m^2 and maintaining pre-watering threshold of soil moisture — 70–80 % of MC.

Leaf plate size and physiological parameters of growth and development were studied as additional indicators to rooting and height increment in order to reveal regularities of woody plants reaction to changing habitat conditions under the influence of artificially created agrotechnical factors depending on their biological properties and needs and adaptive qualities.

In principle, the extreme variant values of soil moisture and fertilizer application doses for the experimental taxa are within the limits of habitual growing conditions, but they should be strongly manifested on their habitus and morphophysiological characteristics. However, in both one- and two-factor field experiments, the relationship between the variants in terms of leaf size, weight, and area generally follows the same pattern as the difference in height increment, but in a less pronounced manner. With increasing percentage of peat-soil in the substrate and norms of mineral fertilizers application, there is only a tendency to increase all leaf parameters, and low soil moisture leads to the development of its xeromorphic structure.

The raw weight of leaf lamina was chosen as an integral indicator of leaf morphology of woody plants. Among the experimental species, the correlation (r = 0.89-0.93) of weight dependence with the dose of mineral fertilizer application was confirmed only in three species: *Ailanthus altissima* (Mill.) Swingle, *Salix alba f. pendula*, *Populus bolleana* Lauche. and *Ligustrum vulgare* L. In other taxa, the relationship with this agronomic factor is not significant at 5 %, especially in common apricots (r = -0,40).

In the two-factor field experiment, the correlation of leaf weight with pre-watering soil moisture is statistically reliable (r = 0.94) only in *Populus bolleana* Lauche. as a moisture-loving species; with the content of peat in the soil substrate — *Ailanthus altissima* (Mill.) Swingle, *Armeniaca vulgaris* Lam., *Salix alba f. pendula* и *Ligustrum vulgare* L. (r = 0,94).

Among physiological indicators of woody plants, transpiration is one of the main ones from the point of view of habitat improvement in the Mangistau desert. The issue of physiological water yield is also relevant because in conditions of soil moisture limit, the process of maximizing plant productivity is reduced to simultaneous optimization of solar radiation absorption and water consumption through transpiration. Moreover, transpiration is an integral physiological process of plant organism and is extremely necessary for its vital activity as a protective mechanism against leaf overheating under direct exposure to sunlight, as a creator of continuous flow of water and mineral nutrients from the root system to other anatomical organs.

In our experiments, according to the average values of transpiration intensity (TI), all introducers were divided into two groups: weakly transpiring (less than 200 mg/g of raw leaf weight per hour) — *Platycladus orientalis* (L.) Franco; medium-transpiring (200–500 mg/g of raw leaf weight per hour) — *Ulmus pumila* L., *Salix alba f. pendula*, *Ligustrum vulgare* L., and *Fraxinus lanceolata* Borkh.

Since transpiration is the final stage of irrigation water cycle in soil and plant, its conjugation with soil moisture and closely related leaf water content is undoubted even from the logical point of view. This has been experimentally confirmed by a number of authors [12–15]. With decreasing soil moisture, the level of transpiration decreases. The less water in the soil, the weaker the water supply of the plant. Reduction of water content in the plant organism automatically reduces the transpiration process due to the auricular and extraauricular regulation.

According to the data of correlation analysis, soil moisture determines only 22.0 % of changes in transpiration intensity (r = 0.39), which is less than expected and is primarily due to its dependence on other factors, especially meteorological (light intensity, relative humidity and air temperature, wind speed, etc.). Moreover, for different woody plants the correlation coefficient varies in very wide ranges — from 0.15 to 0.88. Its maximum value was recorded for the tree of mesophytic series — *Salix alba f. pendula*. The closeness of TI correlation with the rate of monthly feeding with mineral fertilizer (r = 0.15) and the content of peat-soil in the substrate (r = -0.11) is even lower, and its change with the growth of these factors is practically inconsistent with the data on plant height increment.

In the process of research, the content of chlorophyll in leaves, which is the most important component of their photosynthetic apparatus, was also determined. The relationship between photosynthesis and water regime is mainly due to the influence that water has on the whole complex of processes of plant organism vital activity. It is noted, in particular, suppression or enhancement of synthesis of green pigments. Preservation of plant viability under water deficiency is closely related to the functioning of pigment systems. The determining factor affecting the pigment complex of leaves is water availability. Plants with high drought tolerance lose less water and their chlorophyll is more stable [16]. Considering that protein substances play a major role in the development of water-holding capacity of tissues and that a significant part of proteins, especially soluble proteins, is concentrated in chloroplasts, we can assume the influence of chlorophyll content on water-holding capacity and its relationship with lipoprotein complexes [17].

According to the materials of our studies, the change in chlorophyll content in leaves with the growth of variant values of mineral fertilizer rates, soil moisture and the ratio of vegetable and peat soil in the substrate almost completely coincides with the growth in height. Thus, in the single-factor experiment, when increasing fertilizer rates from 0 to 100 g/m^2, the percentage of chorophyll per raw leaf weight increases from 0.47 to 0.66 on average. Increasing the pre-watering threshold of soil moisture from 50–60 to 70–80 % of MC in the two-factor experiment is accompanied by an increase in the content of this pigment from 0.49 to 0.55-0.70, and the percentage of peat in the substrate from 0 to 67 (1: 2) — from 0.53 to 0.63 %. It is interesting to note that coniferous trees are more saturated with chlorophyll (0.70 %) compared to deciduous trees (0.50-0.58 %) regardless of the values of agrotechnical factors.

Judging by the results of correlation analysis, chlorophyll formation is more significantly influenced by the improvement of soil nutrient regime through the application of complex mineral fertilizers than by the

irrigation regime and the method of substrate preparation. The correlation coefficient of its content with these factors is, respectively, 0.78; 0.45 and 0.45. The chlorophyll content of *Salix alba f.* pendula is most closely related to the rate of fertilization (r=0.94) and *Ligustrum vulgare* L. (0.95), with pre-watering humidity — *Ulmus pumila* L. (0.75), *Salix alba f. pendula*(0.76) and *Platycladus orientalis* (L.) Franco (0.53) and with the percentage of peat in the substrate — *Ulmus pumila* L. (0.56), *Salix alba f. Pendula* (0.58) and *Ligustrum vulgare* L. (0.68).

For both field experiments, we also calculated correlation and determination coefficients of height increment, as the main indicator of success of growing conditioned planting material, with transpiration rate and chlorophyll content. Due to high variability and strong dependence on meteorological factors, the correlation of transpiration intensity with the value of growth is generally unreliable at the 5 % level of significance (r=0.11-0.18), and chlorophyll content, on the contrary, is at a fairly high level (r=0.61-0.79). Thus, the saturation of leaves with this pigment is a rather reliable physiological indicator of successful growth and development of plants with CRS.

Due to sufficiently high correlation of chlorophyll content (CHL) with agrotechnical factors, it was possible to derive reliable by significance regression equations of exponential and multiplicative type averaged for the whole group of experimental plants. The formula relationship between CHL and mineral fertilizer application rates is characterized by a gradual increase in the dependent variable up to the rate of mineral fertilizer application 35–40 g/m^2, then its value begins to increase rapidly and reaches at 100 g/m^{2-} 0.70 %. The dependence of CHL and pre-watering soil moisture is close to linear in appearance, but a little bent at the value of soil moisture 65 % of MC. According to the graph of the relationship between CHL and the content of peat in the soil substrate clearly shows that a sharp increase in the first parameter occurs when changing the second in the range from 50 to 80 %, but still in percentage terms, the content of chlorophyll changes here insignificantly — no more than 0.04 %.

It should be noted that in recent years, to study the effectiveness of the use of various moisture-retaining materials in the cultivation of seedlings with a closed root system in the container nursery, another one-factor field experiment was also laid in 5 variants: 1) control (without shelter); 2) Zeba super-sorbent; 3) gravel; 4) sewage treatment plant sludge and 5) sawdust with the involvement of 10 species and forms of woody plants: *Platycladus orientalis* (L.) Franco, *Ulmus pumila* L., *Ailanthus altissima* (Mill.) Swingle, *Armeniaca vulgaris* Lam., *Gleditsia triacanthos* L., *Salix alba f. pendula*, *Morus alba* L., *Sophora japonica* L., *Salix alba f. piramidalis* and *Ligustrum vulgare* L.

Due to the autonomy of the root system in the presence of a container, localization of irrigation and differences in bioecological properties, the selected woody plants reacted differently to the type of water retention material used. At the same time, the general trend is that they take root better in the Zeba option, and grow faster in height when covered with sewage sludge due to additional supply of nutrients. The greatest water saving occurs when sawdust is used — 77.8 % (about 5000 m^3/ha) and almost equally — sludge and gravel 83.5–84.4 % (3000–3200 m^3/ha).

According to the conducted evaluation of economic efficiency, the incurred costs for all variants of the field experiment are recouped in one period of vegetation, but with a significant difference in profitability between the use of super-sorbent Zeb (5.7 %) and other types of sheltering materials. The best economic indicators have the use of sawdust (46.6 %) and sludge (41.9 %).

Conclusion

Thus, based on the analysis of the obtained research material it was concluded that the following agrotechnical practices are the most preferable in terms of biometric and physiological indicators of growth and development of woody plants: 1) — maintenance of pre-watering level of soil moisture within 70–80 % of NV, 2) — mixing of vegetable and peat soil in the ratio of 1: 1 and 3) — monthly feeding with mineral complex fertilizer at the rate of 75 g/m^2.The most effective in the conditions of the Mangistau desert to prevent evaporation of moisture under green plantations are such covering materials as Zeb super-sorbenta, sludge of sewage treatment plants and gravel of medium and fine fractions.

In recent years, the results of research have been successfully tested in the mass propagation of 107 species, forms and varieties of the most promising introducers from 32 genera and 17 families (a total of 65340 containers). In general, the creation of the first specialized nursery in the region on the basis of the MEBG with the application of scientifically sound cultivation technology will contribute to meeting the needs of horticultural and landscaping organizations in seedlings and seedlings of high quality and a wide

range of assortment to solve, ultimately, the problems of increasing the productivity of horticultural and landscaping organizations.

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Ауылшаруашылығын өсіру технологиясын оңтайландырудың негізгі бағыттары жабық тамыр жүйесі бар ағаш өсімдіктерінің көшеттері Маңғыстау шөлінің құрғақ жағдайында

Зерттеу жұмысының мақсаты — Маңғыстаудың құрғақ жағдайында жабық тамыр жүйесі бар ағаш өсімдіктерінің көшеттерін өсіру агротехникасының далалық тәжірибелерін отырғызу арқылы оңтайландыру. Жиналған зерттеу материалының дисперсиялық және корреляциялық талдауы негізінде келесі агротехникалық әдістер ағаш өсімдіктерінің өсуі мен дамуының биометриялық және физиологиялық көрсеткіштері бойынша ең қолайлы деген қорытынды жасалған: 1) топырақ ылғалдылығының алдын-ала деңгейін толық далалық ылғал сыйымдылығының 70-80% шегінде ұстап тұру, 2) 1:1 қатынасында өсімдік пен шымтезек топырағын араластыру және 3) 75 г/м^2 мөлшерінде

минералды кешенді тыңайтқышпен ай сайын құнарландыру. Маңғыстау шөлі жағдайында жасыл желектер астындағы ылғалдың буланууын болдырмау үшін ең тиімдісі Зеб суперсорбентін, тазарту қондырғыларын орнату және орта және ұсақ фракциялардың қиыршық тастары сияқты жабын материалдары. Зерттеу нәтижелері 32 тұқымдас және 17 туыстың (барлығы 65 340 контейнер) ең перспективалы интродукциялық өсімдіктердің 107 түрін, формалары мен сорттарын жаппай көбейту кезінде сәтті сынақтан өтті.

Кілт сөздер: оңтайландыру, ауылшаруашылық технологиясы, ағаш өсімдіктер, көшеттер, контейнерлер, егістік тәжірибесі, тіршілік ету деңгейі, өсу.

И.Ф. Белозеров, Н.А. Толеп, Ф.У. Умирбаева, А.А. Назарова, С.Ж. Бергенкулова

Основные направления оптимизации агротехники выращивания саженцев древесных растений с закрытой корневой системой в аридных условиях пустыни Мангистау

Цель настоящего исследования — оптимизация путем закладки полевых опытов агротехники выращивания саженцев древесных растений с закрытой корневой системой в аридных условиях Мангистау. На основе дисперсионного и корреляционного анализа собранного исследовательского материала сделан вывод о том, что наиболее предпочтительными по биометрическим и физиологическим показателям роста и развития древесных растений являются следующие агротехнические приемы: 1) поддерживание предполивного уровня почвенной влажности в пределах 70–80 % от полной полевой влагоемкости; 2) смешивание растительного и торфяного грунта в соотношении 1: 1 и 3) ежемесячная подкормка минеральным комплексным удобрением из расчета 75 г/м^2. Самыми эффективными в условиях пустыни Мангистау для предотвращения испарения влаги под зелеными насаждениями являются такие укрывные материалы, как суперсорбент Зеба, осадок очистных сооружений и гравий средней и мелкой фракции. Результаты исследований были успешно апробированы при проведении массового размножения 107 видов, форм и сортов наиболее перспективных интродуцентов из 32 родов и 17 семейств (всего 65340 контейнеров).

Ключевые слова: оптимизация, агротехника, древесные растения, саженцы, контейнеры, полевой опыт, приживаемость, прирост.

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Species diversity of wild fruit plants of the natural flora of the Kazakh Altai

The purpose of this work was identification of modern species diversity of wild fruit and berry plants in the flora of the Kazakhstan Altai and their ranking according to a set of biological indicators. As a result of studying the biodiversity of vascular plants of the Kazakhstan Altai, using the route-reconnaissance method, it was established that 52 species of fruit and berry plants belonging to 22 genera and 12 families grow on its territory. The largest number of species taxa is represented by 3 families: Rosaceae, Caprifoliaceae, Grossulariaceae, which contain 29 species, which is 55.77 % of the total. Among plant communities with the participation of fruit and berry species, forest (26 %) and meadow associations (23 %) occupy a dominant position, synanthropic phytocenoses with the participation of *Solanum dulcamara* and *S. nigrum* are also established in abandoned garden plots of settlements in the region. The growth of 7 alien fruit and berry species was identified: *Alkekengi officinarum*, *Berberis vulgaris, Malus baccata, Ribes aureum, Sambucus racemosa*, *Sorbus aucuparia*, *Symphoricarpos albus,* of which only *Malus baccata* formed its own communities. According to life forms, fruit and berry species are represented by trees, shrubs, dwarf shrubs, subshrubs, and herbaceous perennials. Shrubs dominate by 36 species (69.2 %). In relation to the moisture factor, the identified species are ranked by 6 ecological groups, where mesophytes predominate — 36 species (69.2 %). Of the fruit and berry species, 3 species are currently protected at the state level: *Daphne altaica*, *Paris quadrifolia* and *Vaccinium microcarpum,* included in the Red Book of Kazakhstan with the status of rarity category II.

Keywords: life forms, alien species, Kazakhstan Altai, location, fruit and berry plant species, ecological groups.

Introduction

Along with the Convention on Biodiversity, which provides special attention to the issues of studying, preserving and protecting biological diversity as a guarantor of ecosystem sustainability, in 2002 the 6th Conference of the Parties to the Convention adopted the Global Strategy for Plant Conservation (GSPC). At the same time, the second target setting defines the task of regional plant protection, which would take into account the specifics of the regions, since the ongoing process of global climate change and anthropogenic pressures threaten the preservation of natural vegetation and the habitat itself. At the present stage, research on the study of the genetic potential of wild fruit and berry plants and the preservation of their gene pool for solving food security, in the implementation of monitoring for the implementation of scientifically based conservation measures are relevant.

The aim of our research was to identify the modern species diversity of wild fruit and berry plants in the flora of the Kazakh Altai and to rank them according to a set of biological indicators.

Kazakhstan Altai within the East Kazakhstan region, with an area of about 200 thousand $km^{2,}$ in accordance with the classification adopted in the academic publication “Flora of Kazakhstan” (1956), belongs to the floristic region 22. Altai. The geographical position of the region, its geological structure, complexity and diversity of relief, as well as soil-climatic and hydrological conditions determine its division into 3 physical-geographical regions: Southern Altai (Narymsky, Sarymsakty, South Altai Tarbagatai, Kurchumsky, Azutau, Southern Altai, Kabinsky and Bukhtarma Mountains ranges); Western Altai (Ivanovsky, Ulbinsky, Ubinsky, Koksinsky, Lineisky, Kholzun, Zapadnaya Listvyaga ranges); Kalbinsky Altai (Eastern mountain-forest Kalba, Western mountain-steppe Kalba) [1].

Experimental

To obtain more complete information on the species diversity of wild fruit and berry plants in the study area, literary data were analyzed [2–7]; herbarium materials of the Altai Botanical Garden (Ridder), East Kazakhstan Technical University (Ust-Kamenogorsk), Katon-Karagay National Nature Park, Markakol State Nature Reserve, as well as materials of our own long-term developments in the East Kazakhstan region in the administrative districts: Altai, Glubokovsky, Zaysansky, Katon-Karagaysky, Kurchumsky, Samara, Tarbagataisky, Ulansky, Shemonaikhinsky.

The species composition of wild fruit and berry plants was studied using one of the traditional methods of floristic research — route reconnaissance [8]. Life forms of plants were assessed using the method of I.G. Serebryakov [9]. During the route research, floristic lists were compiled, the nature of the species distribution was revealed and biological and economic indicators were determined. The names of the accepted genera and species of wild fruit and berry plants were verified using data from the Plants website of the World Online [10]. The authorship of species, genera and families is given according to the International Plant Names Index [11]. When compiling expedition routes, geographic areas characterized by floristic diversity were taken as key territories. Ecological groups of plants were identified according to the classification of A.V. Kuminova [12]. When identifying individual groups of economically valuable plants, the following scientific publications were used: "Plant Resources of Russia …." [13] and "Annotated List of Medicinal Plants of Kazakhstan" [14]. For a quantitative assessment of the introduction of alien plants into the local flora, the method proposed by L.V. Horun et al. [15] was used.

Results and Discussion

The environmental conditions in the complex (climatic, edaphic, orographic, geological, hydrological) of the Kazakhstan Altai ensured a high species diversity of wild fruit and berry plants in the flora of the region. Targeted studies allowed us to identify the species composition of fruit and berry plants, and establish some patterns of their spatial distribution. Table provides a list of the species diversity of fruit and berry plant species and the identified actual places of their growth with coordinates on the territory of the Kazakhstan Altai. Based on the research results, the locations of 52 species of fruit and berry plants belonging to 22 genera and 12 families were established in the surveyed local flora. The general list also includes species of fruit and berry plants from the families: Cupressaceae Gray, Thymelaeaceae Juss., Ephedraceae Dumort., Melanthiaceae Batsch ex Borkh. with inedible fruits, but which are medicinal or rare.

T a b l e

List of species diversity and locations of wild fruit plants of the Kazakh Altai

Family	Genus, species	Location	Latitude	Longitude	Height above sea level, m
Berberidaceae Juss.	*Berberis heteropods* Schrenk	North-western slope of the Saikan ridge, Aksiyr tract	47.40333	85.45583	1170
	Berberis sibirica Pall.	North-western slope of the Bukhtarma Mountains	49.18972	85.51944	820
	Berberis vulgaris L.	South-eastern spurs of the Ubinsky ridge, Mount Kozlushka	50.27639	83.28917	710
Caprifoliaceae Juss.	*Lonicera caerulea* subsp. *altaica* (Pall.) Gladkova	Foothills of the Ivanovsky ridge, Gray meadow tract	50.35775	83.89667	1211
	Lonicera caerulea subsp. *pallasii* (Ledeb.) Browicz	Bukhtarma Mountains, northwestern foothills, Berezovka River valley	49.51861	84.39306	535
	Lonicera hispida Pall. ex Schult.	Kholzun ridge	50.33722	84.11944	2025
	Lonicera microphylla Willd. ex Roem. & Schult.	Foothills of the Ivanovsky ridge, Gray meadow tract	50.3575	83.89667	1200
	Lonicera stenant Pojark.	Southern Altai Range, upper reaches of the Bukhtarma River	49.28834	86.56886	2020
	Lonicera tatarica L.	Ridge Narymsky, northwestern slope, Shertan tract	48.93444	83.71778	476
	Symphoricarpos albus (L.) K.Koch	South-eastern foothills of the Ulbinsky ridge	49.71944	83.86389	452
Cupressaceae Gray	*Juniperus communis* var. *saxatilis* Pall. Siberian	Foothills of the Ubinsky ridge, south-eastern spurs	50.24611	83.47194	1800
	Juniperus pseudosabina Fisch. & C.A. Mey.	North- western slope of the Ivanovsky ridge, upper reaches of the Bolshaya Poperechka river	50.32222	84.19056	1977
	Juniperus sabina L.	of the Lineisky ridge, upper reaches of the Barsuk river	50.27167	83.16528	820

Continuation of Table

Family	Genus, species	Location	Latitude	Longitude	Height above sea level, m
Elaeagnaceae Juss.	*Hippophae rhamnoides* L.	Narymsky ridge, northwestern foothills, Solonechnaya river valley	49.17389	85.51889	945
Ephedraceae Dumort.	*Ephedra dahurica* Turcz.	Kalbinsky ridge	49.71297	81.58365	649
	Ephedra equisetina Bunge	Zaisan depression, near the village of Birzhan	48.6825	84.2220	586
	Ephedra intermedia Schrenk & C.A. Mey.	Kalbinsky ridge (Western steppe Kalba)	49.50513	83.88988	650
	Ephedra monosperma J.G. Gmel. ex C.A. Mey.	Kurchumsky ridge, Kurchum river valley	47.8881	85.0481	410
Ericaceae Durande	*Vaccinium microcarpum* (Turcz. ex Rupr.) Schmalh. ex Busch	Bukhtarma Mountains	49.1887	85.5585	981
	Vaccinium myrtillus L.	Koksinsky ridge	50.40772	84.24028	1800
	Vaccinium vitis-idaea L.	Chindogatui Mountains, Berel River Valley	49.47417	86.39861	1260
Grossulariaceae DC.	*Ribes acicular* Sm.	Koksinsky ridge	50.37167	83.87722	1854
	Ribes aureum Pursh	Kalbinsky ridge (Eastern Kalba), Koktau Mountain, north-eastern slope	49.42889	82.66694	896
	Ribes graveolens Bunge	Kalbinsky ridge, (Eastern Kalba), Laila tract	49.07389	83.36639	620
	Ribes nigrum L.	Lineisky ridge, upper reaches of the Barsuk river	50.32222	84.19056	1977
	Ribes petraeum Wulfen	Ivanovsky ridge, north-western slope	48.60361	83.57639	467
	Ribes rubrum L.	Narymsky ridge, Kurchum crossing area	50.32028	84.19556	1934
MelanthiaceaeBatsch ex Borkh.	*Paris quadrifolia* L.	Kara-Kabinskaya depression, vicinity of the village of Sogornaya, valley of the river Sogornaya	49.2510	85.3532	672
Rosaceae Juss.	*Cotoneaster melanocarpus* G.Lodd.	Eastern foothills of the Ubinsky ridge	50.32667	83.545	820
	Crataegus chlorocarpa Lenné & K.Koch	South-eastern spurs of the Ubinsky ridge, Mount Kozlushka	49.50167	83.05556	792
	Crataegus sanguinea Pall.	Kalbinsky ridge, Koktau mountains	49.17194	85.78139	1002
	Fragaria vesca L.	Kh. Kalbinsky (Eastern Kalba) ridge, Tainty tract	50.32694	83.54556	825
	Fragaria viridis Duchesne	Samrymsakty ridge, northwestern foothills, in the area of the village of Zhanaulgo	50.32417	83.55111	782
	Malusbaccata(L.) Borkh.	Foothills of the Ubinsky ridge, south-eastern spurs	49.18944	85.52028	895
	Prunus padus L.	Lineisky Ridge, north- western slope	50.26611	83.22889	523
	Rosa acicularis Lindl.	Foothills of the Ivanovsky ridge, Belkina mountain, south-eastern slope	48.39528	84.49278	525
	Rosa laxa Retz.	South-eastern foothills of the Ivanovsky ridge	50.27167	83.16528	727
	Rosa spinosissima L.	Foothills of the Ivanovsky ridge, Belkina mountain, south-eastern slope	50.27611	83.28917	715
	Rubus caesius L.	Bukhtarma mountains, river valley Solonechnaya, env. With. Katon-Karagay	49.3469	82.37256	1299
	Rubus idaeus L.	Kurchumsky ridge, Kalguta river valley	49.36639	85.51889	1125

Continuation of Table

Family	Genus, species	Location	Latitude	Longitude	Height above sea level, m
Rosaceae Juss.	*Rubus sachalinensis* H.Lev.	Kalbinsky Ridge, Koktau Mountains (Medvedka Mountain)	50.37111	84.10861	1456
	Rubus saxatilis L.	Bukhtarma mountains, river valley Solonechnaya, env. Katon-Karagay	49.28522	83.39082	776
	Sorbus aucuparia L.	Foothills of the Ivanovsky ridge, north- western slope	50.37472	83.88861	991
	Sorbus aucuparia subsp. *glabrata* (Wimm. & Grab.) Hedl.	Chindogatui mountains, Rakhmanovskie springs tract	48.47750	86.38944	1273
Solanaceae Juss.	*Alkekengi officinarum* Moench	Foothills of the Ubinsky ridge	50.63945	81.93744	315
	Solanum dulcamara L.	Ubinskyr idge, env. Shemonaikha	48.6454	84.0802	398
	Solanum nigrum L.	Valley of the river Black Irtysh, near the village of Buran	50.26139	83.22972	577
Thymelaeaceae Juss.	*Daphne altaica* Pall.	Foothills of the Azutau ridge, north- ern slope	48.42167	85.72472	1070
	Daphne mezereum L.	Ulbinsky ridge, Ridder area	50.24065	83.23428	980
Viburnaceae Raf.	*Sambucusracemosa*L.	South- eastern spurs of the Ubinsky ridge, Mount Kozlushka	50.27639	83.28917	710
	Sambucus sibirica Nakai	Foothills of the Ivanovsky ridge	50.37472	83.88861	890
	*Viburnum opulus*L.	Narymskyridge, northwestern slope of the Shertan tract	48.93444	83.71778	476

Systematic analysis showed that the largest number of species taxa is represented by the families: Rosaceae Juss. — 16 species (30.77 %), Caprifoliaceae Juss. –7 species (13.46 %), Grossulariaceae DC. — 6 species (11.54 %) (Fig. 1). These three families contain 29 species, which is 55.77 % of the total species diversity of wild fruit plants in the flora of the Kazakh Altai.

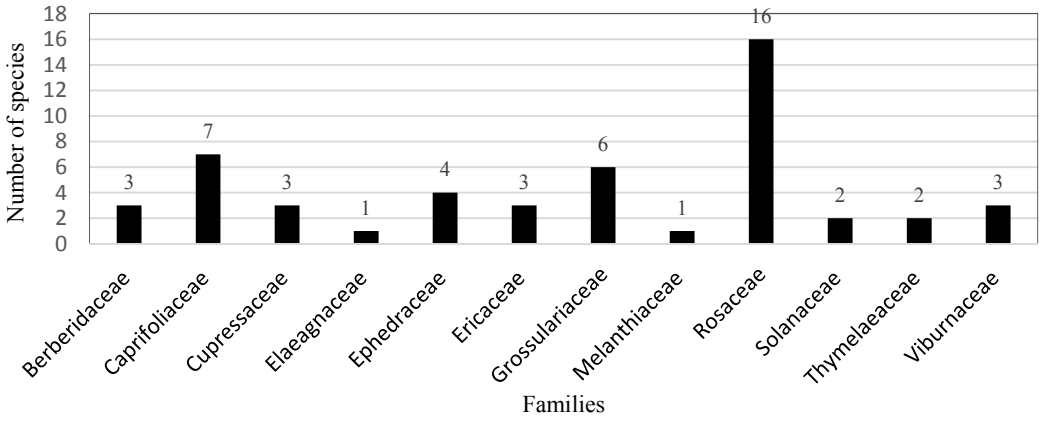

Figure 1. Quantitative composition of species taxa of fruit and berry plants of the Kazakh Altai by families

Formational analysis revealed that the flora coenotypes with the participation of wild fruit and berry plants in the studied region are represented by a wide spectrum, which is facilitated by the geographical position of the Kazakhstan Altai and altitudinal zonation. Among the plant communities with the participation of fruit and berry species, the dominant position is occupied by forest (26 %) and meadow associations (23 %).

Basically, these are dark coniferous, coniferous, and mixed and birch forests, different types of meadows (wet swampy, alpine, dry and damp forest, foothill forb-grass, forb-shrub steppe). Shrub associations with berry bushes are noted on the slopes of gorges, rocky screes in the mountain-forest and mountain-steppe belts.

Synanthropic phytocenoses formed on abandoned garden plots of populated areas were identified, where the subdominant species is *Solanum dulcamara* in the foothills of the Ubinsky ridge, near the town of

Shemonaikha and on the Kurchumsky ridge, in the vicinity of the liquidated village of Cherdoyak; *S. nigrum*- in the valley of the Black Irtysh River, in the vicinity of the village of Buran.

The monitoring carried out in 2021–2023 of the alien fraction in the flora of the Kazakh Altai revealed the growth of 7 alien fruit and berry species: *Alkekengi officinarum*, *Berberis vulgaris, Malus baccata, Ribes aureum*, *Sambucus racemosa*, *Sorbus aucuparia*, *Symphoricarpos albus*. Of the identified alien species, only *Malus baccata*has penetrated into the natural vegetation. The other above-mentioned species were previously cultivated plantings, but after the liquidation of settlements they became wild. At present, their degree of naturalization can be estimated at two points (colonophytes), since they do not spread beyond the places of introduction. Formation of a secondary range *Malus baccata* contributed to the primary introduction of species in the Altai Botanical Garden in 1939–1945. Due to the ecological plasticity and resistance to unfavorable factors, high winter hardiness and decorativeness, the species *was* widely used in landscaping the cities and villages of the region. At the present stage, *Malusbaccata*, forming its own communities, is widely found in the Kazakh Altai [16, 17].

In terms of life forms, fruit plant species in the flora of the region are represented by trees, shrubs, dwarf shrubs, subshrubs and herbaceous perennials. Among them, shrubs occupy a dominant position — 36 species (69.2 %). The remaining groups are represented in small quantities: fruit trees — 6 species (11.53 %), dwarf shrubs — 4 species (7.69 %), herbaceous perennials — 4 (7.69 %), subshrubs — 2 (3.89 %).

In relation to the moisture factor, all identified fruit species were divided into 6 ecological groups: mesophytes, mesoxerophytes, xeromesophytes, xerophytes, mesohygrophytes, hygromesophytes (Fig. 2). In quantitative terms, mesophytes are represented by 36 species (69.2 %), the remaining 16 taxonomic species (30.8 %) belong to 5 ecological groups, with an almost equal ratio of species.

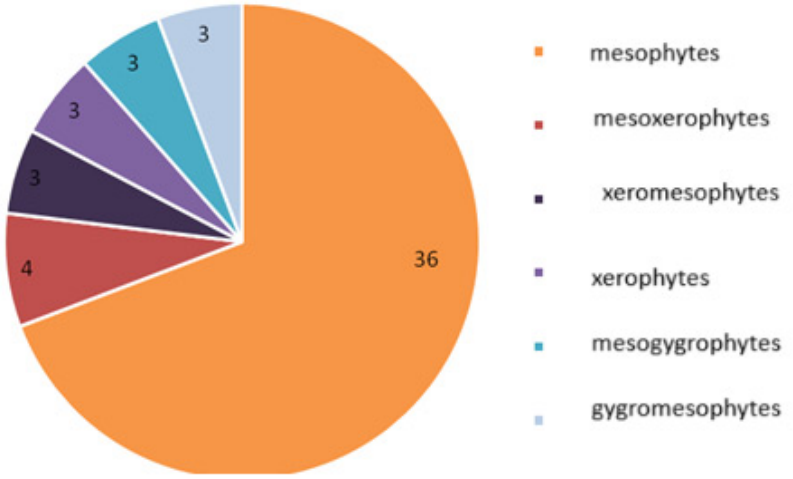

Figure 2. Quantitative ratio of fruit plant species of the Kazakh Altai in relation to the moisture factor

Conclusions

During the analysis of 52 species of wild fruit and berry plants, both with edible and inedible fruits, in the studied territory, different degrees of their rarity were established. Three species are listed in the Red Book of Kazakhstan (2014) with the status of rarity category II: *Daphne altaica, Paris quadrifolia*and *Vacciniummicrocarpum.* Rare species in need of protection, currently based on the results of long-term research, are *Daphne mezereum, Ephedra monosperma*.

Thus, the species diversity of wild fruit and berry plants in the flora of the Kazakh Altai is represented by 52 species taxa belonging to 22 genera, 12 families in the composition of forest and meadow associations. According to the complex of biological indicators, shrubs dominate in life forms — 69.2 %, in relation to the moisture factor — mesophytes, at the state level with the status of rarity category II, 3 species are protected.

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Қазақстан Алтайының табиғи флорасының жабайы жемісті өсімдіктерінің түр алуандығы

Мақаланың мақсаты: қазақстандық Алтайдың флорасында жабайы жемісті-жидекті өсімдіктердің қазіргі заманғы түрлік әртүрлілігін анықтау және оларды биологиялық көрсеткіштер кешені бойынша саралау. Қазақстандық Алтайдың тамырлы өсімдіктерінің биоалуантүрлілігін зерттеу нәтижесінде маршруттық-барлау әдісін пайдалана отырып, оның аумағында 22 тұқымдасқа, 12 туыстасқа жататын жемісті және жидекті өсімдіктердің 52 түрі өсетіні анықталды. Түр таксондарының ең көп саны 3 туыстаста бар. Атап айтсақ, *Rosaceae, Caprifoliaceae, Grossulariaceae*, бұларда 29 түр шоғырланған,

бұл жалпы санның 55,77 %-ын құрайды. Жемісті және жидекті түрлері бар өсімдіктер қауымдастығы арасында орманды (26 %) және шалғынды ассоциациялар (23 %) басым орын алады, сонымен қатар аймақтағы елдімекендердің қараусыз қалған бақша учаскелерінде *Solanum dulcamara* және *S. nigrum* бар синантропты фитоценоздар анықталды. 7 әкелінген жемісті-жидекті түрлердің өсуі айқындалды, олар: *Alkekengi officinarum, Berberis vulgaris, Malus baccata, Ribes aureum, Sambucus racemosa., Sorbus aucuparia, Symphoricarpos albus*, оның ішінде тек *Malus baccata* өз қауымдастықтарын құрған. Тіршілік формалары бойынша жемісті-жидекті түрлер ағашты, бұталы, тоғайлы, жартылай бұталы, шөптесін көпжылдықтар түрінде кездеседі. Бұталар басым, яғни 36 түр (69,2 %). Ылғалдандыру факторына қатысты анықталған түрлер 6 экологиялық топқа бөлінеді, бұл ретте мезофиттер басым, 36 түр (69,2 %). Қазіргі уақытта мемлекеттік деңгейде жемісті-жидекті түрлердің 3 түрі қорғалады: *Daphne altaica, Paris quadrifolia* және *Vaccinium microcarpum*, олар Қазақстанның Қызыл кітабына енгізілген, II сиректілік санаты бар.

Кілт сөздер: тіршілік формасы, енгізілген түрлер, Қазақстан Алтайы, орналасқан жері, жеміс–жидекті өсімдік түрлері, экологиялық топтар.

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Видовое разнообразие диких плодовых растений природной флоры Казахстанского Алтая

Цель данной работы — выявление во флоре Казахстанского Алтая современного видового разнообразия дикорастущих плодово-ягодных растений и ранжирование их по комплексу биологических показателей. В результате изучения биоразнообразия сосудистых растений Казахстанского Алтая, используя маршрутно-рекогносцировочный метод, установлено произрастание на его территории 52 видов плодовых и ягодных растений, относящихся к 22 родам, 12 семействам. Наибольшим числом видовых таксонов представлены 3 семейства: *Rosaceae, Caprifoliaceae*, *Grossulariaceae*, в которых сосредоточено 29 видов, что составляет 55,77 % от общего числа. Среди растительных сообществ с участием плодовых и ягодных видов доминирующее положение занимают лесные (26 %) и луговые ассоциации (23 %), также установлены синантропные фитоценозы с участием *Solanum dulcamara* и *S. nigrum* на заброшенных садовых участках населенных пунктов региона. Выявлено произрастание 7 заносных плодовых и ягодных видов: *Alkekengi officinarum*, *Berberis vulgaris, Malus baccata, Ribes aureum, Sambucus racemosa*, *Sorbus aucuparia*, *Symphoricarpos albus,* из которых только *Malus baccata* образовал собственные сообщества. По жизненным формам плодовые и ягодные виды представлены деревьями, кустарниками, кустарничками, полукустарниками, травянистыми многолетниками. Доминируют кустарники — 36 видов (69,2 %). По отношению к фактору увлажнения выявленные виды ранжированы по 6 экологическим группам, где господствуют мезофиты — 36 видов (69,2 %). Из плодовых и ягодных видов на государственном уровне в настоящее время охраняются 3 вида: *Daphne altaica*, *Paris quadrifolia* и *Vaccinium microcarpum,* включенные в Красную книгу Казахстана, со статусом категории редкости II.

Ключевые слова: жизненные формы, заносные виды, Казахстанский Алтай, местонахождение, плодово-ягодные виды растений, экологические группы.

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Optimization *in vitro* cultivation conditions for an endemic species of Regel's pear

The decline in plant diversity is a pressing global issue driven by climate change, plant diseases, and human activities. This reduction in biodiversity poses significant threats to food security and the sustainability of ecosystems. Conserving wild plant species is crucial as they harbor genes that confer resistance to various biotic and abiotic stresses. One such important species is the Regel pear, endemic to Kazakhstan, known for its resistance to drought and diseases. During research efforts, samples of Regel pear were collected from their natural habitats. Using SSR markers, researchers identified samples that exhibited resistance to scab. In a pioneering step, optimal *in vitro* cultivation conditions were developed to preserve this economically valuable species. The sterilization process for establishing *in vitro* culture and subsequent regeneration was established. The multiplication conditions were refined using DKW nutrient medium supplemented with 1.0 mg/l BAP, 0.5 mg/l IBA, and 0.2 mg/l GA3. These measures aim to ensure the long-term conservation of genetic diversity and enhance agricultural resilience to environmental changes.

Keywords: Pyrus regelii, *invitro* culture, endemic, micropropagation.

Introduction

Declining biodiversity has a negative impact on food security, leading to the deterioration of ecosystems. According to the report on the state of plant genetic resources, several factors contribute to the decline in biodiversity, including climate and habitat changes, invasive species, and the over use of plant resources beyond their natural restoration levels [1, 2, 3].

Kazakhstan holds a leading position in plant diversity within Central Asia, boasting approximately 5,700 species of higher plants, of which 14 % are endemic. However, like many regions worldwide, Kazakhstan faces biodiversity loss due to anthropogenic influences, soil degradation, deforestation, and other factors [4]. The use of biotechnological methods is effective for preserving biodiversity and promoting sustainable development [5, 6, 7].

Kazakhstan is the homeland of many nut and fruit plant species, which are now cultivated globally [8, 9, 10]. According to Vavilov's centers of origin of cultivated plants, the Central Asian center includes species such as apple trees, pears, cherries, plums, pistachios, grapes, and others [11]. Pear species, represented by a wide variety of wild and cultivated local varieties, have significant importance in this region. Central Asia is a key center for the speciation of the genus *Pyrus* L. [12].

Pear production ranks second worldwide after apples. Pears are susceptible to various diseases, with some of the most dangerous being fire blight and scab. Scab is caused by fungi of the genus *Venturia*, specifically *V. naschicola* infecting Asian pear species and *V. pirina* affecting common pears [13, 14].

Wild pear species of fer allelic diversity and combinations that provide resistance and tolerance to various abiotic and biotic stresses. Many wild pear species, including *P. ussuriensis, P. pashia, P. korshinskyi, P. syriaca, P. hopiensis, P. gharbiana, P. betulifolia, P. calleryana, P. cossonii, P. dimorphophylla, P. fauriei, P. pyrifolia, P. ussuriensis, P. regelii, P. communis,* and *P. xerophila*, possess straits of drought, cold, and disease resistance [15, 16, 17].

Regel's pear *(Pyrus regelii)* is an endemic species growing in the Tien Shan and Pamir-Altai regions, with its habitat gradually shrinking. It grows singly or in groups on dry rocky slopes and rocks, among shrubs, in xerophytic woodlands, and thermophilic juniper forests [18]. In southern Kazakhstan, the Regel pear grows, recognized as an economically valuable species due to its significant drought resistance. This species can be utilized for a forestation of arid areas with poor soil conditions. Its fruits are very tart and astringent but can be used as drought-resistant roots tocks [19].

The purpose of this study is to optimize the cultivation conditions of the endemic Regel pear species, which is resistant to scab, in *in vitro* culture to preserve biodiversity and enhance sustainable development in Kazakhstan.

Experimental

The object of research was plant material of the Regel pear, which was collected in the Sairam-Ugam State National Natural Park, Tyulkubas branch (Fig. 1). Table 1 presents the coordinates of the selected samples.

A) specimen 1 B) specimen 2 C) specimen 3

Figure 1. Regel's pear in its natural habitat

Table 1

Coordinates of Regel's pear growth

Species	Number	Longitude	Latitude	Height above sea level, m
Regel's pear	specimen 1	E070°15.33'.	N42°40.33'	880
	Specimen 2	E70°15.091'	N42°41.345'	917
	Specimen 3	E70°15.645'	N42°40.789'	864

DNA extraction

DNA extraction from plant material was carried out according to the CTAB protocol. CTAB lysis buffer contained 2 % cetyltrimethylammonium bromide, 20 mM EDTA, 100 mM Tris-HCl, 1.4 mM NaCl, and 1 % PVP. Purification with chloroform was carried out twice.

Isolation protocol: Leaves were homogenized in 500 µl CTAB buffer for 3 min. at 30 Hz using a high-speed homogenizer Tissuelyser II Qiagen. After incubation at 65 °C for 60 minutes, samples were centrifuged at 20,000 rpm for 10 minutes, then the supernatant was extracted with an equal volume of chloroform and centrifuged for 15 minutes at 20,000 rpm. The extraction procedure was repeated twice. DNA was precipitated with 2/3 isopropanol and centrifuged at 14,000 rpm for 30 minutes. The precipitate was washed twice with 70 % ethanol, dried and dissolved in 100 µl of TE buffer [20].

Molecular genetic analysis

To study the genetic potential of pear resistance to pathogens, molecular genetic analysis was carried out. To select resistant genotypes to scab (*Venturia nashicola*), the SSR marker TsuENH101 (AB621905) was used. Sequence: F: TGCCTAATGGAAGGGTCCTA R: CAAGGAAGAGAAGACCGACG [21]. The 25 µl PCR reaction mixture contained the following: 5 µl template DNA (50 ng/µl); 3 µl PCR buffer (10x); 1.5 µl $MgCl_2$ (25 mM); 1.5 µl off or ward and reverse primers (10 pmol); 0.3 µl of Taq polymerase and 1.8 µl of dNTP (2 mM), the rest of the mixture was made up with deionized distilled water. Amplification

was performed using a 96-well thermal cycler (Applied Biosystems) with the following conditions: 95 °C for 2 min; 40 cycles 95 °C 30 sec, 55 °C 30 sec, 72 °C 45 sec; 72ºC 5 min.

Sterilization and establishment in vitro culture

To sterilize annual axillary buds of the Regel pear, the effects of different concentrations of hydrogen peroxide (H_2O_2) were studied. The following concentrations were tested: I — 3 % H_2O_2; II — 6 % H_2O_2; III — 9 % H_2O_2; IV — 12 % H_2O_2, in all cases the exposure time was 5 minutes.

The effect of nutrient media with the addition of the cytokinin 6-benzylaminopurine (BAP) at a concentration of 1.0 mg/l on the formation of the main shoot was studied. The following options were studied: I — MS with the addition of BAP — 1.0 mg/l; II — DKW with the addition of BAP — 1.0 mg/l; III — QL with the addition of BAP — 1.0 mg/l. In each variant, 30 explants were cultured.

Multiplicaton stage

To multiply shoots, we studied various combinations and concentrations of growth regulators BAP, gibberyllic acid (GA3), and indolyl-3-butyric acid (IBA) on the DKW nutrient medium. Treatments: I — DKW without growth regulators; II — DKW with BAP 0.1 mg/l, IBA 0.1 mg/l, GA 0.2 mg/l; III — DKW with BAP 0.5 mg/l, IBA 0.1 mg/l, GA 0.2 mg/l; IV — DKW with BAP 1.0 mg/l, IBA 0.1 mg/l, GA 0.2 mg/l; V — DKW with BAP 0.1 mg/l, IBA 0.5 mg/l, GA 0.2 mg/l; VI — DKW with BAP 0.5 mg/l, IBA 0.5 mg/l, GA 0.2 mg/l; VII — DKW with BAP 1.0 mg/l, IBA 0.5 mg/l, GA 0.2 mg/l; VIII — DKW with BAP 0.1 mg/l, GA 0.2 mg/l; IX — DKW with BAP 0.5 mg/l, GA 0.2 mg/l; X — DKW with BAP 1.0 mg/l, GA 0.2 mg/l.

In each treatment, 30 shoots were used.

Statistical processing

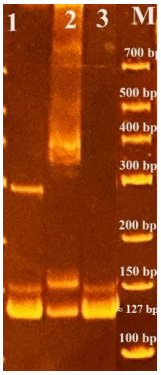
The experimental results were analyzed using one-way and two-way ANOVA, and significant differences were screened using Tukey's post hoc test. The results were analyzed in the statistical package SPSS 23.0 (IBM Inc., New York, USA). Data are expressed as means ± standard error.

Results and Discussion

The habitat of the Regel pear is declining due to diseases, climate change, anthropogenic impact, insufficient watering, and other factors [22]. Scab, caused by two species of fungi, *Venturia pirina* and *Venturia nashicola*, is one of the most severe and common diseases affecting European and Asian pears. Scab pathogens impact the leaves, fruits, and branches of pears. Scab resistance is a crucial goal in pear breeding, along with improving fruit quality, yield, and storage ability. Despite the development of a few scab-resistant pear varieties, none are produced in large quantities [23].

Several studies have focused on mapping the pear genome to identify scab resistance genes, one of which is Vnk. Based on this gene; molecular markers such as SSR, AFLP, and RAPD have been developed [24]. SSR markers, in particular, were developed to determine resistance to black spot [25].

To select scab-resistant samples of Regel pear, molecular genetic analysis was conducted using a microsatellite marker. In the first stage, DNA of the required quality and quantity was extracted from pear leaves. DNA concentration was measured using a small volume spectrophotometer. PCR was carried out with the SSR marker TsuENH101 to select scab-resistant samples. Detection was performed in 8 % polyacrylamide gel (Fig. 2).



M — molecular weight marker
(Ferment as, 25-700 bp);
1 — specimen 1;
2 — specimen 2;
3 — specimen 3

Figure 2.
Electropherogram of Regel pear using
the TsuENH101 SSR marker

According to the results of the analysis, it was shown that all samples tested with the SSR marker Tsu ENH101 were resistant to *Venturia nashicola*. A polymorphic allele with a length of 127 bp was amplified, which demonstrated a significant connection with the Vnk gene responsible for scab resistance (*Venturia nashicola*). Consequently, a study of three Regel pear trees confirmed their resistance to scab. These trees were then established *in vitro* culture for further micropropagation.

One of the critical stages of micropropagation is the sterilization nofex plants for establishment *in vitro* culture. Hydrogen peroxide (H_2O_2) was used as the primary sterilizing agent, a common practice in micropropagation of various plant species [26, 27, 28, 29].

Sterilization of explants was performed in two stages. In the first stage, one-year-old axillary buds were washed multiple times in a soap solution on a magnetic stir restore move surface dust and dirt. Then, under aseptic conditions, they were treated with hydrogen peroxide according to the concentrations specified in the research methods. The results were analyzed on the 14th day of cultivation. Sterilization was considered most effective when the explants remained green and showed no signs of infection (bacterial or fungal) or tissue necrosis.

The study revealed that the most optimal sterilization for Regel pear involved treating the explants with 12 % H_2O_2 for 5 minutes. This method resulted in 70 % of the explants being viable (Fig. 3).

Other studies on pear sterilization have used various sterilizing agents. For example, sodium hypochlorite was found effective for the Pyro dwarf rootstock of the species *P. communis* L. [30]. Additionally, 4 % $HgCl_2$ has been used in several works for the sterilization of common pear and Syrian pear [31, 32]. Czech researchers used 0.15 % $HgCl_2$ in their work on the micropropagation of pear [33]. Therefore, it is necessary to select an appropriate sterilizing agent for each specific type and variety of pear.

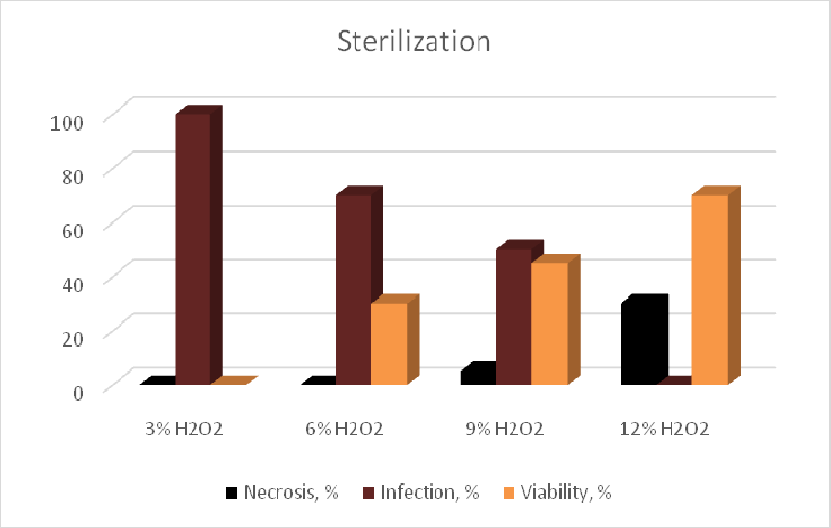
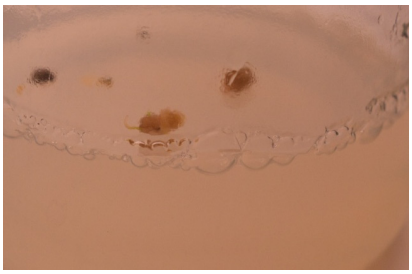


Figure 3. Results of sterilization of axillary buds of the Regel pear

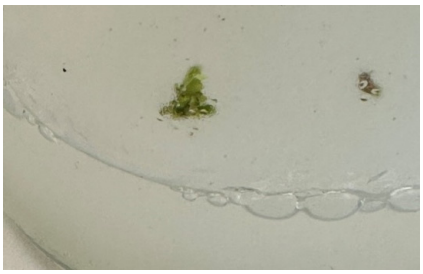
The next step after selecting the optimal sterilization regime is the formation of the main shoot. For micropropagation, the main shoot must be produced by direct organogenesis, without evidence of callus formation, as somaclonal variation may occur.

We studied several variants of culture media with the addition of BAP 1.0 mg/l. The highest average value of shoot regeneration was observed 10–15 days after cultivation on DKW medium. A BAP concentration of 1.0 mg/l caused earlier induction of the main shoot without necrosis. Callus was observed on other variants of nutrient media (Fig. 4).

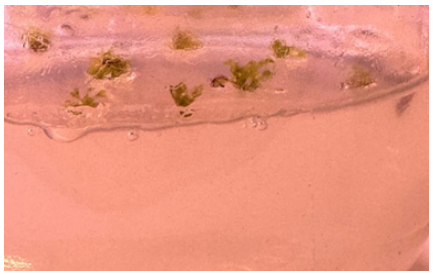
In the micropropagation of plants, the main goal is to obtain the maximum number of genetically identical shoots that can easily take root, acclimatize, and grow successfully under field conditions [34]. Among plant grow the regulators, cytokinins are the most commonly used. Cytokinins in plants regulate shoot branching, initiation of apical growth, and other critical growth processes [35].



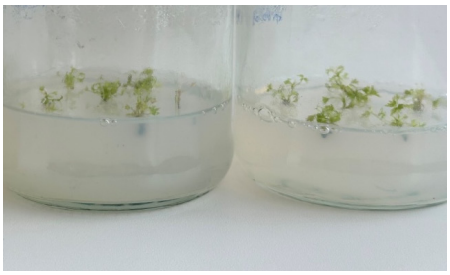
A) Explants on QL medium



B) Explants on DKW medium



C) shoots on the 21st day of cultivation on DKW medium



D) shoots on the 40th day of cultivation on DKW medium

Figure 4. Regel pear shoots formed on regeneration medium

The widely used synthetic cytokinin BAP (6-benzylaminopurine) is effective, versatile, and can be rapidly metabolized in plant tissues [36, 37]. BAP is often included in micropropagation protocols for various pear species [38, 39, 40, 41].

The optimal nutrient medium for the formation of the main shoot in Regel pear was found to be the DKW nutrient medium. This medium was used for the multiplication of Regel pear shoots. To select the optimal multiplication conditions, Regel pear shoots measuring about 0.9 cm were cultivated in DKW medium with various concentrations of plant growth regulators. The concentrations of growth regulators BAP, GA (gibberellic acid), and IBA (indole-3-butyric acid) had different effects on the multiplication of shoots (Table 2). The largest number of multiplied shoots perex plant (10.60±0.53) was observed on DKW medium with BAP 1.0 mg/l and GA 0.2 mg/l (Fig. 5). Shoot proliferation increased with increasing BAP concentration to 1.0 mg/l in treatments IV, VII, and X. The presence of IBA in the nutrient medium did not significantly differ from option X, where IBA was absent.

Micropropagation protocols have been developed for the main varieties of *P. communis* L. [42, 43, 44, 45, 46]. While some studies have been conducted on wild and domesticated *Pyrus* species, there is a lack of scientific research on the micropropagation of Regel pear. This study addresses that gap by providing a detailed protocol for the effective micropropagation of Regel's pear using optimal concentrations of plant growth regulators.

Table 2

Optimizing the multiplication of the Regel pear

Treatment	Plant growth regulators, mg/l			Phenological parameters		
	BAP	IBA	GA	Shoot height, cm	Shoots, pcs.	Number of leaves, pcs
I	-	-	-	1.25±0.04	1.07±0.27	5.60±0.12
II	0.1	0.1	0.2	0.96±0.04	2.03±0.35	13.83±0.11
III	0.5	0.1	0.2	1.07±0.08	4.37±0.56*	18.53±0.14*
IV	1.0	0.1	0.2	0.92±0.04	8.43±0.59*	35.73±0.15*
V	0.1	0.5	0.2	1.36±0.04	4.70±0.54*	23.30±0.15*
VI	0.5	0.5	0.2	1.42±0.05	7.90±0.45*	22.50±0.17*
VII	1.0	0.5	0.2	1.68±0.04*	9.77±0.69*	61.73±0.27*
VIII	0.1	-	0.2	0.57±0.05*	4.87±0.74*	19.37±0.25*
IX	0.5	-	0.2	1.50±0.06	5.77±0.55*	41.97±0.31*
X	1.0	-	0.2	0.71±0.06*	10.60±0.53*	65.40±0.29*

A) Shoots with BAP 1.0 mg/l, GA 0.2 mg/l, IBA 0.5 mg/l

B) Shoots with BAP 0.1 mg/l, GA 0.2 mg/l

C) Shoots with BAP 0.1 mg/l, GA 0.2 mg/l, IBA 0.1 mg/l

D) Shoots with BAP 0.1 mg/l, GA 0.2 mg/l, IBA 0.5 mg/l

Figure 5. Multiplicated shoots of Regel pear

Thus, the most optimal concentration of growth regulators for the formation of shoots that can be used for rooting *in vitro* of Regel pear is BAP 1.0 mg/l, IBA 0.5 mg/l and GA 0.2 mg/l.

Conclusion

Work has been carried out to establish scab-resistant Regel pears *in vitro* culture. The most optimal sterilization for Regel pear is the treatment of explants with 12 % H_2O_2 with an exposure time of 5 minutes, where the viability was 70 %. Conditions have been selected for the formation of the main shoot and multiplication of the Regel pear; the most optimal concentration of growth regulators for the formation of shoots of the Regel pear is BAP 1.0 mg/l, IBA 0.5 mg/l and GA 0.2 mg/l.

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Эндемикалық түр Регель алмұрты үшін *in vitro* өсіру жағдайларын оңтайландыру

Өсімдіктердің әртүрлілігінің азаюы климаттың өзгеруінен, өсімдіктердің аурулары мен адам әсерінен туындаған жаһандық мәселе. Бұл биоалуан түрлілікке теріс әсер етіп, өз кезегінде азық-түлік қауіпсіздігі мен экожүйенің тұрақтылығы мәселелеріне әкеледі. Жабайы өсімдік түрлерін сақтау

ерекше маңызға ие, себебі оларда биотикалық және абиотикалық факторларға төзімділікті қамтамасыз ететін гендер болуы мүмкін. Қазақстанда құрғақшылық пен ауруға төзімділік белгілері бар эндемикалық түр — Регель алмұрты өседі. Зерттеу барысында олардың өскен жерінен үлгілерді іздестіру және жинау жұмыстары жүргізілді. Регель алмұртының паршаға төзімді үлгілері SSR маркерінің көмегімен анықталды. Бұл экономикалық құнды түрді сақтау үшін алғаш рет *in vitro* өсіру шарттары оңтайландырылды. *In vitro*-ға дақылды енгізу және регенерациялау үшін стерилизация протоколы әзірленді. 1,0 мг/л, ИМҚ 0,5 мг/л, ГҚ 0,2 мг/л БАП-пен толықтырылған DKW қоректік ортасының мультипликация шарттары таңдалды. Бұл жұмыс генетикалық әртүрлілікті ұзақ мерзімді сақтауды қамтамасыз етуге және өзгермелі қоршаған орта жағдайларына ауылшаруашылығының тұрақтылығын арттыруға бағытталған.

Кілт сөздер: Pyrus regelii, *in vitro* дақылы, эндемик, микроклональды көбею.

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Оптимизация условий культивирования *in vitro* эндемичного вида груши Регеля

Сокращение растительного разнообразия является глобальной проблемой, вызванной изменением климата, болезнями растений и антропогенным воздействием. Это негативно сказывается на биоразнообразии, что, в свою очередь, приводит к проблемам продовольственной безопасности и устойчивости экосистем. Особую важность представляет сохранение диких видов растений, так как они могут содержать гены, обеспечивающие устойчивость к биотическим и абиотическим факторам. В Казахстане произрастает эндемичный вид — груша Регеля, который обладает признаками устойчивости к засухе и болезням. В ходе исследования проведены работы по поиску и сбору образцов в месте их произрастания. Определены устойчивые образцы груши Регеля к парше с использованием SSR-маркера. Впервые были оптимизированы условия культивирования *in vitro* для сохранения этого хозяйственно-ценного вида. Отработаны стерилизация для введения в культуре *in vitro* и регенерация. Подобраны условия мультипликации — питательная среда DKW с БАП 1,0 мг/л, ИМК 0,5 мг/л, ГК 0,2 мг/л. Эти усилия направлены на обеспечение долгосрочной сохранности генетического разнообразия и повышение устойчивости сельского хозяйства к изменяющимся условиям окружающей среды.

Ключевые слова: Pyrus regelii, *in vitro,* культура, эндемик, микроклональное размножение.

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Native dendroflora of Western Kazakhstan at introduction in the Mangistau desert

The article is devoted to the study of the indigenous dendroflora of Western Kazakhstan and its introduction into the desert conditions of Mangistau. The flora of the Mangistau region includes 770 species of higher spore and vascular plants belonging to 333 genera and 73 families. In Atyrau region, 899 species of higher vascular plants have been recorded, associated with 351 genera and 85 families. Indigenous woody plants comprise 7.8 % of the total flora in the Atyrau region and 16.7 % in the Mangistau region, indicating their low representation in the vegetation cover. The status of natural populations of six woody fruit and berry species has been studied: *Crataegus ambigua, Crataegus altaica, Rosa laxa, Rosa iliensis, Ribes aureum*, and *Lonicera tatarica*. The selection of representatives of the indigenous dendroflora of Western Kazakhstan has begun for the formation of a collection, which includes 14 species, four of which are rare and endangered, listed in the Red Book of Kazakhstan. It analyzes indigenous woody plants, their nutritional, medicinal, and ecological functions, as well as their potential for ecosystem restoration and ensuring food security.

Keywords: aborigenal dendroflora, Western Kazakhstan, Mangistau, Atyrau, flora, population, introduction.

Introduction

The conservation and sustainable use of biodiversity is an important objective of biological science, promoting the introduction of sustainable species for introduction, food security and ecosystem restoration [1]. Plant resources, in particular wild and cultivated plants, play a key role in national security.

Western Kazakhstan, characterized by a climate ranging from semi-desert to desert, exhibits significant floristic diversity, which emphasizes its desert character [1]. The Mangistau and Atyrau regions are distinguished by dendroflora adapted to arid conditions, however, remain insufficiently studied.

Desert conditions of Western Kazakhstan, characterized by harsh climate and deficit of water resources, create difficult conditions for the growth of woody plants. The diversity of relief, soil mosaic and harsh climate form unique natural complexes, contributing to the spread of tolerant non-traditional woody plants.

This determines the adaptation of local dendroflora to extreme environmental conditions. However, introduction of native tree species can significantly improve the ecological situation and contribute to the restoration of natural resources.

Taking into account the climatic diversity of Western Kazakhstan, in Mangyshlak experimental botanical garden the study of natural populations and organized introduction of promising non-traditional woody plants, the brief results of which are presented in this article.

Experimental

The main objects of the study are floristic diversity of plants of Mangistau and Atyrau oblasts. Expedition trips were conducted according to the route-reconnaissance method [2-3], with the establishment of semi-stationary key sites for studying the diversity of fruit and berry plants. Herbarium, vegetative and seed materials will be collected during field studies.

Optimization of growing conditions of planting material was carried out in the open (at the nursery) and closed (in the greenhouse) ground. Observations of phenological phases, growth and development dynamics will be carried out according to the methodological guidelines for botanical gardens of Kazakhstan [4] and forest nurseries [5].

Results and Discussion

Selection of economically valuable plants in natural conditions and enrichment of cultural flora of any region should be made not only by cultivated plants, but also by species represented in the natural flora. Nat-

ural flora has a significant prospect of use as a source of plants resistant to local climatic conditions, having decorative, medicinal, food, honey-bearing, ameliorative properties.

The extra arid conditions of Western Kazakhstan, especially in the Mangistau and Atyrau regions, contributed to the formation of a diverse relief and unique vegetation cover [6–9].

The flora of Mangistau region includes 770 species of higher spore and vascular plants belonging to 333 genera and 73 families. The most numerous families by the number of species are Amaranthaceae (114) and Asteraceae (101), which indicates the arid conditions of the region and the presence of significant areas of saline or saline areas.

Brassicaceae (74), Poaceae (69) and Fabaceae (59), which are adapted to dry and desert conditions and play the role of edifiers of steppe and desert flora, are also the three leaders in the number of species. Multispecies families including 15 or more species include Apiaceae (16), Polygonaceae (23), Scrophulariaceae (24), Caryophyllaceae (28) and Boraginaceae (36). The structure of families is conditioned by the location of the territory on the border of the Boreal and Old Mediterranean subkingdoms of the Holarctic Kingdom. High ranks of the families Amaranthaceae and Boraginaceae are characteristic of the Turanian flora, and a large number of species of the families Asteraceae, Poaceae and Fabaceae indicates the influence of the Mediterranean flora. The presence of Caryophyllaceae, Ranunculaceae, Brassicaceae and Lamiaceae indicates the boreal features of the flora of the region.

In Atyrau region 899 species of higher vascular plants belonging to 351 genera and 85 families were recorded. Ten leading families (Asteraceae, Amaranthaceae, Poaceae, Brassicaceae, Fabaceae, Caryophyllaceae, Polygonaceae, Boraginaceae, Scrophulariaceae, Lamiaceae) comprise 596 species, which is 66.2 % of the total number, and 214 genera (60.9 % of the total number of genera of the flora). Among the most numerous families are Asteraceae (134 species), Amaranthaceae (106), Poaceae (75), Brassicaceae (66) and Fabaceae (57 species), characteristic of the floras of the Iran-Turan sub-region of the Saharan-Gobi region.

Analysis of the flora of Mangistau and Atyrau oblasts revealed a significant number of species with potential for practical application, among which the diversity of ornamental plants stands out, represented by 215 and 135 species, respectively. Most of the species belong to herbaceous perennials. In ornamental landscaping of tree and shrub species *Amygdalus nana, Lonicera tatarica, Juniperus sabina, Rosa laxa, Salix triandra, Salix alba, Spiraea hypericifolia*, *Clematis orientalis, Caragana grandiflora* are used.

In terms of size, the group of plants used for economic purposes is made up of melliferous species, which account for more than 10 % of the total number of species. Here the most valuable are plants from the families *Salicaceae* (*Salix pentandra, Salix triandra, Salix alba*); *Rosaceae* (*Rosa laxa, Spiraea hypericifolia, Crataegus altaica*), *Fabaceae* (*Astragalus ammodendron*), as well as good mellifers are *Nitraria schoberi, Halimodendron halodendron*.

The group of food plants includes 129 species in Mangistau oblast and 70 species in Atyrau oblast from the total number of flora. Fruit and berry woody species make up a smaller part of this group. Food woody plants account for 7.8 % in Atyrau oblast and 16.7 % in Mangistau oblast, indicating a low proportion. These include: *Lonicera tatarica*, *Ribes aureum*, *Crataegus ambigua*, *Crataegus altaica*, *Malus baccata*, *Malus sieversii*, *Rosa laxa*, *Rosa canina*, *Rubus caesius*, *Prunus spinosa* (Table).

Analysis of distribution of fruit and berry crops by families showed that the most numerous is the family Rosaceae, which includes 8 species from 6 genera in Atyrau oblast and 8 species from 5 genera in Mangistau oblast. The second place is occupied by three families containing 2 species from 1 genus (Nitrariaceae, Elaeagnaceae, Moraceae), with the family Moraceae occurring only in Mangistau oblast. Other families (Caprifoliaceae, Grossulariaceae, Peganaceae, Solanaceae) are represented by 1 genus and species.

T a b l e

List of wild fruit plants of Atyrau and Mangistau oblasts

Family	Rod	View	Life form	Environmental Group	Gathering place
Atyrau region					
Caprifoliaceae	Lonicera L.	*L. tatarica* L.	Shrub	Mesophyte	Imankara Mountains, Yellowtau Mountains, Maikungam Sands

Continuation of Table

Family	Rod	View	Life form	Environmental Group	Gathering place
Elaeagnaceae	*Elaeagnus* L.	*E. angustifolia* L.	Shrub or low tree	Xerophyte	Ural River floodplain near Sary-Togai, Makhanbet villages Sands of Naryn Zhangyr River flood-plain Uter River floodplain Taisongan Sands Zimovka Aksai (vicinity of Ushterek settlement)
		E. oxycarpa Schlecht.	Wood	Xerophyte	Ural River floodplain near Sary-Togai, Makhanbet, Eltai villag-es
Grossulariaceae	*Ribes* L.	*R.aureum* Pursh	Shrub	Mesophyte	
Nitrariaceae	*Nitraria* L.	*N. schoberi* L.	Shrub	Xerophyte	
		sibirica Pall.	Shrub	Xerophyte	
Peganaceae	*Malococarpus*	*crithmifolius* (Retz.) C.A. Mey	Shrub	Xerophyte	
Rosaceae	*CerasusL.*	*C. fruticosa* Pall.	Shrub	Mesophyte	
	Crataegus L.	*C.altaica Lge.*	A small tree	Xeromesophyte	Zheltau Mountains
	Malus Mill.	*M. baccata* (L.) Borkh.	Wood	mesophyte	
		M. sieversii (Ledeb.) M. Roem	Wood	mesophyte	
	Prunus L.	*P. spinosa* L.	Shrub	Mesophyte	
	Rosa L.	*R. canina* L.	Shrub	Mesophyte	
		R. laxa Retz.	Shrub	Mesophyte	The Inderbor Mountains
	Rubus L.	*R. caesius* L.	Shrub	Mesophyte	
	Amygdalus	*Amygdalus nana*	Shrub	Xeromesophyte	
Mangistau region					
Caprifoliaceae	*Lonicera* L.	*L. tatarica* L.	Shrub	Mesophyte	Kolenkeli Mountains Zheltau Mountains
Elaeagnaceae	*Elaeagnus* L.	*E. angustifolia* L.	Shrub or low tree	Xerophyte	Western Karatau Tubkaragan Peninsula
		E. oxycarpa Schlecht.	Wood	Xerophyte	Tubkaragan Peninsula
Grossulariaceae	*Ribes* L.	*R.aureum* Pursh	Shrub	Mesophyte	Western Karatau Southern Aktau
Moraceae	*Morus* L.	*M.alba* L.	Wood	Xeromesophyte	Tubkaragan Peninsula
		nigra L.	Wood	Xeromesophyte	Tubkaragan Peninsula
Nitrariaceae	*Nitraria* L.	*N. schoberi* L.	Shrub	Xerophyte	Karagie Depression, Tubkaragan Peninsula,
		sibirica Pall.	Shrub	Xerophyte	Caspian coast
Peganaceae	*Malococarpus*	*crithmifolius* (Retz.) C.A. Mey	Shrub	Xerophyte	Caspian Sea coast, Tubkaragan Peninsula, Western Karatau, Eastern Karatau,
Rosaceae	*Crataegus* L.	*C. ambigua* C.A. Mey.	Shrub or tree	xeromesophyte	Tubkaragan Peninsula, Western Karatau, Eastern Karatau, Northern Aktau Mountains
		C.altaica Lge.	A small tree	Xeromesophyte	Zheltau Mountains

Continuation of Table

Family	Rod	View	Life form	Environmental Group	Gathering place
Rosaceae	*Rubus* L.	*R. caesius* L.	Shrub	Mesophyte	Tubkaragan Peninsula, Southern Aktau Mountains, Western Karatau,

Comparative analysis of the ecological spectrum of fruit and berry plants has shown that in both regions a significant proportion of mesophytes are mesophytes. Distribution of species by ecological groups is as follows: in Mangistau — 7 mesophytes, 6 xeromesophytes and 5 xerophytes; in Atyrau — 9 mesophytes, 1 xeromesophyte and 5 xerophytes.

Extremely arid conditions, poor soils, high salinity and high summer temperatures favor the distribution of xeromesophytes, which require certain moisture conditions, in coastal zones, floodplains, stony and clay soils, knobby sands and mountainous areas [10-11].

The current status of natural populations of six tree fruit species was investigated: *Crataegus ambigua*, *Crataegus altaica*, *Rosa laxa*, *Rosa iliensis*, *Ribes aureum* and *Lonicera tatarica*.

Crataegus altaica is found in the Zheltau Mountains, located on the border of Atyrau and Mangistau oblasts. This species is concentrated mainly in the lower part of the mountain on stony slopes, with dense thickets observed on the northern slopes of Zheltau. Here *Crataegus altaica* forms herb-shrub-bush-bogwort communities covering areas of 500–600 m², mainly in the lower parts of gorges and along their bottoms, on stony and loamy soils. The vegetation cover is characterized by diversity with projective coverage of 50–65 %. The main species of the community are *Crataegus altaica*, *Lonicera tatarica* and *Rosa laxa*, as well as various perennials. Structurally, the community is divided into three tiers: woody (200–600 cm high), represented by *C. altaica; shrubs* and bushes*. altaica*; shrub (120–200 cm), including *Rhamnus sintenesii*, *Lonicera tatarica*, *Spiraea hypericifolia*, *Rosa laxa*, and *Atraphaxi sreplicata*; and herbaceous (up to 70 cm) with such species as *Centaurea adpressa*, *Marrubium vulgare*, *Nepeta cataria*, *Ephedra distachya*, *Agropyron desertorum*, *Achillea nobilis*, and others.

Crataegus ambigua is endemic to Western Kazakhstan and a rare endangered species, included in the Red Data Book of Kazakhstan [12] and the Catalog of Rare Species of Mangystau Oblast [13]. In a number of works, the name *Crataegus ambigua* (doubtful hawthorn) is retained for the Mangyshlak hawthorn [14–16], when other authors [17] recognize it as an independent species *Crataegus transcaspica* (Transcaspian hawthorn).

In the natural flora of Mangistau, C. *ambigua* is found in the gorges of oases of the Karatau Mountains and the Tyubkaragan Peninsula. Here, on steep stony slopes with bedrock outcrops, wormwood-shrub communities with petrophytic perennials (*Centaurea squarrosa*, *Cousinia onopordioides*, *Lagochilus acutilobus*, *Verbascum songaricum*), shrubs (*Rhamnus sintenesii*, *Caragana grandiflora*, *Atraphaxis replicata*) and semishrub *Convolvulu sfruticosus* develop. Mesophytic thickets (*Carex diluta*, *Mentha longifolia*, *Phragmites australis*, *Plantago lanceolata*) grow along the bottom of the gorge near springs, and *Achnatherum splendens* grows on saline soils near springs, with projective coverage of 60–65 %. In gorges*, C. ambigua* forms hawthorn-joster-grass communities found in the lower parts of gorges and along stream beds. These communities are structured into three tiers: woody (up to 300 cm, with *C. ambigua), shrubby* (up to 300 cm, with *C. ambigua*), shrub (120–200 cm, with *Rhamnus sintenesii*, young hawthorns and *Caragana grandiflora*), and herbaceous (up to 70 cm), represented by *Centaurea squarrosa*, *Teucrium polium*, *Prangos odontalgica*, *Gallium humifusum*, *Mentha longifolia*, *Marrubium vulgare*, *Nepeta cataria*, *Crambe edentula*, *Ephedra distachya*, *Plantago lanceolata*, *Veronica amoena*, *Cynanchum sibiricum*, *Scandix stellata*, *Stellari amedia*, *Barbarea arcuata*, *Polygonum aviculare*, *Erodium cicutarium*, *Lamium amplexicaule*, *Verbascum songaricum*, and rarely occurring *Ziziphora tenuior*.

Lonicera tatarica was found in the Kolenkeli Mountains of Mangistau Oblast and the Zheltau Mountains of Atyrau Oblast. Distribution and tier structure of communities with participation of Tatar honeysuckle is similar to communities formed by *Crataegus altaica* and described above. Honeysuckle communities are located on stony plains punctuated by gorges. In the Kolenkeli Mountains*, Lonicera tatarica* grows on the upper parts of gentle slopes in sparse groups, occupying patches of 12×3.5 m, 8×3 m, 4×2 m, and 2.5×5 m in size. It forms small thickets in the composition of gurganic-wormwood and boyalycheid-solanaceous com-

munities (*Lonicera tatarica — Artemisia gurganica — Salsola arbusculiformis*). The vegetation here is typically mountain-desert, with low species diversity and total projective cover of 40–45 %. Two tiers are distinguished in the community: upper shrubby (120–220 cm) and herbaceous (60–80 cm). The shrub layer is represented by middle-aged, young and old shrubs of honeysuckle and tavolga. The herbaceous tier includes *Cichorium intybus*, *Agropyron fragile*, *Ephedra distachya*, *Descurainia sophia*, *Lepidium latifolium*, *Poa bulbosa*, *Tanacetum santolina*, *Stipa lessingiana*, *Achillea nobilis* and others. On stony peaks there are wormwoods, including *Artemisia gurganica*, *A. lerchiana* and shrub *Salsola arbusculiformis*, with herbs (*Ephedra aurantiaca*, *Agropyron desertorum*, *Tulipa biflora*, *Tulipa schrenkii*, *Melandrium viscosum*, *Goldbachia pendula*, etc.). Due to the steep relief and remoteness of slopes, the vegetation here is not used for grazing.

Rosa laxa is found on the Western Karatau Ridge in the Akmysh and Kogez Gorges, in the Zheltau Mountains (Sarbulak Gorge) of Mangistau Oblast, and in the Zheltau and Inder Mountains of Atyrau Oblast. In the Akmysh Gorge *Rosa laxa* is part of the hawthorn-herbaceous community (*Crataegus ambigua — Herba varia*), confined to rocky scree of the lower part of slopes. Three tiers are distinguished in the community: woody (up to 4.5 m), formed by adults of the doubtful hawthorn (*Crataegus ambigua*) and common apricot (*Armeniaca vulgaris*); shrubby (up to 160 cm), including *Rhamnus sintenisii*, *Rosa laxa*, *Convolvulus fruticosus*, *Atraphaxis replicata*, *Caragana grandiflora*, young hawthorn plants; and herbaceous tier (up to 60 cm), including *Mentha longifolia*, *Teucrium polium*, *Artemisia austriaca*, *Meristotropis triphylla*, *Lagochilus acutilobus* and other species.

In the Kogez Gorge *Rosa laxa* participates in the hawthorn-joster-herbaceous community (*Crataegus ambigua — Rhamnus sintenisii — Herba varia*), characteristic of the mountain desert. Three tiers were also identified here: Woody (up to 5-5.5 m), represented by white willow, single specimens of Sievers apple and common apricot, and adult hawthorns; shrubby (up to 200 cm), including thickets of *Rhamnus sintenisii*, *Caragana grandiflora*, *Rosa iliensis*, *Prunus spinosa*; and herbaceous tier (up to 70 cm) with such species as *Nepeta cataria*, *Cichorium intybus*, *Teucrium polium*, *Inula britannica*, *Artemisia austriaca*, *Melilotus albus*, *Scandix stellata*, *Stellaria media, Chorispora tenella*, *Camelina sylvestris* and others. In both Akmysh and Kogez gorges, *Rosa laxa* vitality is good, plants flower abundantly, although fruiting is average, with no signs of damage or disease. Renewal from root shoots is also observed.

In Atyrau oblast *Rosa laxa* forms small thickets in the Zheltau Mountains, being a part of a shrubby *herbaceous* community (*Atraphaxis spinosa* + *Rosa laxa — Herba varia*). The community is located on stony scree in the middle part of the gorge slopes, where *Atraphaxis spinosa* dominates with *Rosa laxa* co-dominant. The vegetation consists of two tiers: the upper shrubby tier (80–120 cm) is represented by individuals of *Atraphaxis spinosa* and *Rosa laxa*, and the second herbaceous tier (20–50 cm) includes *Centaurea squarrosa*, *Echinops ritro*, *Silene suffrutescens*, *Malacocarpus critmifolium* and other species. In the Zheltau Mountains, rose hips show poor fruiting, but the general condition of plants is assessed as satisfactory.

In the Inderbora mountains, *Rosa laxa* forms large thickets in deep cavities, forming a briar-herbaceous community with a diverse vegetation cover. Two tiers are distinguished in these communities: Upper shrubby (100–200 cm), represented by *Spiraea hypericifolia*, *Rubus caesius* and *Rosa laxa*, and lower herbaceous (30–70 cm), consisting of *Nepeta cataria*, *Marrubium vulgare*, *Verbascum songaricum*, *Potentilla pedata*, *Plantago salsa*, *Lavatera thuringiaca*, *Lactuca serriola*, *Artemisia lercheana*, *Ephedra lamotolepis*, *Agropyron fragile*, *Poa bulbosa*, *Euphorbia seguieriana*, *Allium sabulosum*, *Kochia prostrata* and other species. The rosehip population is characterized by good condition and the presence of a significant number of young fruit-bearing individuals, as well as the absence of pests and damage.

Rosa iliensis Chrshan is a rare, endangered and narrowly endemic species. In the natural environment it lives in the Ili River valley, preferring floodplain tugai and moisture-loving conditions.

In Mangistau it occurs in Western Karatau, in the stream valley and on stony slopes of the Kogez Gorge, being a part of hawthorn-herbaceous community (*Crataegus ambigua — Herba varia*), forming a shrubby tier. The height of a single shrub reaches 2.5 m, the curly branches can grow up to 7 m, clinging to nearby trees. Individual shrubs vary in size from 5 to 8 m long and 3-4 m wide. Plants are well-branched, dense and abundantly fruiting; fruits are smooth, globular, black, 5-6 mm in diameter.

Ribes aureum Rursh. was recorded in the Karaturan Gorge of the Southern Aktau Range and in the Kogez Gorge of the Western Karatau Range. In the Karaturan gorge, golden currant grows in a silk-grass community (*Morus alba — Herba varia*), where *Moru salba* dominates and *Artemisia lessingiana* is a co-dominant. The vegetation is distributed in three tiers: tree (up to 5 m high), shrub (120–150 cm) and herb (up to 50–60 cm). The woody tier is represented by *Morus alba*, the shrubby tier by *Rhamnus sintenesii*,

Atraphaxis replicata and *Ribes aureum*. The herbaceous tier is characterized by a diversity of species including *Artemisia lessingiana*, *Agropyron fragile*, *Medicago caerulea*, *Potentilla supina*, *Eremopyron bonaepartis*, *Poa bulbosa*, *Alhagi pseudalhagi*, *Malacocarpus critmifolium*, *Ephedra distachya*, *Echinops ritro*, *Nepeta cataria*, *Haplophyllum obtusifolium* and *Schumannia karelinii*. *Ribes aureum* occurs sporadically in this community, the plants are of medium maturity and in good condition, but most of the trees are non-bearing. Root regeneration was identified during the survey.

In Mangyshlak Experimental Botanical Garden the selection of representatives of indigenous dendroflora of Western Kazakhstan for the formation of the collection was started. It includes 15 species of tree and shrub plants collected in natural conditions, among which 7 rare and endangered species included in the Red Book of Kazakhstan and the Catalog of rare species of Mangystau region. Phenological observations and primary biometric measurements were made. The following is a brief characterization of introducers:

Doubtful hawthorn (Crataegus ambigua C.A. Mey. Ex A.Beck.). It is a shrub or small tree up to 3-4 m high with a broadly round crown, belonging to mesoxerophytes. The trunk is gray, strongly gaunt and branched; young shoots are grayish-yellow in color. Spines are stout, 1-1.5 cm long. Leaves are leathery, green above, lighter below, with 7 lobes and toothed edges, 4-5 cm long and 3-4 cm wide, petiole 1.5-2 cm long. The plant flowers and fruits abundantly. Flowers are white, five-petaled, 1.5 cm in diameter, with 15 stamens and one pistil. Grown from seeds collected in the natural flora of Mangistau. Flowering begins in the third decade of April and lasts until mid-May. Fruits are purplish-red, fleshy, juicy, globular, 12–14 mm in diameter, with 1-2 seeds (seed length 8-9 mm, width 4-5 mm, ribbed, elliptical shape), ripening in October. Propagated by seeds; the most effective is the fall sowing of freshly harvested seeds. It has high winter hardiness and drought resistance. It has potential for use in medicine, ornamental horticulture, beekeeping and food industry.

White silkworm (*Morus alba* L.) is a 15–20 m tall tree belonging to mesoxerophytes. Branches are grayish-brown, young ones are downy; buds are broadly ovate, about 6 mm long. Leaves are 6–15 cm long and 4–10 cm wide, ovate or oblong-ovate, may be entire or more often pinnately 2–5-lobed, roundly urban-toothed along the margin. The plant was brought from the natural flora of Mangistau (Tyubkaragan peninsula). The height of a 5-year-old specimen is 1.2 m, average growth is 27 cm. Growth rate is medium, with high winter hardiness and drought resistance. Flowering occurs in the second half of April to the first decade of May, fruiting — in the third decade of June. Fruits are 1-2.5 cm long, greenish-white, pink or purplish-black, very juicy and sweet. The species has prospects for use in ornamental horticulture and food industry.

Sievers' apple-tree (*Malus sieversii* (Ledeb.) M.Roem) is a tree belonging to xeromesophytes. The apple-tree specimens were attracted to the culture by live plants from the Ural River floodplain. The apple-tree starts vegetation in the first decade of March; leaf budding is recorded from the second decade of March to the middle of April. Young specimens have not reached the generative period yet. The condition of plants in the collection is satisfactory, height up to 1.5 m. The species has prospects as a food, ornamental and melliferous plant, as well as a scion for cultivated varieties of apple trees.

Populus diversifolia (*Populus diversifolia* Schrenk) — small trees belonging to xerophytes. Plants were attracted by live specimens and cuttings from Ustyurt Reserve (Mangistau oblast). Vegetation begins in the first decade of March, leaf unfolding occurs in the middle of March, and the end of their growth — in the third decade of July. Budding was recorded in early April, flowering — from mid to late April. Fruit formation was not recorded. The height of plants reaches 1.2-1.8 m, the condition in culture is very good. The species has prospects of application for landscaping of the region and as a phytomeliorative plant.

The prickly plum or sloe (*Prunus spinosa* L.) is a small tree or shrub belonging to mesoxerophytes. Plants were attracted from the Ural River valley. The beginning of vegetation is observed in the second decade of March, and leaf budding and growth occurs from mid-March to the second half of April. The attracted specimens are young, they have not entered the generative period. The condition of the plants is very good, with a height of up to 80 cm. Tern has prospects as a food, ornamental, ameliorative and melliferous plant.

Steppe almond (AmygdalusnanaL.) is a low-growing shrub belonging to mesoxerophytes. It is grown from seeds. Vegetation begins in the second decade of March, full leaf budding is completed by the end of March; budding occurs in late March, and flowering — in the first and second decades of April. Fruit setting has not been recorded in culture. Under botanical garden conditions, plants reach a height of 30–35 cm and are in good condition. The species has potential for use in ornamental and melliferous purposes.

Rosehip loose (*Rosa laxa* Retz.) is a tall shrub, reaching 2.5 m, belongs to mesoxerophytes. Old branches are brown, young branches are brown-greenish. Spines up to 7 mm long are located in pairs under the leaves, they are curved and slightly flattened. Leaves are about 7 cm long and consist of 5–9 oval leaflets,

glabrous on both sides, gray-green in color with simple toothed edges. The plant was brought from the vicinity of Lake Inder (Atyrau region). Vegetation begins in the first decade of March, leaf budding is observed from mid-March to early May. Budding is observed in the first half of May, flowering — from the middle to the end of May, fruiting — from the end of May, fruit ripening occurs in late September. The plant is characterized by high winter hardiness and drought resistance, the average growth during the growing season is 21 cm. In culture stable, the condition is very good. Promising for ornamental and medicinal use Iliya rosehip (*Rosa iliensis* Chrshan) is a low, densely branched shrub with thin, zigzag branches; it belongs to xeromesophytes. Branches are covered with powerful hook-shaped spines up to 7 mm long. Leaves are 8 cm long and consist of 7-8 oval-elliptic leaflets with acuminate apex, simply toothed margins and are green-blue above and gray-green below. The plant is brought from seed. It blooms from early May to the end of the first decade of June. Flowers form loose semi-umbrellas, corollas white or slightly pinkish, 3 cm in diameter. Fruits are black, globular, ripening in late September. The species is close to Begger's briar, differing only in black fruits. It has high winter hardiness and drought resistance, the average growth is 12 cm. It is promising for ornamental and melliferous use; it is found in nature in the Ili River valley.

Dog rosehip (*Rosa canina* L.) is a large shrub up to 3-4 m high and with a base diameter up to 4 cm, belonging to xeromesophytes. Old shoots are gray-brownish-brown, thick and arcuately curved. Young shoots have a red upper part and green lower part, with sparse sickle-shaped spines up to 1 cm long. Leaves are up to 12 cm long and consist of 5–7 broadly oval, pointed at the apex. Inflorescences are semi-umbrellas containing up to 12 flowers, more often 3-4, with bright pink corollas up to 6 cm in diameter. The plant is grown from seeds and blooms from the second decade of April to mid-May. The fruits are oval, smooth, dark maroon, ripen in late September and are used medicinally. The plant is propagated by seeds and gives abundant self-seeding, the average annual growth during the growing season is 24 cm. It is characterized by high decorative value, both in the period of flowering and fruiting. Dog rose is a common rootstock for garden roses, providing unpretentiousness, winter hardiness and resistance to diseases. It has prospects as an ornamental, medicinal and melliferous plant.

Spiraea hypericifolia L. is a low shrub belonging to xerophytes. It was brought into culture by cuttings and young specimens from steppe areas of Atyrau and northern part of Mangistau oblast. The beginning of vegetation is observed in the first decade of March, leaf budding is fixed from the middle to the end of March. At the moment, plants have not reached generative state, which did not allow to record budding and flowering. The condition of plants is satisfactory, height is 40–50 cm. This species has prospects of application in ornamental and honey-bearing horticulture.

Golden currant (*Ribes aureum* Pursh.) is a shrub belonging to xeromesophytes. It is attracted by living plants from the Ural River floodplain. The beginning of vegetation falls on the middle of March, leaf budding was recorded from the second half of March to the third decade of April. Budding begins in the middle of April, flowering — from the second half of April to the end of April. Fruiting is abundant, from late April to mid-June. Growth of shoots is completed in mid-April. The condition in culture is very good, the height of plants is 120–140 cm. The species has prospects as an ornamental, ameliorative and food plant.

Malacocarpuscrittmifolius (Retz.) C.A. Mey.) is a shrub with whitish bark, belonging to xeromesophytes. It is a rare relict species. It was brought into culture by seedlings from the natural flora of Mangistau. Height reaches 1.5 m, bush diameter — 2.95 m, average growth — 16 cm. Vegetation begins in the first decade of April, flowering occurs from the second decade of May to the end of August, fruiting — from the second half of June to the third decade of September. Both fully ripe and unripe fruits can occur on one specimen. Winter resistance and drought tolerance are high. It is well propagated by seeds. The species has prospects as an ornamental and food plant.

Nitraria schoberi L. is a 1-2 m high shrub with whitish-gray bark, spreading-branched, with prickly twigs at the ends, belonging to xerophytes. Seedlings from the natural flora of Mangistau were attracted to the botanical garden and planted in the form of a clump. Height reaches 1.3-2 m, bush diameter — 5.95 m, growth varies from 21 to 58 cm. The growth rate is high. Vegetation begins from the first decade of April, flowering — from the second decade of May to the second decade of June, fruiting — from the second decade of June to the end of July. It has high winter hardiness and drought resistance, well propagated by seeds. The species has prospects as an ornamental, food and medicinal plant.

Gester sintenisii (*Rhamnus sintenisii* Rech. fil.) is a strongly branched thorny shrub belonging to xerophytes. Living plants from the natural flora of Mangistau were attracted to the botanical garden. Height reaches 1.1-2 m, bush diameter — 4.5 m, average growth is 15–20 cm. The growth rate is average. Vegetation begins in the second decade of March, flowering — from the first decade of May to the third decade of

May, fruits ripen in June–July. It has high winter hardiness and drought resistance, and is propagated by seeds. The species has prospects as an ornamental and medicinal plant.

Blue raspberry or blackberry (*Rubus caesium* L.) is a thorny climbing shrub belonging to mesophytes. Plants were attracted from the gorges of Tyubkargan peninsula in Mangistau oblast. The beginning of vegetation falls on the second decade of March, leaf budding is recorded from mid-March to mid-April. Budding begins in early May, flowering — from the first decade of May to mid-August. Fruiting is abundant and prolonged, from the end of May to the end of August. The height of shoots in culture reaches 120–140 cm, the condition is good. The plant has prospects as a melliferous and food plant.

Conclusion

Aboriginal dendroflora of Western Kazakhstan is an important resource for introduction in desert conditions of Mangistau. Despite the natural limiting factors of the desert zone, all the species under consideration are well adapted and can be used as fruit and berry plants. Proper use of these plants can significantly improve the ecological situation in the region, contributing to the restoration of the natural balance and sustainable development of local communities.

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Батыс Қазақстанның аборигенді дендрофлорасын Маңғыстаудың шөліне интродукциялау

Мақала Батыс Қазақстанның аборигенді дендрофлорасын зерттеуге және оны Маңғыстаудың шөлді жағдайларына интродукциялауға арналған. Маңғыстау облысының флорасы 333 тұқымдас пен 73 туысқа жататын жоғары споралы және тамырлы өсімдіктердің 770 түрін қамтиды. Атырау облысында 351 тұқымдас пен 85 тұқымдасқа жататын жоғары тамырлы өсімдіктердің 899 түрі тіркелген. Аборигенді ағаш өсімдіктері Атырау облысында жалпы флораның 7,8%-ын; Маңғыстау облысында 16,7%-ды құрайды, бұл олардың өсімдік жамылғысындағы үлесінің төмендігін көрсетеді. *Crataegus ambigua, Crataegus altaica, Rosa laxa, Rosa iliensis, Ribes aureum* және *Lonicera tatarica* секілді алты ағаш жеміс-жидек түрлерінің табиғи популяцияларының жағдайы зерттелді. Батыс Қазақстанның дендрофлорасының өкілдерін жинау жұмыстары басталды, оның құрамына 15 түр, соның ішінде Қазақстанның және Маңғыстау облысының Қызыл кітабына енгізілген 7 сирек және жойылып бара жатқан түрлер бар. Аборигенді ағаш өсімдіктерінің азықтық, дәрілік және экологиялық функциялары, сондай-ақ экожүйелерді қалпына келтіру мен азық-түлік қауіпсіздігін қамтамасыз ету мақсатында қолдану перспективалары талданды.

Кілт сөздер: табиғи өсімдіктер дүниесі, Батыс Қазақстан, Маңғыстау, Атырау, өсімдіктер әлемі, популяциясы, интродукциясы.

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Аборигенная дендрофлора Западного Казахстана при интродукции в пустыне Мангистау

Статья посвящена исследованию аборигенной дендрофлоры Западного Казахстана и её интродукции в пустынные условия Мангистау. Флора Мангистауской области включает 770 видов высших споровых и сосудистых растений, принадлежащих к 333 родам и 73 семействам. В Атырауской области зафиксировано 899 видов высших сосудистых растений, относящихся к 351 роду и 85 семействам. Аборигенные древесные растения составляют 7,8 % от общего числа флоры в Атырауской области и 16,7 % в Мангистауской области, что указывает на их низкую долю в растительном покрове. Изучено состояние природных популяций шести древесных плодово-ягодных видов: *Crataegus ambigua*, *Crataegus altaica*, *Rosa laxa*, *Rosa iliensis*, *Ribes aureum* и *Lonicera tatarica*. Начат отбор представителей аборигенной дендрофлоры Западного Казахстана для формирования коллекции, в которую включены 15 видов, в том числе 7 редких и исчезающих, занесённых в Красную книгу Казахстана и Мангистауской области. Анализируются аборигенные древесные растения, их пищевые, лекарственные и экологические функции, а также перспективы использования для восстановления экосистем и обеспечения продовольственной безопасности.

Ключевые слова: природная флора, Западный Казахстан, Мангистау, Атырау, флора, популяция, интродукция.

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Features of introduction of *Dactylorhiza fuchsii* (Druce) Soó in the conditions of the Astana botanical garden

This article presented the initial results of experimental work aimed at establishing an introduction population from living specimens of *Dactylorhiza fuchsii* in the Astana Botanical Garden (ABG). In the flora of Central Kazakhstan, there are 17 species from the family Orchidaceae, with only one species, *Dactylorhiza fuchsii*, listed in the Red Book of Kazakhstan. Propagation and cultivation of orchids under introduction conditions for species conservation and potential reintroduction into their natural habitat have become increasingly relevant. Knowledge of orchid habitats and their ecological preferences is essential for their proper conservation and the development of introduction methods. As a result of a three-year study of the introduction of *Dactylorhiza fuchsii*, it has been established that this population exhibits moderate survival rates of generative and vegetative individuals. Over the results of three years, a total of 3 individuals were accounted for (21 % of those initially planted). The age composition consists of two ontogenetic states: 2 individuals in the generative (g) state and 1 in the vegetative (v) state. Ontogenetic states of *Dactylorhiza fuchsii* were determined based on morphological characteristics of above-ground organs, including leaf number, size of the lower leaf, and number of veins in it. Non-flowering individuals were categorized as generative.

Keywords: introduction, *Dactylorhiza fuchsii,* Astana Botanical Garden, population, Red Book, Central Kazakhstan Upland, conservation.

Introduction

Since the establishment of the collection of natural flora at the Astana Botanical Garden, special attention has been given to cultivating rare and endangered species, as well as those with shrinking ranges and populations, of the flora of Kazakhstan. This effort is also in response to the pressing task of preserving the gene pool of the local regional flora. Protected plants in the Akmola region include species listed in the Red Data Book of Kazakhstan, which require constant monitoring and observation within the region. This includes *Dactylorhiza fuchsia* [1].

Dactylorhiza fuchsii is successfully cultivated in the botanical gardens of Moscow, St. Petersburg, Yekaterinburg, and others [2, 3]. However, the introduction of this species in the conditions of the Central Siberian Botanical Garden has proven to be less promising [4]. *D. fuchsii* grows well in cultivation (both in partial shade and open areas) without requiring special substrates. This species can be easily propagated in vitro using mature seeds, and the seedlings develop well. The plants adapt easily when transplanted into non-sterile conditions. They typically flower in the 5th to 6th year after sowing [5, 6]. There is report about incidental reintroduction experiment with this species. A single individual was planted in the Podolsk district of the Moscow region on a hayfield with dry loamy soil. Over 8 years, the plant spread within a 15-meter radius in atypical habitat conditions for the species due to self-seeding. A total of 23 individuals were found, 7 of which was flowering [7].

The first experiments to establish an introduction population of *D. fuchsii* at the Main Botanical Garden of the Russian Academy of Sciences were conducted in 1958. At that time, 20 individuals were brought from the Moscow region and planted in a plot of broad-leaved forest. Long-term observations were carried out to study their seasonal development rhythms. Individual specimens from these original samples still exist to this day [8].

The family Orchidaceae represents a diverse and globally significant group of plants with high conservation requirements and priority status. The issue of the disappearance of orchids growing within the flora of the Central Kazakhstan Uplands is particularly acute. Due to limited germination, mycorrhizal specificity, and pollinator specialization, orchids are particularly vulnerable to changes in ecosystem balance, especially

alterations in moisture content, light regimes, nutrient availability, and competitive pressures [9]. Changes in habitat or their complete destruction have led to the extinction or decline in the population and distribution of many orchid species, resulting in legal protection and/or inclusion in the Red Data Book [10]. A study and compilation of a checklist for Orchidaceae in the northern part of Kazakhstan was conducted based on herbarium materials, field research, and literature [11].

In the flora of the Central Kazakhstan Uplands, there are 17 species from the family Orchidaceae [1], including 6 species of the genus *Dactylorhiza* [12], of which only one species, *Dactylorhiza fuchsii*, is listed in the Red Data Book of Kazakhstan [1]. In light of this, the propagation and cultivation of orchids under introduction conditions are becoming increasingly relevant for species conservation and the potential for subsequent reintroduction into their natural habitats [13]. Therefore, understanding the habitat and ecological preferences of orchids is essential for their proper conservation and the development of introduction methods.

One of the main objectives of botanical gardens is preservation genetic diversity and promoting sustainable use of plants and ecosystems. As a result of habitat disturbance, plants may face the threat of extinction or serious genetic erosion. Plant genetic diversity, which plays a crucial role in human development, is decreasing. Excessive use of medicinal, food, and ornamental plants growing in natural conditions leads to depletion of their populations. In 1994, the International Council of Botanical Gardens for Plant Conservation, with support and financial assistance from the International Plant Genetic Resources Institute, United Nations Educational, Scientific and Cultural Organization (UNESCO), Food and Agriculture Organization (FAO) of the United Nations, United Nations Environment Program (UNEP), and World Wide Fund for Nature (WWF), developed measures. According to the "Strategy of Botanical Gardens for Plant Conservation" [14], botanical gardens today are regarded as centers for the conservation and study of plants, where the introduction and cultivation of rare plants are seen as methods for their preservation. Establishing collections of rare plants in botanical gardens are serving not only as insurance and material for research but also as an opportunity for educational outreach and sometimes as a primary source for restoring disappearing species in nature. In essence, botanical gardens fulfill a triple function: conservation, propagation, and education. The development of methods for objective assessment of population status and identification of mechanisms for the resilience of rare orchid species can only be achieved through comprehensive study of their biological characteristics, ecological preferences, population structure and dynamics, and consortial relationships with other components of the biocoenosis. A systematic approach to studying rare orchid species allows for predicting the subsequent development of specific populations and devising the most effective conservation measures for each species.

Thus, threat of anthropogenic changes to the vegetation cover of the Central Kazakhstan Uplands, there is an unprecedented need for the introduction studies of the rare medicinal plant *Dactylorhiza fuchsii*.

The aim of this study is to conduct introduction research on *Dactylorhiza fuchsii* in the conditions of the Astana Botanical Garden.

Experimental

Introduction studies of new species, forms, cultivars of plants, or their transfer from the wild into cultivation are being conducted for the first time at the Astana Botanical Garden (ABG) in Astana.

The climate of Astana is sharply continental, characterized by dry summers and cold, snowy winters. The warm season lasts for 4 months, from May to September, with maximum daily average temperatures exceeding 19 °C. The hottest month is July, with an average maximum temperature of 26 °C and a minimum of 14 °C. The cold season spans 3.8 months, from November to March, with minimum daily average temperatures below -4 °C. The coldest month in Astana is January, with an average maximum temperature of -20 °C and a minimum of -11 °C.

Traditional methods of introduction research were employed [15]. Plant emergence records and phenological observations will be conducted using the methodologies developed by B.I. Ivanchenko (1962) [16] and B.A. Dospechov (1968) [17].

D.fuchsii (Druce) Soo is a meadow-forest species found in Kazakhstan within floristic regions classified under 22 altitudinal zones. It inhabits habitats with moist meadow-like moisture, growing in both open spaces and shady forests depending on light availability. It prefers neutral soil acidity and nutrient-rich soils. The population of *D.fuchsii* is declining due to habitat destruction and the collection of generative shoots for bouquets. This species has been listed in the Red Book of Kazakhstan (2014).

The initial material for introduction research consisted of plant samples collected in the territory of the Kokshetau National Park (Fig. 1).

Figure 1. Populations of *Dactylorhiza fuchsii* in the territory of Kokshetau National Park

The original material was sourced exclusively from natural habitats in the form of live plants. Significant importance was placed on the age, phenological phase, and overall condition of the transplanted plants. In the first year, all introductants were placed in the primary introduction plot. All samples were kept under uniform conditions: meadow-chernozem soil with added sand, and standard agronomic practices (watering, weeding, and loosening) were applied. Observations on experimental plants were conducted from 2021 to 2023 by measuring biometric parameters such as plant height, inflorescence size, flower dimensions, and so on.

Results and Discussion

Observations of the phenorhythm of the test plants in different environmental conditions demonstrate the adaptability of individuals to changing external factors and the completeness of passing through ontogenetic stages. Therefore, phenological data are one of the most important indicators in plant introduction.

The first introduction experiments to establish a population of *D. fuchsii* were conducted in the shaded conditions of the Astana Botanical Garden in 2021. Seven individuals were transported from the Ormandybulak Forestry, Kokshetau National Park, and planted on September 15, 2021 (Fig. 2).

However, the individuals of *D.fuchsii* did not establish themselves. In 2022, work on creating an introduction population of this species was continued. On the adjacent territory near the building of the Astana Botanical Garden, an area of 1x1 m² was planted with 14 individuals (Fig. 3). After planting, all individuals were labeled and mapped for subsequent observations. The plants consisted of 7 generative (g) individuals and 7 vegetative (v) individuals. Due to weather conditions in 2023, changes in phenological terms were noted. The first flowering of the rare species was observed on June 13, with mass flowering beginning in the third decade of June. The end of flowering of this ephemeral species was noted from June 25–28.

Figure 2. Planting of *Dactylorhiza fuchsii* in 2021 at the territory of Astana Botanical Garden

Figure 3. Introduced plants in 2022-2023, territory of ABG

The specimens brought from natural populations of the rare species (Table) showed a low degree of adaptation to the new conditions, characterized by incomplete phenological stages of development in the introduction conditions (up to the budding stage, but no flowering occurred).

T a b l e

Morphological parameters of introduced plants of *Dactylorhiza fuchsii* in ABG

Biometric indicators	Plant 1	Plant 2	Plant 3
Leaf length, cm	13	5	10
Leaf width, cm	1.4	0.7	1,6
Leaf length, cm	7	4	10.5
Leaf width, cm	1.5	1	2

The main developmental phases, both in the wild and on the collection plot, occurred at the same time.

Observations of the seasonal phenological rhythms of the rare *D.fuchsii* showed that the duration of vegetation depends on weather conditions and can vary from 7 to 30 days. From 2022 to 2023, flowering of the species was not observed.

The record of individuals in 2023 showed that the population amounted to 3 individuals (21 % of those planted). The age composition of this group was represented by two ontogenetic states: generative (g) — 2 individuals (14 %) and virgin (v) individuals — 1 (7.1 %), and they did not bloom. We cannot assess the survival rate of the plants in the first years because orchids are capable of entering a state of secondary dormancy, caused by various factors. According to M.G. Vakhrameeva [18], the duration of the secondary dormancy state in *D. fuchsii* individuals ranges from 1 to 3 years, and in some cases, up to 4 years. The ontogenetic states of *D. fuchsii* are determined by the morphological characteristics of the above-ground organs: the number of leaves, the size of the lower leaf, and the number of veins in it. We classified non-flowering individuals as generative. Khomutovsky M.I. (2012) reports that species of the genus *Dactylorhiza* behave differently under cultivation conditions. One of the most resilient plants in open ground conditions is *D. fuchsii*, which annually flowered and set fruits with viable seeds. Vegetative reproduction of tuberous species is more frequently observed in populations at the edges of their ranges in extreme conditions. Additionally, *D. fuchsii* (both vegetative and generative) successfully passed all phenological phases. However, due to the lack of pollinators in the greenhouse, the tested specimens did not set fruits [19].

D.fuchsii is capable of surviving and spreading in urban habitats [20].

As a result of the initial introduction of *Dactylorhiza* species at the Altai Botanical Garden, four species of the genus *Dactylorhiza* (*D. fuchsii*, *D. incarnata*, *D. maculata*, and *D. umbrosa*) were introduced. *D. incarnata* proved to be more plastic and adaptable to cultivation conditions, as indicated by increased inflorescence length, number of flowers per inflorescence, and dimensions of basal leaves in terms of length and width. Due to the high nutrient content in the soil, the number of flowers per inflorescence increased for all four species. Additionally, plant height decreased for all species due to receiving more sunlight [21].

Conclusions

Therefore, the rare species considered in this article has shown resilience under introduction conditions at the Astana Botanical Garden. The conditions provided by the botanical garden are favorable for this species; it is possible to predict normal survival of the introduced population in this area in the coming years. Regarding the population growth due to the appearance of young individuals, data will only become available in a few years.

Based on a three-year monitoring of the introduced *D. fuchsii* population, it has been determined that this population exhibits moderate survival rates among pre-generative individuals. Virgin individuals show the highest survival rates. The census in 2023 revealed that the population consisted of 3 individuals (21 % of those planted). The age composition includes 2 generative (g) and 1 virgin (v) individuals.

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Астана ботаникалық бағы жағдайында *Dactylorhiza fuchsii* (Druce) Soó интродукциялау ерекшеліктері

Мақалада алғаш рет Астана қаласының Астана ботаникалық бағында (АББ) *Dactylorhiza fuchsii* тірі өсімдіктерінен интродукциялық популяцияны құру бойынша эксперименттік жұмыстың нәтижелері келтірілген. Орталық Қазақстан ұсақ шоқыларының флорасында *Orchidaceae* тұқымдасының 17 түрі бар және тек бір түрі — *D. fuchsii* Қазақстанның Қызыл кітабына енгізілген. Түрлерді сақтау үшін

орхидеяларды интродукциялық жағдайда көбейту және өсіру, оларды кейін табиғи тіршілік ортасына бейімделу мүмкіндігі үлкен өзектілікке ие. Орхидеялардың тіршілік ету ортасы мен экологиялық бейімділігін білу оларды дұрыс сақтау және енгізу әдістерін әзірлеудің міндетті шарты болып табылады. *D. fuchsii* интродукциясындағы өсімдіктердің жағдайын үш жылдық бақылау нәтижесінде, бұл популяция генеративті және виргинильді дарақтардың орташа өмір сүруімен сипатталатыны анықталды. Үш жыл ішінде жеке дарақтарды есепке алу 3 дарақты құрады (жерсіндірілгені 21 %). Жас құрамы екі онтогенетикалық жағдаймен сипатталады: 2 (g) және 1 (v). *D. fuchsii* онтогенетикалық күйлері жерүсті мүшелерінің морфологиялық белгілерімен анықталады: жапырақ саны, төменгі жапырақ өлшемдері және ондағы жіпшелер саны. Гүлденбеген дарақтарды біз генеративті күйге жатқыздық.

Кілт сөздер: интродукция, *Dactylorhiza fuchsii,* Астана ботаникалық бағы, популяция, Қызыл кітап, Орталық Қазақстанның ұсақ шоқылары, сақтау.

А.Е. Халымбетова, С.К. Мухтубаева, С.А. Абиев, Ж.А. Адамжанова

Особенности интродукции *Dactylorhiza fuchsii* (Druce) Soó в условиях Астанинского ботанического сада

В статье впервые приведены результаты экспериментальной работы по созданию интродукционной популяции из живых растений *D. fuchsii* в Астанинском ботаническом саду города Астаны. Во флоре Центрально-Казахстанского мелкосопочника насчитывается 17 видов из семейства *Orchidaceae* и только один вид — *Dactylorhiza fuchsii* занесен в Красную книгу Казахстана. Размножение и выращивание орхидных в интродукционных условиях для сохранения видов и возможности последующего возвращения их в естественную среду обитания приобретают большую актуальность. Знание среды обитания и экологических предпочтений орхидей является необходимым условием для их надлежащего сохранения и разработки методов интродукции. В результате трехлетнего мониторинга состояния растений в интродукции *D. fuchsii* установлено, что данная популяция характеризуется средней приживаемостью генеративного и виргинильного особей. Учет особей за три года составил 3 особи (21 % от высаженных). Возрастной состав представлен двумя онтогенетическим состоянием: 2 (*g*) и 1 (*v*). Онтогенетические состояния *D. fuchsii* определены по морфологическим признакам надземных органов: число листьев, размеры нижнего листа и число жилок в нем. Нецветущие особи мы отнесли к генеративным.

Ключевые слова: интродукция, *Dactylorhiza fuchsii,* Астанинский ботанический сад, популяция, Красная книга, Центрально-Казахстанский мелкосопочник, сохранение.

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Checklist of rare plants of the flora Ulytau Region

In the article a list and a brief analysis of rare plants of the flora of Ulytau region, listed in the Red Book of Kazakhstan was presented. According to the conducted researches 20 species of rare plants included in the Red Book of Kazakhstan are registered in Ulytau region: *Adonis volgensis, Anabasis turgaica, Astragalus krascheninnikovii, Crambe tataria, Craniospermum subvillosum, Dactylorhiza fuchsii, Ledebouriella seseloides, Oxytropis subverticillaris, Pulsatilla patens, Silene betpakdalensis, Spiraeanthus schrenkianus, Stipa pennata, Tanacetum ulutavicum, Tulipa albertii, Tulipa biebersteiniana, Tulipa biflora, Tulipa borszczowii, Tulipa patens, Tulipa suaveolens, Valeriana chionophila*. We propose to exclude 5 species (*Crambe tataria, Pulsatilla patens, Stipa pennata, Tulipa biebersteiniana* and *Tulipa patens*) from the Red Data Book of Kazakhstan, as they do not need protection. We consider it is necessary to include in the next edition of the Red Data Book of Kazakhstan 8 species of narrow-local endemics growing only in Ulytau region: *Astragalus krascheninnikovii, Clausia kasakhorum, Gagea sarysuensis, Hedysarum ulutavicum, Seseli betpakdalense, Seseli mironovii, Silene anisoloba, Thymus crebrifolius*.

Keywords: Kazakhstan, Asia, biodiversity, endemism, rare plants, Red Book.

Introduction

Red Data Books have become a “tool” for inventorying rare and endangered species, scientific and legal foundation for their protection, environmental awareness and education of the population. The problem of studying and preserving rare plant species is urgent, timely both at the national and regional levels [1].

There are about 5,658 higher vascular plants in the flora of Kazakhstan [2], of which 370 species are listed in the Red Book of Kazakhstan [3]. One of the interesting places of floral diversity is the Kazakh Uplands, where 2,100 species of higher vascular plants from 557 genera belonging to 126 families grow [4]. The Kazakh Uplands is located on the vast Kazakh shield and is represented by low, strongly dissected mountain ranges rising above the smoothed surface of the Mesozoic peneplain [5]. In the north, the uplands passes into the West Siberian lowland, in the northeast into the wide Irtysh valley, and in the west and southwest it is bordered by the young Neogene plateaus of Turgai and the southern part of Betpakdala, in the south it is bordered by the lake basin. Balkhash, in the southeast and east, rests on the Altai and Tarbagatai mountains. It is part of the Ural-Mongolian geosynclinal belt [4].

One of the unique geographical points in the Kazakh Uplands are the Ulytau mountains (Ulytau district, Ulytau region), which, on the one hand, are a little-studied floral area, on the other hand, have prospects for active development as a tourist and recreational territory. The Ulytau State National Natural Park has been created on the territory of the Ulytau Mountains, occupying 54.46 thousand hectares, or 28.2 % of the territory surveyed by us. The Ulytau Mountains are the geographical center of the Republic of Kazakhstan, they are distinguished by unique geomorphological structures, including both forest and steppe, meadow [6].

More than 819 species of higher vascular plants from 89 families and 366 genera grow in the flora of the Ulytau Mountains. On the territory of Bolshoy Ulytau, there are 5 narrow–localized endemes (*Anabasis turgaica, Clausia kasakhorum, Lepidium eremophilum, Tanacetum ulutavicum, Thymus crebrifolius*), 6 endemic species of Kazakh smallmouth (*Astragalus kasachstanicus, Atraphaxis decipiens, Erysimum kazachstanicum, Gagea sarysuensis, Lappula rupestris, Thymus eremita*), 7 species — endemic and subendemic to Kazakhstan: *Artemisia albicerata, Gypsophila rupestris, Serratula dissecta, Silene anisoloba, S. balchaschensis, Thymus kirgisorum*, *Th. rasitatus*. The 8 species are included in the “Red Book of Kazakhstan”: *Adonis wolgensis, Anabasis turgaica, Craniospermum echioides, Stipa pennata, Tanacetum ulutavicum, Tulipa biebersteiniana, Tulipa patens, Tulipa schrenkii* [7].

The main objective of this study was to conduct an inventory of rare plants in the Ulytau Region and to compile a modern list of rare species of this region.

Experimental

Ulytau region is located in the central part of Kazakhstan, with its administrative center in the city of Zhezkazgan. The oblast was formed relatively recently — on June 8, 2022. Ulytau region borders with Kostanay region in the north, Karaganda region in the northeast and east, Zhambyl region in the southeast, Turkestan and Kyzylorda regions in the south, and Aktobe region in the west. This study makes an inventory of rare plants listed in the Red Book of Kazakhstan [3].

The research is based on the results of field studies and literature data, as well as materials from herbarium collections LE, MW, AA and NUR.

Life form, rarity category, ecological habitat and occurrence are given for each species. Rarity categories are given according to the Red Data Book of Kazakhstan [3]. The frequency of occurrence of the species was assessed according to four gradations: "usually" — species grows ubiquitously in most suitable habitats; "occasionally" — the plant occurs sporadically not throughout the territory, but is regularly identified in certain ecotopes; "rarely" — species noted sporadically in some floristic areas; "very rarely" — one to three locations are known throughout the Ulytau region [8]. Genera and species are listed in alphabetical order. Latin names of species were checked against international plant databases [9, 10].

Results and Discussion

According to the results of the research, it was found that in Ulytau region there are 20 species of rare plants listed in the Red Book of Kazakhstan [3]. Of these, 9 species are classified as III category of rarity, 8 species as II category, 2 species as I category, and 1 species as IV category. Analysis of life forms showed that of all rare species of Ulytau region, only one shrub (*Spiraeanthus schrenkianus* Maxim.) and one semi-shrub (*Silene betpakdalensis* Bajt.) were noted, all other species are herbaceous perennials (Table).

T a b l e

List of rare plants of Ulytau Region included in the Red Book of Kazakhstan

No	Plant name	Rarity category	Life form
1	*Adonis volgensis* Steven ex DC.	III	Perennial
2	*Anabasis turgaica* Iljin & Krasch.	III	Perennial
3	*Astragalus krascheninnikovii* Kamelin (=*Astragalus kokaschiki* Gamajun.)	I	Perennial
4	*Crambe tataria* Sebeok	II	Perennial
5	*Craniospermum subvillosum* Lehm. (=*Craniospermum echioides* (Schrenk) Bunge).	II	Perennial
6	*Dactylorhiza fuchsii* (Druce) Soo	II	Perennial
7	*Ledebouriella seseloides* (Hoff m.) H. Wolff	II	Perennial
8	*Oxytropis subverticillaris* C.A. Mey.	III	Perennial
9	*Pulsatilla patens* (L.) Mill.	II	Perennial
10	*Silene betpakdalensis* Bajt.	II	Semi-shrub
11	*Spiraeanthus schrenkianus* Maxim.	III	Shrub
12	*Stipa pennata* L.	III	Perennial
13	*Tanacetum ulutavicum* Tzvelev	III	Perennial
14	*Tulipa albertii* Regel	II	Perennial
15	*Tulipa biebersteiniana* Schult. et Schult. f.	III	Perennial
16	*Tulipa biflora* Pall.	I	Perennial
17	*Tulipa borszczowii* Regel	II	Perennial
18	*Tulipa patens* Agardh. ex Schult. et Schult. f.	III	Perennial
19	*Tulipa suaveolens* Roth	III	Perennial
20	*Valeriana chionophila* Popov & Kult.	IV	Perennial

Below is an outline of rare plants of Ulytau region included in the Red Book of Kazakhstan:

1. *Adonis volgensis* Steven ex DC. Perennial. Declining species (III category) [3]. Grows in grassy-typchak and grassy steppes. Occurs rarely.

Note. *Adonis volgensis* has a relatively wide distribution in Kazakhstan, the species is found in Central, Northern and Eastern Kazakhstan. The state of *A. volgensis* populations in Northern Kazakhstan is stable, which is ensured by good seed reproduction [11].

2. *Anabasis turgaica* Iljin & Krasch. Perennial. A rare species numbers of which are decreasing catastrophically fast, which may put it at risk of extinction (Category III) [3]. Occurs rarely.

Note. *Anabasis turgaica* is a narrowly localized endemic of the Ulytau Mountains [12], practically the only herbaceous species among the genus Anabasis. This species is characterized by a thickened caudex, from which branching herbaceous shoots depart [7].

3. *Astragalus krascheninnikovii* Kamelin (=*Astragalus kokaschiki* Gamajun.). Perennial. Rare species (category I) [3]. Grows along the edges of dry watercourses in clay desert. Occurs rarely.

Note. This species is a narrow local endemic of Betpakdala [12], known from Kokashi tract, Zhanaarka district, Ulytau region (classical location of the name *Astragalus kokaschiki*) and 40-50 km from Lake Tailykol, in the valley of the Sarysu River (classical location of the name *Astragalus krascheninnikovii*).

4. *Crambe tataria* Sebeok. Perennial. Rare species (II category) [3]. Grows along roadsides. Occurs occasionally.

Note. Prior to the 90s of the XX century, the plant was not found on the territory of the Kazakh Shallow Soil. All modern herbarium collections were made along the Karaganda-Zhezkazgan highway. Most likely, the species "escaped" from the culture. For a long time, *C. tataria* was cultivated in the Karaganda Botanical Garden and recommended as an ornamental plant [4].

5. *Craniospermum subvillosum* Lehm. (=*Craniospermum echioides* (Schrenk) Bunge). A very rare species (category II) [3]. Grows on rocky and rubbly slopes of hills. It occurs rarely.

Note. *Craniospermum echioides* was considered endemic to Kazakhstan. However, later information appeared about its distribution in Dzungaria, in Southwestern Mongolia and Northwestern China [13]. According to the latest international classification [10], *Craniospermum echioides* is recognized as a synonym of *Craniospermum subvillosum*.

6. *Dactylorhiza fuchsii* (Druce) Soo. Perennial. A rare species, occurring in small numbers in a small area (category II) [3]. It grows in forest meadows, forest edges and shrubs, on the banks of rivers and streams. It occurs rarely.

Note. *Dactylorhiza fuchsii* is morphologically similar to *Dactylorhiza maculata*. When they co-occur, they form populations that include plants with intermediate morphology, indicating possible hybridization. We consider that *Dactylorhiza maculata* is generally a European species, with only isolated occurrences in Asia, particularly in the western part of Siberia and in Kazakhstan. Determining the exact eastern distribution limit of this species is challenging due to its similarity with *D. fuchsii* in this region, where their ranges overlap [14].

7. *Ledebouriella seseloides* (Hoff m.) H. Wolff. Perennial. Rare species (II category) [3]. Grows on rubbly slopes of hills. Occurs very rarely.

Note. In Ulytau region was found in Aktau mountains: "Kazakhstan, Dzhezkazgan region, east of Atasu, Aktau mountains, 26.06.1991, M.G. Pimenov, E.V. Kluikov (MW0861099)". The species was described from East Kazakhstan. Type species: "Altai in campis et collibus siccis lapidosis ad montam Tschingistau, 08.1826, Ledebour 226" (LE). According to the international classification, this species is considered a synonym of *Saposhnikovia divaricata* (Turcz. ex Ledeb.) Schischk. [10]. Additional studies are needed to establish the taxonomic position of this species using modern molecular genetic methods.

8. *Oxytropis subverticillaris* C.A. Mey. Perennial. Species with rapidly decreasing range (III category) [3]. Occurs rarely.

Note. *Oxytropis subverticillaris* is morphologically close to *Oxytropis rhynchophysa* [15]. Z.V. Karamysheva and E.I. Rachkovskaya (1973) give priority to the name *Oxytropis subverticillaris* for the Kazakh Uplands, because *Oxytropis subverticillaris* was described from a single specimen in the phase of secondary flowering. J.U. Baimukhambetova (1989), who studied the type material of these species, concluded that they are identical and, taking into account the priority, the name *Oxytropis subverticillaris* should be left [4].

9. *Pulsatilla patens* (L.) Mill. Perennial. Rare species (II category) [3]. Grows in steppes and on slopes of hills. Occurs commonly.

Note. The intraspecific structure of *P. patens* is extremely complex and confusing. In Central and Northern Kazakhstan, *P. patens* with purple and yellow coloration of perianth petals, which were previously attributed to different species, are observed. Plants with purple flowers were referred to *P. patens* and with yellow flowers to *Pulsatilla uralensis* (Zămels) Tzvel. (=*Pulsatilla flavescens* (Zuccar.) Juz.) [4]. Currently, it is necessary to conduct systematic studies of the *P. patens* complex of Northern and Central Kazakhstan using molecular genetic methods. It should be noted that in Central Kazakhstan plants with purple flowers

predominate, and in Northern Kazakhstan plants with yellow flowers predominate [16]. In this area, the ranges of the two species overlap, and transitional populations with common taxonomic characters are formed.

10. *Silene betpakdalensis* Bajt. Semishrubby shrub. Very rare species (II category) [3]. Grows on rubbly-melkozem slopes of hills and foothill plains. Occurs very rarely.

Note. In Ulytau region one locality of this species is known 100 km south of Zhezkazgan city (KUZ) [4]. The plant is described from the Chu-Ili Mountains: "Prov. Almatansis, montes Tschu-Iliensis, fl. Anda-Ssaj in decliviis saxosis, 26 VI 1954, fl. et fr. Immat., lg. M. Bajtenov" (AA).

11. *Spiraeanthus schrenkianus* Maxim. Shrub. Rare species with a decreasing range (III category) [3]. Grows on clay slopes of hills. Occurs very rarely.

Note. In Ulytau region one locality of *Spiraeanthus schrenkianus* is known in Northern Betpakdala: Zhanaarkinsky district, Northern Betpakdala, vicinity of Zhuantobe Mountain, 46°26'N, 70°28'E, 17 VII 2011, A. Kupriyanov, O. Kupriyanov. Kupriyanov, O. Kupriyanov (KUZ, KAZ 01474). Single plants, small groups of bushes are found in the territory of the Kazakh Uplands, the main part of the Betpakdala population is located to the south in Central Betpakdala [4]. *Spiraeanthus schrenkianus* is a rare and endemic species that deserves special attention [12]. It is one of the oldest plants of our planet. It probably grew here in the Eocene, about 40 million years ago, during climate aridization, forming the oldest shrub-steppe communities [17].

12. *Stipa pennata* L. Perennial. Species with decreasing abundance (III category) [3]. Grows on slopes of hills mainly from the northern side, on steppe hollows, in bushes. Occurs usually.

Note. At present, this species does not need State protection, as the species occupies vast areas in Kazakhstan. The species was included in the Red Data Book of Kazakhstan due to extensive plowing of virgin lands in Northern and Central Kazakhstan, as well as other anthropogenic impacts.

13. *Tanacetum ulutavicum* Tzvelev. Perennial. Reducing in number species (III category) [3]. Grows in cracks in granite rocks. Occurs rarely.

Note. *Tanacetum ulutavicum* is a narrow-local endemic of the Ulytau Mountains [12]. The species was described from the Ulutau Mountains: "Karaganda region, middle part of Karsakpai district, slope of Kazan-Tau mountain, 12 km south of Ulutavicum, 12 VII 1929, n 298, N. Shipchinsky" (LE). This species is morphologically close to *Tanacetum achilleifolium* and *T. millefolium*, in relation to which it is a narrowly endemic race confined to rocky and stony habitats [4].

14. *Tulipa albertii* Regel. Perennial. Rare species (II category) [3]. Grows on rubbly and fine-grained slopes, screes and low mountains. Occurs occasionally.

Note. *Tulipa albertii* is endemic to Kazakhstan [12]. In Ulytau oblast there is the northernmost border of the range of this species.

15. *Tulipa biebersteiniana* Schult. et Schult. f. Perennial. Reducing in number species (III category) [3]. Grows in steppe, on forest edges, among shrubs, along river valleys. Occurs rarely.

Note. *Tulipa biebersteiniana* was described in 1829 from specimens from the North Caucasus (between Mozdok and Kizlyar). The species was named in honor of the Russian botanist F.K. Bieberstein-Marshall. Some systematists refer *T. biebersteiniana* and *T. patens* to synonyms of the widespread in Europe *T. sylvestris* subsp. *Australis* [18, 19]. However, according to Zonneveld (2009), the difference in DNA content between *T. biebersteiniana* and *T. sylvestris* may be a basis for recognizing *T. biebersteiniana*.

16. *Tulipa biflora* Pall. Perennial. Endangered species (category I) [3]. Grows on stony and rubbly slopes of hills. Occurs occasionally.

Note. The species was described in 1776 by P.S. Pallas based on specimens from the Caspian deserts. Location of type specimens is unknown. According to the latest system of the genus Tulipa [18], many species from sect. Biflores A.D. Hall ex Veldkamp & Zonn. are considered synonyms of the *T. biflora* s.l. complex, including *T. buhseana* and *T. sogdiana*. Currently, systematic studies of *T. biflora* s.l. group should be carried out using modern molecular research methods.

17. *Tulipa borszczowii* Regel. Perennial. Rare species (II category) [3]. Grows in sandy massifs, along loess plumes of desert hills and chinks. Occurs rarely.

Note. The main areal of this species is located in the Aral deserts and in the northern part of the Kyzylkum desert [20]. The northernmost limit of the range of this species is located in the Ulytau region.

18. *Tulipa patens* Agardh. ex Schult. et Schult. f. Perennial. Rare, decreasing in number, species (III category) [3]. Grows in dry sagebrush steppes, in steppe meadows, on rubbly slopes, solonetz meadows and solonets, in interfold gulleys. Occurs usually.

Note. The taxonomic position of *Tulipa patens* is relatively controversial, some authors [18, 19] refer it synonymously to *T. sylvestris* subsp. *australis*. Other authors [21, 22, 23] consider this species as an independent taxon. We also believe that *Tulipa patens* deserves recognition on the basis of a complex of morphological characters and ecology.

19. *Tulipa suaveolens* Roth (=*Tulipa schrenkii* Regel.). Perennial. Decreasing in number species. III category. Grows in steppes, deserts and semi-deserts, on plains and foothills. Occurs rarely.

Note. The species is usually known as *Tulipa schrenkii*, which was described from the Esil River valley in 1873. However, the older name *Tulipa suaveolens* takes precedence [18]. The main range of the species within the Kazakh Shallow Soil is in the extreme west, and in the east, it reaches the Aktau-Shunak Mountain junction [4].

20. *Valeriana chionophila* Popov & Kult. Perennial. Insufficiently studied species (IV category) [3]. Grows in the semi-desert plain on loamy soils. Occurs rarely.

Note. *Valeriana chionophila* is given for the first time for Ulytau region. The species was found in Ulytau region, near Surguti, Kubentaev S.A., Alibekov D.T., 04.04. 2024 (NUR). The new location is the northernmost limit of the range of this species. Earlier this species was first found in Karaganda region, in Targyl mountains, near Gulshat, Kubentaev S.A., Alibekov D.T., 15.04. 2021 (NUR).

According to our long-term field research and literature analysis, we propose to exclude the following species from the Red Data Book of Kazakhstan: C*rambe tataria, Pulsatilla patens, Stipa pennata, Tulipa biebersteiniana* and *Tulipa patens*. According to our data, these species do not need protection, because they are often found in different regions of Kazakhstan, sometimes in large areas and with high abundance. In addition, *Crambe tataria* in Ulytau region is an adventive species that occupies disturbed communities, which is also a reason for its exclusion from the Red Data Book of Kazakhstan.

The territory of Ulytau region served as a corridor of species migration from north to south and from east to west for a long historical period. Therefore, endemism in this territory is weakly expressed. However, the isolation of the Ulytau Mountains both in the Paleozoic and Quaternary periods led to the preservation of some paleo and neo-endemics [4]. On the territory of Ulytau region there are 6 species of narrow-local endemics growing exclusively only in this region, such as: *Anabasis turgaica* Iljin & Krasch., *Astragalus krascheninnikovii* Kamelin, *Clausia kasakhorum* Pavlov, *Gagea sarysuensis* Murz., *Hedysarum ulutavicum* Knjaz, *Seseli betpakdalense* Bajtenov, *Seseli mironovii* (Korovin) Pimenov & Sdobnina, *Silene anisoloba* Schrenk, *Tanacetum ulutavicum*, *Thymus crebrifolius* Klokov. Of these plants, 5 species (*Clausia kasakhorum*Pavlov, *Anabasis turgaica*Iljin & Krasch*, Hedysarum ulutavicum* Knjaz*., Tanacetum ulutavicum* Tzvelev, *Thymus crebrifolius* Klokov) are found only in the Ulytau Mountains. Three species (*Astragalus krascheninnikovii* Kamelin*, Seseli betpakdalense* Bajt*., Seseli mironovii* (Korovin) Pimenov & Sdobnina) occur only in Betpakdal. Of all narrow local endemics growing exclusively in Ulytau region, only *Anabasis turgaica* and *Tanacetum ulutavicum* are protected at the State level. At present, it is necessary to study the state of populations, abundance and distribution of other narrow-local endemics of Ulytau region. We consider it necessary to include the following endemic species in the next edition of the Red Data Book of Kazakhstan: *Astragalus krascheninnikovii, Clausia kasakhorum, Gagea sarysuensis, Hedysarum ulutavicum, Seseli betpakdalense, Seseli mironovii, Silene anisoloba, Thymus crebrifolius*.

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Ұлытау облысы флорасының сирек өсімдіктерінің тізімі

Мақалада Қазақстанның Қызыл кітабына енген Ұлытау өңірінің сирек кездесетін өсімдіктерінің тізімі мен қысқаша талдауы берілген. Жүргізілген зерттеулерге сәйкес, Ұлытау өңірінде Қазақстанның Қызыл кітабына енген сирек кездесетін өсімдіктердің 20 түрі тіркелген, атап айтсақ: *Adonis volgensis, Anabasis turgaica, Astragalus krascheninnikovii, Crambe tataria, Craniospermum subvillosum, Dactylorhiza fuchsii, Ledebouriella seseloides, Oxytropis subverticillaris, Pulsatilla patens, Silene betpakdalensis, Spiraeanthus schrenkianus, Stipa pennata, Tanacetum ulutavicum, Tulipa albertii, Tulipa biebersteiniana, Tulipa biflora, Tulipa borszczowii, Tulipa patens, Tulipa suaveolens, Valeriana chionophila*. Оның ішінде 5 түр (*Crambe tataria, Pulsatilla patens, Stipa pennata, Tulipa biebersteiniana* және *Tulipa patens*) қорғауды қажет етпейтіндіктен Қазақстанның Қызыл кітабынан шығаруды ұсынамыз. Қазақстанның Қызыл кітабының келесі басылымына Ұлытау өңірінде ғана өсетін *Astragalus krascheninnikovii, Clausia kasakhorum, Gagea sarysuensis, Hedysarum ulutavicum, Seseli betpakdalense, Seseli mironovii, Silene anisoloba, Thymus crebrifolius* сияқты жіңішке жапырақты эндемиктердің 8 түрін енгізуді қажет деп санаймыз.

Кілт сөздер: Қазақстан, Азия, биоәртүрлілік, эндемизм, сирек өсімдіктер, Қызыл кітап.

С.А. Кубентаев, Д.Т. Алибеков, Ш.Т. Тустубаева, Б.Б. Кубентаева

Чек-лист редких растений флоры Улытауской области

В статье представлены список и краткий анализ редких растений флоры Улытауской области, занесенных в Красную книгу Казахстана. Согласно проведенным исследованиям, в Улытауской области зарегистрировано 20 видов редких растений, занесенных в Красную книгу Казахстана: *Adonis volgensis, Anabasis turgaica, Astragalus kraschenninnikovii, Crambe tataria, Craniospermum subvillosum, Dactylorhiza fuchsii, Ledebouriella seseloides, Oxytropis subverticillaris, Pulsatilla patens, Silene betpakdalensis, Spiraeanthus schrenkianus, Stipa pennata, Tanacetum ulutavicum, Tulipa albertii, Tulipa biebersteiniana, Tulipa biflora, Tulipa borszczowii, Tulipa patens, Tulipa suaveolens, Valeriana chionophila*. Из них 5 видов (*Crambe tataria, Pulsatilla patens, Stipapennata, Tulipa biebersteiniana* и *Tulipa patens*) предлагаем исключить из Красной книги Казахстана, поскольку они не нуждаются в охране. Считаем необходимым включить в следующее издание Красной книги Казахстана 8 видов узколокальных эндемиков, произрастающих только в Улытауской области: *Astragalus kraschenninnikovii, Clausia kasakhorum, Gagea sarysuensis, Hedysarum ulutavicum, Seseli betpakdalense, Seseli mironovii, Silene anisoloba u Thymus crebrifolius*.

Ключевые слова: Казахстан, Азия, биоразнообразие, эндемизм, редкие растения.

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Assessment of the effect of humates produced by "Shubarkol Komir" JSC on germination of vegetable seeds

Humic preparations are valuable sources of humic acids, which increase soil fertility and have growth-regulating activity on agricultural crops. Application of new humic preparations from local weathered coals allows providing agricultural producers with domestic preparations. To identify the optimal doses of application, we conducted a series of experiments on germination of vegetable seeds to increase their germination. The results of the study showed that humic preparations in different concentrations may not have the same activity on the seeds of plants of different species. The best germination rates are as follows: for white cabbage seeds after soaking in a solution of potassium humate at a concentration of 0.005 %, for eggplant seeds — a mixture of potassium and sodium humate at a concentration of 0.5 %, for tomato seeds — potassium humate 0.005 %, for sweet pepper seeds — a mixture of potassium and sodium humate 0.005 %, for cucumber seeds — a mixture of potassium and sodium humate 0.01 %. The results can be used for agricultural and greenhouse applications.

Keywords: humic preparations, seed material, vegetable crops, pre-sowing soaking, germination, germination energy.

Introduction

Humic substances (or humates) are high-molecular polymers of irregular structure, which are formed in nature (soil, peat areas, coals, bottom sediments, etc.) as a result of transformation of dead biomass of plants and animals. Biological activity of humates was discovered in the late XIX century [1]. Humate production is carried out from a wide range of raw materials: coals, peats, soil extracts, composts, sapropels, wastes of organic origin [2].

Humic preparations are used as organic fertilizers, natural stimulants to activate seed germination and plant growth, to improve soil fertility, for remediation of contaminated soils, as feed additives for farm animals and birds [3–5]. The possibility of using humic preparations for detoxification of oil products and salts of heavy metals is known [6, 7]. Given the diversity of processes for obtaining humic substances, sources of organic raw materials for their production, humates themselves may differ in structure and biological activity.

Based on the prospects of their widespread use in agriculture and environmental protection, there is a need for comprehensive testing of new humic preparations to determine their biological activity, develop principles of agro-system management and biosafety assessment.

An important advantage of humic substances is their relatively low cost and the availability of large reserves of raw materials (including weathered coal), which allows for the production and use of preparations based on them in agricultural and environmental technologies.

In Central Kazakhstan, "Shubarkol Komir" JSC has developed fertilizers based on humates from weathered coals from the Shubarkol deposit, which can be used in agriculture and vegetable growing, in particular, to increase the germination of vegetable seeds.

The purpose of our work was to study the effect of humates produced by "Shubarkol Komir" JSC on germination of seeds of some vegetable plants.

Experimental

The objects of research were humates provided by "Shubarkol Komir" LLP: potassium humate, a mixture of potassium humate and sodium humate (2:1 ratio), distilled water served as a control. The tested humates were diluted in concentrations of 0.1 %, 0.01 %, 0.5 %, 0.05 % and 0.005 %.

Seeds of the following vegetable crops were taken in the experiment: white cabbage, eggplant, tomatoes, cucumbers and sweet pepper.

Experiments to assess seed germination were conducted in laboratory conditions based on standard methods [8–10]. Germination was carried out on Petri dishes on 2-layer filter paper (Fig.) in 4-fold repetition. Plant seeds were soaked for 24 hours in appropriate humate solutions.

Figure 1: Pre-sowing soaking of vegetable seeds in humate solutions

Statistical processing of data was carried out using the online calculator https://medstatistic.ru/ and Excel program, the mean germination rates and germination energy with deviation were estimated, the reliability of the results was evaluated on the basis of Student's criterion.

Results and Discussion

The analysis of germination indices on the background of potassium humate and a mixture of potassium humate and sodium humate for different crops were not the same. Thus, for white cabbage seeds, the best germination indices were observed on the background of potassium humate at a concentration of 0.005 % (Table 1); in this variant, seed germination was 63.4 %, germination energy — 51.2 %, as well as for the same type of humate at a concentration of 0.01 %. Germination and germination energy amounted to 60.8 and 41.2 %, respectively. For the other variants, the viability indicators were significantly lower than the control values, or at the level of the control — preliminary soaking in water.

Table 1

Indices of germination and germination energy of white cabbage seeds on the background of application of different concentrations of humic preparations

Experiment variant	Germination energy,%	Germination,%
Control (water)	30,5±0,6	38,5±0,8
0.5 % humate K	11,4±0,2*	13,5±0,1*
0.1 % humate K	10,0±0,3*	20,8±0,4*
0.01 % humate K	41,2±1,1	60,8±3,6*
0.05 % humate K	8,9±0,1*	12,0±0,3*
0.005 % humate K	51,2±3,0*	63,4±2,7*
0.1 % K-Na humate	20,0±0,4*	32,0±0,5
0.01 % K-Na humate	20,0±0,4*	22,3±0,5
0.5 % K-Na humate	0	0
0.05 % K-Na humate	29,8±0,6	31,2±0,9
0.005 % K-Na humate	30,7±0,6	32,3±1,2
*Note – Significance of differences of indicators from control at P≤0.05		

Combined application of potassium and sodium humate at a concentration of 0.5 % resulted in the absence of cabbage seed germination.

The germination efficiency of eggplant seeds was at a rather low level. The best germination indices were recorded on the background of potassium and sodium humate mixture in concentration of 0.5 %, in this variant of the experiment germination was 90.0 %, germination energy — 40.6 % (Table 2), which significantly exceeded similar indices for the control variant. Lower indicators were observed for the humate mixture at a concentration of 0.1 %, germination and germination energy were 60.0 and 52.5 %, respectively.

Table 2

Indices of germination and germination energy of eggplant seeds on the background of application of different concentrations of humic preparations

Experiment variant	Germination energy,%	Germination,%
Control	10,5±0,1	40,8±1,2
0.5 % humate K	11,2±0,2	51,5±2,3*
0.1 % humate K	41,4±0,9*	44,6±1,3
0.01 % humate K	20,3±0,4	23,4±0,5*
0.05 % humate K	43,2±1,0*	45,8±0,8
0.005 % humate K	20,0±0,6	23,5±0,2*
0.1 % K-Na humate	52,5±2,7*	60,0±3,2*
0.01 % K-Na humate	10,0±0,2	11,3±0,2*
0.5 % K-Na humate	40,6±1,8*	90,0±4,1*
0.05 % K-Na humate	21,2±0,4	30,4±0,6*
0.005 % K-Na humate	10,0±0,1	18,2±0,3*
*Note – Significance of differences of indicators from control at P≤0.05		

The optimal concentration for potassium humate is 0.5 %, which increased germination up to 51.5 %. The other variants exceeded the control values, but were significantly lower than the specified concentrations.

Tomato seeds showed good germination rates. Practically all variants, except for potassium humate 0.5 %, showed germination rates above or at the level of control parameters. Maximum germination values were obtained on the background of potassium humate at a concentration of 0.005 %. Seed germination was 90.3 %, germination energy 70.0 % (Table 3).

Table 3

Indicators of germination and germination energy of tomato seeds on the background of application of different concentrations of humic preparations

Experiment variant	Germination energy,%	Germination,%
Control	40,6±0,9	45,6±0,8
0.5 % humate K	11,5±0,2*	20,7±0,2*
0.1 % humate K	52,4±1,8	55,2±1,5*
0.01 % humate K	41,5±0,6	44,6±0,7
0.05 % humate K	51,6±1,8*	55,0±1,7*
0.005 % humate K	70,0±2,5*	90,3±4,1*
0.1 % K-Na humate	53,2±1,4*	51,9±2,2
0.01 % K-Na humate	70,3±2,9*	82,0±3,3*
0.5 % K-Na humate	70,8±2,3*	70,1±3,8*
0.05 % K-Na humate	40,4±0,5	60,8±3,0*
0.005 % K-Na humate	30,0±0,5*	41,2±1,0
*Note – Significance of differences of indicators from control at P≤0.05		

For the mixture of potassium and sodium humate, the highest germination rates were observed for the concentration of 0.01 %, at which germination was 82.0 % and germination energy 70.3 %.

The seed material of sweet pepper confirmed the data made on the previous crop. Potassium humate at concentrations of 0.5 % and 0.01 % had a depressing effect on germination, as seed germination in these variants of experiments was significantly lower than the control values (Table 4).

Table 4

Indices of germination and germination energy of sweet pepper seeds on the background of application of different concentrations of humic preparations

Experiment variant	Germination energy,%	Germination,%
Control	70,4±2,5	80,8±3,6
0.5 % potassium humate	61,6±2,2	65,4±2,3*
0.1 % potassium humate	80,5±3,3*	91,5±4,1*
0.01 % potassium humate	51,0±1,2	54,2±2,5*
0.05 % potassium humate	80,0±3,1*	90,5±3,4*
0.005 % potassium humate	72,8±2,7	81,9±2,6
0.1 % K-Na humate	71,0±2,0	80,5±3,0
0.01 % K-Na humate	74,3±2,6	78,4±2,2
0.5 % K-Na humate	62,4±2,0	83,4±2,6
0.05 % K-Na humate	54,5±2,0*	70,0±2,2
0.005 % K-Na humate	72,3±2,4	93,4±3,1*
*Note – Significance of differences of indicators from control at P≤0.05		

Significantly higher germination indices were obtained in the variant of application of potassium and sodium humate mixture at a concentration of 0.005 %, at which germination was 93.4 % and germination energy 72.3 %; and for potassium humate at a concentration of 0.05 % — germination was estimated at 90.5 %, germination energy 80.0 %.

When testing humic preparations on cucumber seeds, an insignificant difference was established in comparison with the control (Table 5). Significant excess over the control was observed on the background of presowing soaking seeds in the solution of potassium and sodium humate mixture at a concentration of 0.01 %. Germination and germination energy in this variant amounted to 100 %.

Table 5

Indices of germination and germination energy of cucumber seeds on the background of application of different concentrations of humic preparations

Experiment variant	Germination energy,%	Germination,%
Control	90,4±4,2	92,5±3,8
0.5 % humate K	90,0±3,3	96,4±4,2
0.1 % humate K	92,5±3,8	95,0±3,6
0.01 % humate K	71,6±2,4*	72,5±2,7*
0.05 % humate K	90,7±1,9	92,8±4,1
0.005 % humate K	82,6±2,5	85,6±3,3
0.1 % K-Na humate	93,3±2,9	94,8±3,0
0.01 % K-Na humate	100±0,0*	100±0,0*
0.5 % K-Na humate	92,5±2,4	95,6±4,0
0.05 % K-Na humate	91,8±2,2	92,3±2,5
0.005 % K-Na humate	94,0±3,1	95,3±3,0
*Note – Significance of differences of indicators from control at P≤0.05		

On the contrary, the concentration of potassium humate 0.01 % had an inhibitory effect on the germination of cucumber seeds.

Conclusion

Thus, pre-sowing soaking of vegetable seeds in solutions of humates produced by “Shubarkol Komir” JSC allows to significantly increase germination and germination energy. The best germination indices were observed for white cabbage seeds after soaking in potassium humate solution at a concentration of 0.005 %, for eggplant seeds — potassium and sodium humate mixture at a concentration of 0.5 %, for tomato seeds — potassium humate 0.005 %, for sweet pepper seeds — potassium and sodium humate mixture 0.005 %, for cucumber seeds — potassium and sodium humate mixture 0.01 %.

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«Шұбаркөл Көмір» АҚ өндірген гуматтардың көкөніс өсімдіктері тұқымдарының өнуіне әсерін бағалау

Гуминді препараттар топырақ құнарлығын арттыратын және ауылшаруашылық дақылдарының өсуін реттейтін белсенділігі бар гумин қышқылдарының құнды көзі. Жергілікті морыған көмірлерден жаңа гуминді препараттарды қолдану ауыл шаруашылығы тауарын өндірушілерді отандық препараттармен қамтамасыз етуге мүмкіндік береді. Қолданудың оңтайлы дозаларын анықтау үшін біз көкөніс тұқымдарының өнгіштігін арттыру үшін бірнеше тәжірибелер жүргіздік. Зерттеу нәтижелері әртүрлі концентрациядағы гуминді препараттардың әртүрлі түрдегі өсімдіктердің тұқымдарында бірдей белсенділікке ие болмауы мүмкін екенін көрсетті. Ақ қырыққабат тұқымы 0,005% концентрациядағы калий гуматының ерітіндісіне, баклажан тұқымы — 0,5% концентрациядағы калий мен натрий гуматтарының қоспасына, қызанақ тұқымдары — 0,005% калий гуматына, тәтті бұрыш тұқымдары — 0,005% калий мен натрий гуматының қоспасына, қияр дәндері — 0,01% калий гуматының қоспасына және натрийге батырылғаннан кейін ең жақсы өну көрсеткіштерін көрсетті.

Кілт сөздер: гуминдік препараттар, тұқым материалы, көкөніс дақылдары, егу алдындағы сіңіру, өну, өну энергиясы.

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Оценка эффекта гуматов производства АО «Шубарколь комир» на прорастание семян овощных растений

Гуминовые препараты являются ценными источниками гуминовых кислот, которые повышают плодородие почвы, оказывают рост-регулирующую активность на сельскохозяйственные культуры. Использование новых гуминовых препаратов из местных выветрелых углей позволяет обеспечить сельскохозяйственных производителей отечественными препаратами. Для выявления оптимальных доз применения нами проведен ряд опытов по прорастанию семян овощных культур для повышения их прорастания. Результаты исследования показали, что гуминовые препараты в разных концентрациях могут оказывать неодинаковую активность на семена растений разных видов. Лучшие показатели прорастания следующие: для семян капусты белокочанной после замачивания в растворе гумата калия в концентрации 0,005 %, для семян баклажанов — смесь гуматов калия и натрия в концентрации 0,5 %, для семян томатов — гумат калия 0,005 %, для семян перца сладкого — смесь гумата калия и натрия 0,005 %, для семян огурцов — смесь гумата калия и натрия 0,01 %. Результаты могут использоваться для применения в сельском и тепличном хозяйствах.

Ключевые слова: гуминовые препараты, семенной материал, овощные культуры, предпосевное замачивание, всхожесть, энергия прорастания.

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Resource potential of the medicinal plant *Achillea millefolium* L. in forest protected areas of the Western and Southern Altai ridges

In the article the results of field studies of the medicinal plant *Achillea millefolium* L. in forest protected areas of the Western and Southern Altai ridges were presented. The total study area covers 4 ranges of the Western Altai (Ivanovsk, Ulbinsk, Ubinsk, Listvyaga) and 3 ranges of the Southern Altai (Narymsk, Kurchumsk and South Altai Tarbagatai). The survey of *Achillea millefolium* raw material stocks and its ecological state were assessed using generally accepted methods, taking into account intensive harvesting of this plant in the region. In 2 ridges: Ubinsk (Ust-Kamenogorsk SI) and Ivanovsk (Pikhtovsk SI) we have revealed and taken into account that yarrow forms thickets on grass-grassy meadows and along forest edges. Useful properties and uses of *Achillea millefolium* has a wide range, this is evidenced by their chemical composition: isovalerian, fatty and salicylic acid, asparagine, sterol, phenol, bitter and tannins, alkaloid, flavonoid, glycoside, essential oil, terpenoid, steroid, sesquiterpene derivatives, resins, saponin. The survey of common yarrow showed that raw material should be harvested during flowering. In terms of exploitable reserve, it is noted that it varies in the range of 4.19–7.89 tons. Yarrow raw reserves in the Southern Altai are accounted for in 13 populations, in 4 pilot forest protection institutions: Zyryanovsk State Institution (4 populations); Bolshenarymsk State Institution (2 populations); Katon-Karagai (KK) SNNP (4 populations); Kurchumsk State Institution (3 populations). The exploitable stock in the Southern Altai varies in the range 4.95–118.31 tons. The stocks volume in the following pilot SIs are suitable for commercial harvesting: Bolshenarymsk SI, Katon-Karagay SNNP, Kurchum SI and Zyryanovsk SI.

Keywords: medicinal plants, Western and Southern Altai, biotopes, stocks of raw materials, stock volume.

Introduction

The history of human development is inextricably linked to the cognition of the surrounding world and the involvement of natural resources in economic use. The higher the level of development of the productive forces of society, the higher the rate of their development and diverse application.

The plant world in all its great diversity has long been widely used by man in his daily economic activities. Even at the dawn of its development man highlighted, studied and described the surrounding plants, their useful properties [1].

In the natural flora of Kazakhstan there are a significant number of useful plants widely used in the national economy. In addition to well-known environmental and anthropogenic factors, the thickets of such species are affected by the most destructive — the process of direct unregulated mass harvesting of raw materials.

Plant resources, which are an integral part of natural biological resources, under the influence of ecological and anthropogenic factors are now undergoing significant, sometimes irreparable transformations. As a result, entire plant complexes and communities are irretrievably disappearing.

At present, an important task in the study of plant resources is the balanced use and protection of the riches of natural flora, as well as the vegetation cover as a whole.

Intensive exploitation impairs the ability of the population to recover losses and leads to a rapid decline in the productivity of the land. To avoid this, the rules for harvesting medicinal raw materials should be strictly followed. Systematic disruption of vegetative and seed regeneration of plants as a result of immoderate, improper collection and annual continuous intensive exploitation of the same arrays violates not only the age structure of populations, but also leads to significant shifts in their numbers, the static equilibrium of the

number of components in the phytocenosis fluctuates, which itself can cause degradation of the plant community [2].

The natural flora of the Kazakhstan part of Altai is rich in floristic composition and natural reserves of some medicinal plants used in folk and traditional medicine. However, for rational use and preservation of natural thickets of useful plant species it is necessary to carry out full-fledged resource studies, on the basis of which the current state and norms of withdrawal from nature are determined annually.

Such studies as the current state of economically valuable, intensively exploited, rare and endangered species of medicinal plants on the territory of the studied region need to be supplemented. There is practically no scientific information on the ecological state of medicinal plants promising for harvesting. Taking into account the above-mentioned, the purpose of the research was to study the issues on assessment of resource potential and ecological safety of medicinal plants of the Kazakhstan part of Altai, available for procurers. One of such objects is *Achillea millefolium* L.

Achillea millefolium is a perennial plant with (5) 20–60 cm of height; rhizome is thin, creeping, branched; plant is pubescent with fine white hairs; stems are few or solitary, erect or ascending from the base, straight, less often slightly sinuous, simple or branched in the upper part with shortened olive branches in the axils of middle and upper stem leaves; leaves are lanceolate, oblong-lanceolate or almost linear, pinnately-stigmatous, twice or thrice pinnately dissected, with numerous segments widely spaced 1.5–10 mm apart, lower stem leaves and leaves of infertile shoots 10–35(40) cm length, 0.8–5 cm width, axis 1-2 mm wide, usually in upper part with single intermediate teeth between main segments, lobes and teeth lanceolate, rarely linear, 0.5-1.5 mm long, 0.3-0.4 mm wide, acuminate at the top into short cartilaginous acuminate; baskets are in numerous, compound shields, 2–15 cm in diameter.; wrappers oblong to almost ovate, 3-4(6) mm long, 2-4 mm wide; leaflets of the envelope are green, keeled with a projecting median vein, with a filmy border along the margin, often brownish colored; bracts ovate to oblong-elliptic, filmy, downy above, with scattered glands on the dorsum; tongues of marginal flowers white, pink or red (1) 2–4 mm long, 1.5–3(4.5) mm wide, almost rounded, 2-3 toothed at the apex, bend twice shorter than the length of the wrapper; tubular flowers up to 20 in number, with glands outside [3].

Chemical composition of *Achillea millefolium*: isovaleric acid, salicylic acid, asparagine, sterol, phenol [4] bitter substances, tannins, coumarin, alkaloid, essential oil, terpenoid [5] steroid, sesquiterpene derivatives [6], resin, saponin, coumarin [7], fatty acid, alkaloid, flavonoid, essential oil [8], glycoside [9].

Useful (pharmacological and other) properties and uses of *Achillea millefolium*: tonic, stimulant, aromatic, cold, flu, amenorrhoea remedy [10] anti-inflammatory [11, 12], stimulating bile flow [13], diuretic [14], analgesic [15], gastroprotective, antibacterial [16], antioxidant, antimicrobial [17], antiseptic, expectorant, vetrogonic, antispasmodic, styptic, choleretic gastrointestinal [18], anti-ulcer [19], hepatoprotective, antispasmodic [20], hypotensive [21], anxiolytic [22], hypoglycaemic, hypolipidemic [23], antimutagenic [24] antitumour [25].

Experimental

Resource survey of the territory was carried out by the route-reconnaissance method [26] and in accordance with the generally accepted “Methodology for determining the reserves of medicinal plants” [27], as well as taking into account the methodological guidelines for the study of medicinal plant resources [28], [27], as well as taking into account the methodological guidelines for the study of medicinal plant resources [28]. Stocks of raw materials were counted in specific thickets using the method of counting sites or model specimens. Traditional geobotanical methods were used to describe plant communities with the participation of resource objects [29, 30].

The structure of cenopopulations of rare medicinal plants was studied according to the methods of T.A. Rabotnov [31] and O.V. Smirnova [32]. To find out the life cycle, the method of A.A. Uranov was applied [33]. When studying the ecological and biological features of the species in the field, the methodological guidelines developed by M.F. Golubev and E.F. Molchanov were applied.

The assessment of stocks of raw materials of common yarrow was carried out in forest protection areas within the following forestry farms and the National Park: Zyryanovsk State Forestry Department, Bolshenarymsk State Forestry Department, Katon-Karagai State Forestry Department, Kurchumsk State Forestry Department. The surveyed area covers 4 ridges of the Western Altai (Ivanovsk, Ulbinsk, Ubinsk, Listvyaga,) and 3 ridges of the Southern Altai (Narymsk, Kurchumsk and South Altai Tarbagatai) (Fig.).

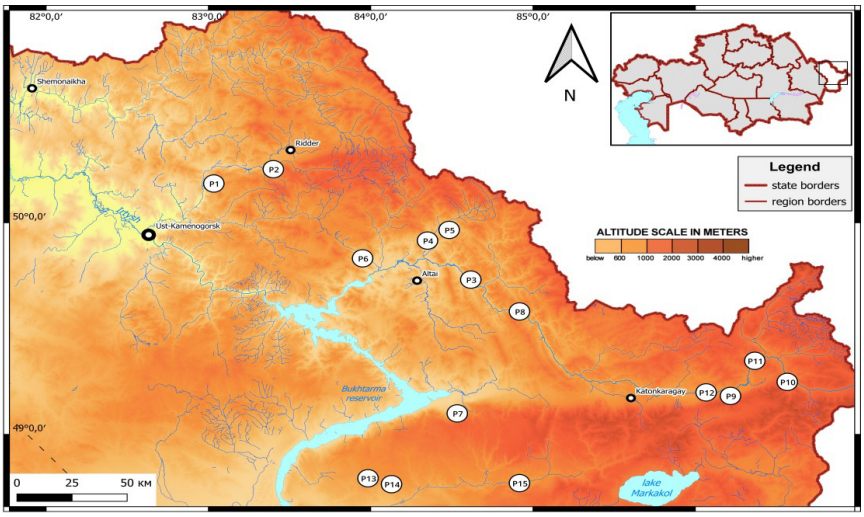

Figure. Map of *Achillea millefolium* population scheme in forest protected areas of the Western and Southern Altai ridges

Results and discussion

Common yarrow *Achillea millefolium* — herbaceous perennial plant of the family Asteraceae Bercht. Asteraceae Bercht. & J. Presl. It blooms in July-August and bears fruit in September-October. It grows in forest, forest-steppe and steppe zones, in meadows, steppe and meadow mountain slopes, on fallow lands, along field margins. The above-ground part is used as a raw material.

Stocks of common yarrow in the phase of blossoming — beginning of flowering were identified and accounted for 2 ridges: Ubinsk and Ivanovsk, where yarrow forms thickets on grass-grass meadows and on forest edges (Fig.).

On the territory of Ust-Kamenogorsk SI, Tarkhan forestry (P1) average yield of air-dry raw material of yarrow was 838.2 kg/ha. The exploitation reserve (ER) of air-dry aboveground phytomass of yarrow on the area of 5.0 ha was 4.19 tons (Table 1). Taking into account the duration of recovery of the species' stocks after harvesting of raw materials, the volume of possible annual harvesting (VPAH) should not exceed 0.83 tons of air-dry above-ground phytomass. The species is a part of grass-grass (*Dactylis glomerata, Achillea millefolium, Fragaria viridis*) communities on forest edges.

On the territory of Pikhtovsk SI, Kedrovsk forestry (P2), the average yield of air-dry yarrow raw material was 607.20 kg/ha. ER on the area of 13.0 ha was equal to 7.89 tons with VPAH not more than 1.57 tons. The species is a part of Yarrow-grass (*Dactylis glomerata, Achillea millefolium, Phleum pretense*) communities in extensive meadows.

Common yarrow *Achillea millefolium*: raw stocks of yarrow in the Southern Altai are accounted for in 13 populations, in 4 pilot forest protection institutions: Zyryanovsk State Institution (4 populations); Bolshenarymsk State Institution (2 populations); Katon-Karagay (KK) SNNP (4 populations); Kurchumsk State Institution (3 populations).

The survey was carried out during the flowering phase. The species is poorly eaten by livestock, and for this reason yarrow dominates in herbaceous communities in areas with heavy overgrazing.

In Zyryanovsk SI yarrow reserves were identified on the Ulbinsk ridges and in the Bkhtarminsk Mountains, on the territories of 4 forestries: Bykovskoy, Lesnopristansk, Stolboushinsk and Osinovsk. The species forms yarrow-timothy-leaved-clover, yarrow-hedge, yarrow, yarrow-chicory communities.

The main habitats of the species in the Zyryanovsk SI are flat meadows, lowlands, hayfields and old fallow lands. In Bykovsk forestry (P3), the ER of air-dried yarrow raw material on an area of 25.0 ha was 9.9 tons, with VPAH not exceeding 1.98 tons (Table 2). The species grows in yarrow-thymopheif-clover (*Phleum pratense, Trifolium pratense, Achillea millefolium*) communities in flat meadows.

In Lesnopristansk forestry (P4), the ER of yarrow on the area of 5.0 ha is 2.44 tons with the VPAH not exceeding 0.48 tons. The species is a part of yarrow-hedge (*Dactylis glomerata, Achillea millefolium*) communities in flat meadows.

Table 1

Stocks of raw materials of the medicinal plant *Achillea millefolium*, identified in the territories of the pilot forest protection organizations in Western Altai

Population number	Location (ridge, forestry, quarter, thicket coordinates)	Price population, ecology	Area, ha		Air-dry stock density, kg/ha		Operating reserve of air-dry raw materials, tonnes		VPAH, air-dry raw materials	
			Total	Occupied species	Above-ground part	Under-ground part	Above-ground part	Under-ground part	Above-ground part	Under-ground part
Ust-Kamenogorsk										
P1	Ubinsk, Tarkhansk, 29, N 50,185835, E 83,034009		6	5	838.20	–	4.19	–	0.83	–
Pikhtovsk										
P2(66)	Ivanovsk, Kedrovsk, 01, N 50,257407, E 83,409735		15	13	607.20	–	7.89	–	1.57	–

Table 2

Stocks of raw materials of the medicinal plant *Achillea millefolium*, identified on the ridges of the Southern Altai Mountains

Population number	Location (ridge, name of the State Unit of Forestry or SNNP, forestry, quarter, coordinates of the thicket)	Area, ha		Air-dry stock density, kg/ha (grass)	Operating stock of air-dry raw material, tons (grass)	SNNP, air-dry raw material, tons (grass)
		Total	Occupied species			
Zyryanovsk						
P3	Bukhtarma Mountains, Bykovsk, 70, N 49,74808, E 84,630533	25	20	495.00	9.90	1.98
P4	Ulbinsk, Lesnopristansk, 45, N 49,927754, E 84,36158	5	4	610.50	2.44	0.48
P5	Ulbinsk, Stolboushinsk, 116, N 49,973095, E 84,488364	30	25	445.50	100.23	20.04
P6	Ulbinsk, Osinovsk, 57, N 49,833838, E 83,955742	15	12	478.50	5.74	1.14
Bolshenarymsk						
P7	Narymsk, Kokthereksk, 117, N 49,116321, E 84,548268	15	12	412.50	4.95	0.99
P8	Bukhtarma Mountains, Novo-Berezovsk, 11, N 49,584335, E 84,925789	16	13	396.00	5.14	1.02
Katon-Karagay SNNP						
P9	South Altai tarbagatai, Shyngystaysk, 23, N 49,195082, E 86,218586	20	17	402.6	6.84	1.36
P10	South Altai tarbagatai, Archatinsk, 46, N 49,264389, E 86,573621	23	19	429.00	8.15	1.63
P11	South Altai tarbagatai, Berelskoy, 51, N 49,352481, E 86,370288	28	23	891.00	20.49	4.09
P12	Listvyaga, Czernowinsk, 92, N 49,210689, E 86,072882	50	41	752.40	30.84	6.16
Kurchum						
P13	Kurchumsk, Cherdoyaksk, 48, N 48,814893, E 84,076826	15	12	478.50	5.74	1.14
P14	Kurchumsk, Cherdoyaksk, 53, N 48,788062, E 84,110417	8	6	491.70	2.95	0.59
P15	Kurchumsk, Pugachevsk, 143, N 48,768721, E 84,931526	15	12	514.80	6.17	1.23

In Stolboushinsk forestry (P5) on the area of 30.0 ha the ER of air-dry raw material was 100.23 tons with the VPAH not exceeding 20.04 tons. The species forms mono-dominant yarrow (*Achillea millefolium*) communities on flat meadows.

In Osinovsk forestry (P6) the ER on the area of 15.0 ha was 5.74 tons, with a VPAH of not more than 1.14 tons of air-dry aboveground phytomass. The species is a member of yarrow-chicory (*Cichorium intybus, Achillea millefolium*) communities on old deposits.

The total ER of yarrow raw material in the Zyryanovsk SI was 118.31 tons, with a total VPAH of no more than 23.64 tons of air-dry aboveground phytomass (Table 2).

Two populations of yarrow were identified in Bolshenarymsk State Unit on the Narymsk Ridge and Bukhtarma Mountains, in Kokterek and Novoberezovoi forestries. Raw material reserves were surveyed in yarrow (*Achillea millefolium*) and yarrow-tipchak (*Festuca valesiaca, Achillea millefolium*) communities on foothill terraces and on steppe slopes of foothills.

In Kokterek forestry yarrow thickets were found (P7) on the area of 15.0 ha, where ER of air-dry raw material was 4.95 tons, VPAH should not exceed 0.99 tons of dry raw material. In Novoberezovoi forestry (P8) yarrow reserves were identified on the area of 16.0 ha (ER — 5.14 tons, VPAH should not exceed 1.02 tons).

The total ER of yarrow raw material in Bolshenarymsk SI was 10.09 tonnes, with a total VPAH of not more than 2.01 tons of air-dry above-ground phytomass (Table 2).

In the Katon-Karagai SNNP, yarrow raw material reserves were identified on the South Altai Tarabagatai and Listvyaga ridges, in Shyngystay, Archatinsk, Berelsk and Chernivinsk forestry. In Shyngystay forestry (P9) yarrow thickets were found) on an area of 20.0 ha, where ER was 6.84 tons, with a total VPAH not exceeding 1.36 tons. In Archatinsk forestry (P10) the ER of milfoil on an area of 23.0 ha was 8.15 tons with a total VPAH not exceeding 1.63 tons. In Berelsk forestry (P11) on an area of 28.0 ha, the ER was 20.49 tons with a VPAH of 4.09 tons. In Chernovinsk forestry (P12) on an area of 50.0 ha, the ER was 30.84 tons with a VPAH not exceeding 6.16 tons.

The species is found in the national park in grass-grassy meadows, on steppe slopes of foothills and in intermountain hollows. Communities with yarrow participation are usually dominated by the following species: *Dactylis glomerata, Festuca valesiaca, Phleum pratense, Poa pratensis, Linaria vulgaris.*

The total ER of yarrow raw material for Katon-Karagai SNNP was 66.32 tons with a total VPAH of no more than 13.24 tons of air-dry aboveground phytomass.

Three populations of common yarrow on the Kurchumsk Ridge in Cherdoyaksk and Pugachevsk forestry were surveyed in Kurchumsk State Unit. Two populations of yarrow were identified in Cherdoyaksk forestry: in P13 on an area of 15.0 ha, where the ER was 5.74 tons with a VPAH not exceeding 1.14 tons, and in P14 on an area of 8.0 ha (ER — 2.95 tons, VPAH not exceeding 0.59 tons). In Pugachevsk forestry (P15) yarrow reserves are recorded on the area of 15.0 ha (ER — 6.17 tons, VPAH- 1.23 tons). The species forms yarrow-grass and yarrow-grass communities on foothill meadows and steppe slopes of hills.

Conclusion

As a result of field studies covering forest protected areas of four ridges of Western Altai (Ivanovsk, Ulbinsk, Ubinsk, Listvyaga) and three ridges of Southern Altai (Narymsk, Kurchumsk and South Altai Tarbagatai), the reserves of *Achillea millefolium* raw materials and its ecological state were assessed using generally accepted methods, taking into account intensive harvesting of this plant in the region.

Stocks of common yarrow were carried out in the phase of budding — the beginning of flowering. In 2 ridges: Ubinsk (Ust-Kamenogorsk SI) and Ivanovsk (Pikhtovsk SI) we have revealed and taken into account that yarrow forms thickets on grass-grassy meadows and on forest edges. The survey was conducted in the flowering phase. The exploitable stock showed that it varies in the range of 4.19–7.89 tons.

Yarrow raw reserves in the Southern Altai are accounted for in 13 populations, in 4 pilot forest protection institutions: Zyryanovsk State Institution (4 populations); Bolshenarymsk State Institution (2 populations); Katon-Karagai (KK) SNNP (4 populations); Kurchumsk State Institution (3 populations). The exploitable stock in the Southern Altai varies in the range 4.95–118.31 tons.

Yarrow stocks in the following pilot SIs are suitable for commercial harvesting: Bolshenarymsk SI (ER — 10.09 tons; VPAH — 2.01 tons), Katon-Karagai SNNP (ER — 66.32 tons, VPAH — 13.24 tons), Kurchumsk PA (ER — 14.86 tons, VPAH — 2.96 tons) and Zyryanovsk SI (ER — 118.31 tons, VPAH — 23.64 tons).

It is revealed that in order to restore raw material stocks, the volume of possible annual harvesting of raw materials should not exceed 30 % of the exploitable stock.

Thus, the raw material base of medicinal plant *Achillea millefolium* of East Kazakhstan region is able to meet the needs of the domestic pharmaceutical industry. Also, it meets the requirements of regulatory documents in the field of environmental safety, which allow us to recommend their use for economic purposes and harvesting in industrial quantities.

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Батыс және Оңтүстік Алтай жоталарының орман қорғау территорияларындағы *Achillea millefolium* L. дәрілік өсімдігінің ресурстық әлеуеті

Мақалада Батыс және Оңтүстік Алтай жоталарының орман қорғау аймақтарындағы *Achillea millefolium* L. дәрілік өсімдігінің далалық зерттеулерінің нәтижелері берілген. Негізгі зерттеу аймағы Батыс Алтайдың 4 жотасын (Ивановский, Үлбі, Убинский, Листвяга) және Оңтүстік Алтайдың 3 жотасын (Нарым, Күршім және Оңтүстік Алтайлық Тарбағатай) қамтиды. Жалпы қабылданған әдістермен *Achillea millefolium* шикізат қорын зерттеу және аймақтағы осы өсімдіктің қарқынды жиналуын ескере отырып, оның экологиялық жағдайы бағаланды. Екі жотада, яғни Убинский («Өскемен» ММ) және Ивановский («Пихта» ММ) жоталарының мыңжапырақ шөпті шалғындарында және ормандардың шеттерінде қалың бұталар түзетіні анықталып, есепке алынды. *Achillea millefolium* пайдалы қасиеттері мен қолданылуы кең ауқымға ие, яғни изовалерия, май және салицил қышқылдары, аспарагин, стерол, фенол, ащы және таниндер, алкалоид, флавоноид, гликозид, эфир майы, терпеноид, стероид, сесквитерпен туындылары, шайырлар, сапонин сияқты химиялық құрамымен дәлелденген. Кәдімгі мыңжапырақты зерттеу шикізатты жинау гүлдену кезінде жүргізілуі керек екенін көрсетті. Пайдалану қоры бойынша ол 4,19-7,89 т диапазонында өзгеретіні байқалды. Оңтүстік Алтайдағы мыңжапырақтың шикізат қоры 13 популяцияда, 4 пилоттық орман қорғау мекемесінде тіркелген, олар: «Зырян» ММ (4 популяция); «Үлкен Нарым» ММ (2 популяция); «Қатын Қарағай» (ҚҚ) МҰТП (4 популяция); «Күршім» ММ (3 популяция). Оңтүстік Алтайдағы пайдалану қоры 4,95-118,31 тонна аралығын құрайды. Мыңжапырақ қорларын өнеркәсіптік дайындауға мына пилоттық табиғатты қорғау мекемелері: «Үлкен Нарым» ММ, «Қатын Қарағай» МҰТП, «Күршім» ММ және «Зырян» ММ жарамды.

Кілт сөздер: дәрілік өсімдіктер, Батыс және Оңтүстік Алтай, биотоптар, шикізат қоры, дайындау көлемі.

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Ресурсный потенциал лекарственного растения *Achillea millefolium* L. на лесоохранных территориях хребтов Западного и Южного Алтая

В статье представлены результаты полевых исследований лекарственного растения *Achillea millefolium* L. на лесоохранных территориях хребтов Западного и Южного Алтая. Общая область исследования охватывает 4 хребта Западного Алтая (Ивановский, Ульбинский, Убинский, Листвяга) и 3 хребта Южного Алтая (Нарымский, Курчумский и Южно-Алтайский Тарбагатай). Общепринятыми методами были оценены запасы сырья *Achillea millefolium* и его экологическое состояние, учитывая интенсивную заготовку данного растения в регионе. В двух хребтах: Убинском (Усть-Каменогорское ГУ) и Ивановском (Пихтовское ГУ) нами выявлены и учтены, что тысячелистник образует заросли на разнотравно-злаковых лугах и по опушкам леса. Полезные свойства и применение *Achillea millefolium* имеет широкий спектр, об этом говорит их химический состав: изо-валериановая, жирные и салициловая кислота, аспарагин, стерол, фенол, горькие и дубильные вещества, алкалоид, флавоноид, гликозид, эфирное масло, терпеноиды, стероиды, производные сесквитерпены, смол, сапонин. Обследование тысячелистника обыкновенного показало, что заготовку сырья следует проводить во время цветения. По эксплуатационному запасу отмечается, что он варьирует в диапазоне 4,19–7,89 т. Сырьевые запасы тысячелистника на Южном Алтае учтены в 13-ти популяциях, в 4-х пилотных лесоохранных учреждениях: Зыряновское ГУ (4 популяции); Большенарымское ГУ (2 популяции); Катон-Карагайский (КК) ГНПП (4 популяции); Курчумское ГУ (3 популяции). Эксплуатационный запас в Южном Алтае варьирует в диапазоне 4,95–118,31 т. Для промышленных заготовок пригодны запасы тысячелистника в следующих пилотных природоохранных учреждениях: «Большенарымское» ГУ, «Катон-Карагайский» ГНПП, «Курчумское» ГУ и «Зыряновское» ГУ.

Ключевые слова: лекарственные растения, Западный и Южный Алтай, биотопы, запасы сырья, объем заготовок.

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Morphological and anatomical structure of *Rubus saxatilis* leaf

Introduction to the practical use of local raw materials of medicinal plants has an important practical significance for pharmacy and cosmetic industry. Interest in raw materials of *Rubus saxatilis* is due to the biological activity of compounds, use in folk medicine, as well as significant amounts of raw materials growing in Central Kazakhstan. To introduce the raw material into practical application, the task of analyzing the anatomo-morphological structure and identifying diagnostic features of the raw material was set. The results showed that at the macroscopic level as diagnostic features of *Rubus saxatilis* raw material can be indicated the difference in the structure of the upper and lower side of leaves, type of veining, the presence of soft prickles, the structure of triple-complex leaves, almost complete absence of pubescence. At the microscopic level, the diagnostic features of this species are the shape of transverse sections, the shape of leaf epidermis cells and leaf petiole, the localization of receptacles in the mesophyll, the presence of rare simple unicellular trichomes and essential oil glands raised above the surface of the epidermis. The results obtained can serve as additional taxonomic characters in determining the species and authentication of raw materials of *Rubus saxatilis*.

Keywords: Rubus saxatilis, plant raw material, anatomo-morphological structure, diagnostic features, leaf, leaf petiole.

Introduction

The search for new sources of plant resources and biologically active substances in the natural flora is an important task for the food, pharmaceutical and parapharmaceutical industries of Kazakhstan [1, 2].

When making cosmeceutical preparations, the emphasis should be on local raw materials, which are widely distributed in nature, can be successfully grown in culture, contains a sufficient level of active components, that is, can become a substitute for expensive foreign analogs.

Sufficiently widespread object in the natural conditions of Central Kazakhstan [3], which is a medicinal plant used in folk medicine, is boneset (stone raspberry) — *Rubus saxatilis* L. (family Rosaceae).

In ancient times, people used *Rubus saxatilis* leaves and applied it to the skin, thus treating rubella and urticaria, and in case of biliary scabies the juice from the leaves was taken internally. In case of skin inflammations and acne, people prepared a decoction from its flowers and washed their faces with it. It has also been proven in scientific studies that leaf extracts are effective against platelet reactivity [4].

In folk medicine, *Rubus saxatilis* is known for its ability to support the health of the gastrointestinal tract, especially the intestines, helps not only to reduce the risk of constipation, but also to fight it. This is due to the presence of dietary fiber, namely pectin substances [5, 6].

Due to the presence of a large number of antioxidant substances, including ascorbic acid, vitamin E, carotenoids and polyphenols, the berries and leaves of *Rubus saxatilis* can resist Parkinson's and Alzheimer's diseases, as they promote brain activity and have neuroprotective properties, that is, they can protect nerve cells (neurons) from damage and death, and improve their functioning and survival [5].

The presence of ascorbic acid makes the berry an excellent remedy against scurvy, it also activates the function of cells, supporting the synthesis of collagen, which is important in the creation of cosmeceuticals, increases stress resistance and immunity, thus useful both for the prevention and treatment of avitaminosis, various colds, stimulates hematopoiesis, it is important for the prevention and treatment of cardiovascular diseases, increases the elasticity and density of capillary walls [5, 7]. In addition, ascorbic acid promotes the synthesis of cholesterol, a precursor of vitamin D [8]. A scientific study was conducted, which revealed that fruits of *Rubus* genera are able to inhibit the growth of pathogenic microorganisms, as well as *inhibit* the growth of some cancer cells *in vitro* [9].

Due to the presence of saponins in the leaves of *Rubus saxatilis*, the raw material has astringent, choleretic, antiseptic, sedative, adsorbent and other actions. Due to its sedative properties, the raw material of

Rubus saxatilis can also be used to create medicinal preparations that are aimed at the treatment and prevention of insomnia. Saponins are also able to strengthen the human immune system and act against allergic skin reactions, and therefore they are widely used to create cosmeceuticals [10].

Based on the useful properties of *Rubus saxatilis* raw material and its potential use for the production of cosmeceutical preparations, we conducted an anatomo-morphological study of the leaves of this species to establish the features of the structure and diagnostic features of the raw material at the macro- and microscopic level.

Experimental

Collection of raw material *Rubus saxatilis* (leaves with petioles) was carried out in the stage of fruiting (1st decade of August 2023) in the tract Karaagash (Belodymovsky branch, State National Natural Park "Buiratau").

In the analysis of morphological parameters, the appearance, surface structures, colors of leaves and petioles were investigated. Samples of raw material were examined with Digital Microscope Levenhuk DTX 30, using magnification 16*10, 16*4.

For microscopic study, the raw materials were soaked in a mixture of glycerol: alcohol: water (ratio 1:1:1:1), and microparameters were made manually with a razor [11]. Microphotographs were obtained using BiVisual Dio microscopy, photos were analyzed using Altamy Studio program, and processed in Paint 10.1 program. Classical summaries were used to describe plant morphology and anatomy [12–14].

Results and Discussion

Rubus saxatilis is a perennial herbaceous plant that grows widely under the canopy of small-leaved and mixed forests of Central Kazakhstan [3], dominating in the herbaceous layer.

Leaves of bonesetter are triple compound, raised above the surface on long petioles, rough, covered with stiff whitish hairs. The leaf length is 10–15 cm, width 12–16 cm. The terminal lobes are elliptical, with an acute apex, wedge-shaped base and coarsely serrated edge. The raw material is pieces of leaves and petioles, green and light green in color (Fig. 1). The upper side is dark green, matte, while the lower side is whitish, with well-developed veins (Fig. 2). The veins are weakly expressed on the upper side. The veining is pinnately setose. Rare white trichomes are noted along large veins.

Soft prickles are noted at the base of the leaves; the tip is pointed and darkly colored. The petiole is rounded, finely ribbed, light green with reddish spots. From other species of raspberries, the raw material of boneset is characterized by the structure of the leaf surface, soft prickles and long leaf petioles.

On the transverse section, the leaf of *Rubus saxatilis* is flat, dorsoventral type (Fig. 3). On both sides there is a single-layer epidermis, the cells of the upper epidermis are larger, round-rectangular in shape, the cells of the lower epidermis are small, rounded or prosenchyma-shaped. The epidermis is covered on the outer side by a layer of cuticle, which is thicker on the lower side. Stomata are few, located on both sides of the leaf plate. The leaf mesophyll is differentiated into columnar and spongy tissues. The columnar mesophyll is arranged in one layer and consists of elongated cells, while the spongy mesophyll is 2-3-layered. Small conductive bundles, collateral, of closed type, oval or rounded in shape, are noted in the mesophyll. Rounded receptacles are found in places.

The leaf epidermis and petioles bear rare essential oil glands (Fig. 4) and trichomes, simple, unicellular (Fig. 5). The glands are raised above the surface of the epidermis, multicellular, consisting of a rounded head and a 2-3-celled pedicel.

The leaf petiole on the transverse section is curved (Fig. 6). The internal structure is characterized by the presence of 3 conductive bundles: 2 bundles of rounded shape, located at the edges, 1 bundle in the middle, elongate-oval, slightly curved. The bundles are collateral, closed type, with a "cap" of a significant area of sclerenchyma. The inner part is filled with loose and thin-walled cells of spongy parenchyma.

Figure 1. Appearance of *Rubus saxatilis* raw material

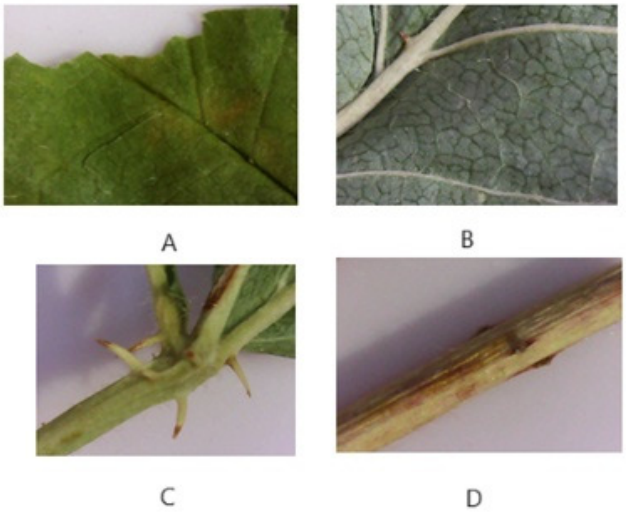
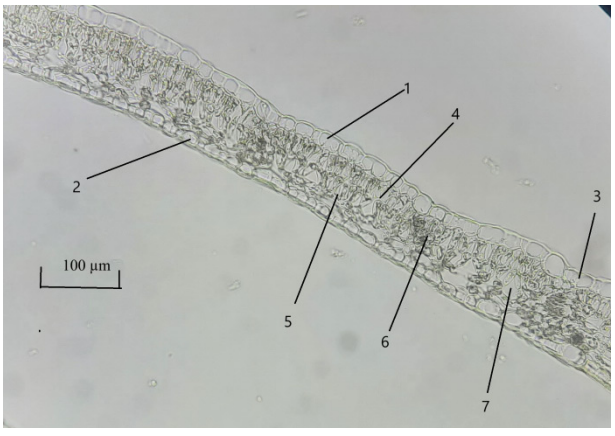


Figure 2: Appearance of leaf and petiole of *Rubus saxatilis*: A — upper side of leaf, B — lower side of leaf, C — prickles at the base of petiole, D — appearance of petiole



1 — upper epidermis, 2 — lower epidermis, 3 — stomata, 4 — columnar mesophyll, 5 — spongy mesophyll, 6 — conducting bundle, 7 — receptacle

Figure 3: Transverse section of a *Rubus saxatilis* leaf (fragment)

Figure 4: Appearance of the essential oil gland of *Rubus saxatilis*

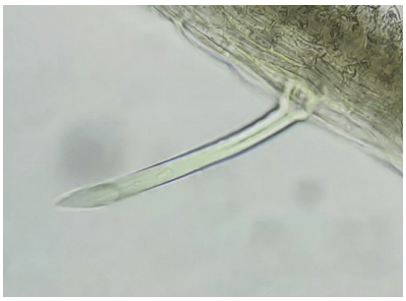
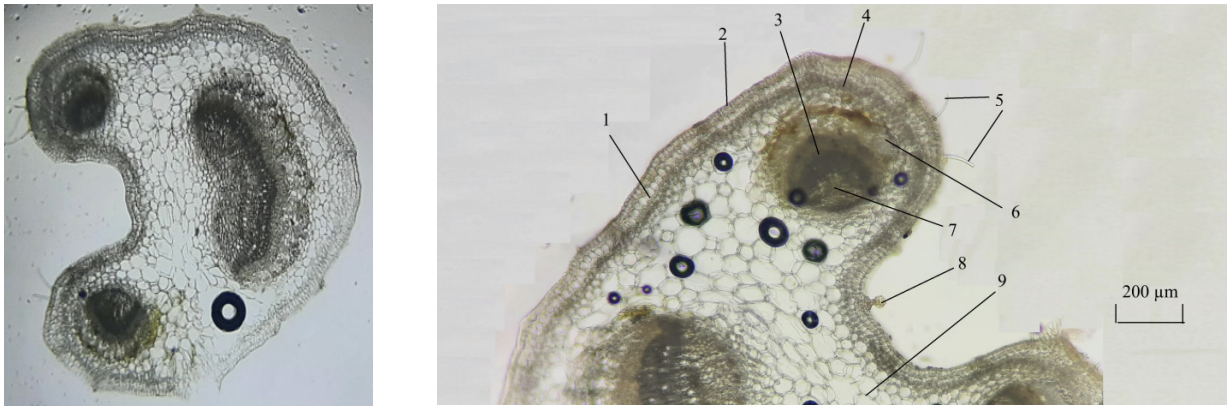


Figure 5. Appearance of a simple trichome of *Rubus saxatilis*



А Б

А — general view of leaf petiole (Eq. 16x4),
В — fragment, 1 — bark parenchyma, 2 — epidermis, 3 — phloem, 4 — collenchyma,
5 — simple trichomes, 6 — sclerenchyma, 7 — xylem, 8 — gland, 9 — spongy parenchyma

Figure 6. Transverse section of the leaf petiole of *Rubus saxatilis*

Single-layered epidermis consisting of rectangular cells with thickened outer walls and a layer of cuticle is noted along the perimeter. Rare simple trichomes, usually located in the corners, and single essential oil glands are noted on the epidermis. A thin layer of bark parenchyma and areas of angular collenchyma lie beneath the epidermis.

The investigated species differs from other species of the genus *Rubus* L. by smaller volume of sclerenchyma, more mesophytic structure of leaves, weak pubescence and absence of woodiness in the structure of leaf petiole.

Conclusion

As diagnostic signs of *Rubus saxatilis* raw material can be indicated the difference in the structure of the upper and lower sides of leaves, the type of veining, the presence of soft prickles and the shape of the leaf petiole. Analysis of anatomical slices allows us to determine the diagnostic features of this species, such as the shape of leaf epidermis cells and leaf petiole, the shape and localization of receptacles, the presence of simple trichomes and essential oil glands.

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Rubus saxatilis жапырағының морфологиялық және анатомиялық құрылымы

Дәрілік өсімдіктердің шикізатын практикалық қолдануға енгізу фармация мен косметика өнеркәсібі үшін маңызды практикалық маңызы бар. *Rubus saxatilis* шикізатына деген қызығушылық қосылыстардың биологиялық белсенділігіне, халықтық медицинада пайдаланылуына, сондай-ақ Орталық Қазақстанда өсетін шикізаттың едәуір көлеміне байланысты. Шикізатты практикалық қолдануға енгізу үшін анатомиялық-морфологиялық құрылымды талдау және шикізаттың диагностикалық белгілерін анықтау міндеті қойылды. Нәтижелер макроскопиялық деңгейде *Rubus saxatilis* шикізатының диагностикалық белгілері ретінде жапырақтардың жоғарғы және төменгі жағының құрылымындағы айырмашылықты, венация түрін, жұмсақ тікенектердің болуын, үш қабатты жапырақтардың құрылымын, түктің толық болмауын көрсетті. Микроскопиялық деңгейде бұл түрдің диагностикалық белгілері көлденең қималардың пішіні, жапырақ пен жапырақ жапырақшасының эпидермис жасушаларының пішіні, мезофилдегі контейнерлердің локализациясы, сирек кездесетін қарапайым бір жасушалы трихомалар мен эпидермис бетінен жоғары көтерілген эфир майы бездерінің болуы. Алынған нәтижелер *Rubus saxatilis* шикізатының түрін анықтауда және түпнұсқалығын растауда қосымша таксономиялық белгілер бола алады.

Кілт сөздер: Rubus saxatilis, өсімдік шикізаты, анатомиялық-морфологиялық құрылымы, диагностикалық белгілері, жапырағы, жапырақшасы.

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Морфологическая и анатомическая структура листа *Rubus saxatilis*

Введение в практическое использование местного сырья лекарственных растений имеет важное практическое значение для фармации и косметической промышленности. Интерес к сырью *Rubus saxatilis* обусловлен биологической активностью соединений, использвоанием в народной медицине, а также значительными объемами сырья, произрастающего в Центральном Казахстане. Для введения сырья в практическое применение была поставлена задача анализа анатомо-морфологического строения и

выявления диагностических признаков сырья. Результаты показали, что на макроскопическом уровне в качестве диагностических признаков сырья *Rubus saxatilis* можно указать разницу в строении верхней и нижней сторон листьев, тип жилкования, наличие мягких колючек, строение тройчатосложных листьев, практически полное отсутствие опушения. На микроскопическом уровне диагностическими признаками данного вида являются форма поперечных срезов, форма клеток эпидермиса листа и листового черешка, локализация вместилищ в мезофилле, присутствие редких простых одноклеточных трихом и эфирномасличных железок, приподнимающихся над поверхностью эпидермиса. Полученные результаты могут служить дополнительными таксономическими признаками при определении вида и подтверждении подлинности сырья *Rubus saxatilis*.

Ключевые слова: Rubus saxatilis, растительное сырье, анатомо-морфологическое строение, диагностические признаки, лист, черешок листа.

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Resource potential of amaranth and possibilities of its cultivation in the conditions of the south of Western Siberia

Amaranth, with more than 60 species, was introduced to Europe in the 16th century and is currently gaining popularity due to its high content of protein, vitamins and antioxidants. Its importance has increased in recent decades, both globally and in the conditions of Siberia, where it has become an object of selective breeding. The article provides a brief historical sketch on the study and breeding of new amaranth varieties in the south of Western Siberia. In addition, the biological features of amaranth (*Amaranthus* L.) and its importance as a valuable food and fodder crop are considered. The analysis of breeding traits allowed us to identify the most promising samples for successful cultivation in the south of Western Siberia: amaranth panicle (PC-318 and PC-391) and dark amaranth (PC-42). They are characterized by the shortest growing season and have greater resistance to adverse factors. The results of the study show that amaranth can become an important crop for Western Siberia, providing high yield and adaptability in difficult climatic conditions.

Keywords: squalene, growing season length, *Amaranthus cruentus* L., *Amaranthus hypohondriacus* L., *Amaranthus caudatus* L., *Amaranthus tricolor* L., introducer, ontogenesis stages.

Introduction

Amaranth (*Amaranthus* L.) is a genus of plants in the Amaranth family (Amaranthaceae Juss.) with more than 60 species. The greatest diversity of forms, species and varieties is represented on the territory of South America and Mexico, which is its homeland. Northern India and China are considered to be the second center of form formation. Amaranth was introduced to Europe only in the 16th century by the Spaniards for ornamental purposes and only two centuries later it was cultivated for seeds and animal feed.

Amaranth is of great importance in the food industry and fodder production. Plants contain a large amount of protein, balanced and unique in amino acid composition, valuable oils, pectin. Daily consumption of 100 g of amaranth seeds provides the human body with essential amino acids for 140 % of the adequate daily intake. It is important to note the presence of antioxidants in the seeds and green mass: carotenoids, amaranthine, squalene and vitamins B_2, C. The ascorbic acid content in different varieties of amaranth can be up to 50 mg/100 g [1–4]. In fodder production, amaranth is valued for its high potassium content and a large amount of easily digestible plant protein (1.0-1.5 tons/ha) [5]. The most valuable species in economic terms are: amaranth panicle (*Amaranthus cruentus* L.), amaranth sad (*A. hypohondriacus* L.), amaranth *caudate (A. caudatus* L.), and amaranth *tricolor (A. tricolor* L.).

In Russia, fodder species of amaranth became known in the 30s of the XX century, when Nikolai Ivanovich Vavilov brought seeds from an expedition to South America. He actively advocated for the wider use of amaranth in agriculture because of the large number of advantages of this crop. Even in difficult climatic conditions, high yields were noted because the C-4 type of photosynthesis provides amaranth with rapid growth and drought resistance [6, 7]. The resumption of amaranth research as a valuable food, fodder and ornamental crop occurred only at the end of the XX century and is currently being actively pursued [8]. Due to the difficult weather and climatic conditions of Siberia, the assortment of fodder crops in the region was rather scarce. To solve this problem, comprehensive research on the evaluation of non-traditional crops and selection of promising introducers was launched. Since the mid-1980s, active study of agrobiological features of the "forgotten" high-protein crop in Siberia began using seed samples transferred from VIR (Federal Research Center All-Russian Institute of Plant Genetic Resources named after N.I. Vavilov). Thus, at the workshop "Results of research and applied work with amaranth for 1987-1988", the staff of Altai State University Marina Mikhailovna Yablokova, Raisa Nikolaevna Afonina and Elena Vasilievna Repetunova presented a report on the successful experience of growing amaranth in the conditions of the Altai Territory [9].

In the conditions of the Tomsk and Novosibirsk regions, scientists under the leadership of Valentina Pavlovna Rykova also identified promising early maturing samples of the collection, which in the zone of risky agriculture give high yields [10, 11].

A little later, in 1995, the Federal Research Center IRCIG SB RAS together with the Omsk Agrarian Scientific Center registered the first in Siberia broad-plastic and early maturing amaranth variety "Cherginsky" [12].

Since the early 2000s, Svetlana Ivanovna Mikhailova, Tatiana Petrovna Astafurova, and Anastasia Anatolievna Burenina have been actively studying amaranth biology at Tomsk State University [13–17]. In 2006, the State Register of Breeding Achievements Allowed for Use in the Russian Federation included the variety "Yantar" developed by the Federal Altai Scientific Center for Agrobiotechnology and FIC ICIG SB RAS. The variety has a short vegetation period (106 days) and has a special value in fodder production. It significantly surpasses oilseed radish, rape, peas and beans in terms of yield of fodder mass and quality of plant raw material [18, 19].

In 2019, scientists of the Kuzbass State Agricultural Academy showed interest in grain forms of amaranth and optimized the technology of their cultivation in the conditions of the West Siberian forest-steppe in the Kemerovo region. In particular, the dependence of the quality of green mass and grain yield on the biological characteristics of the variety and such an agrotechnical technique as row spacing width was determined [20]. Currently, the staff of the Siberian Botanical Garden of TSU is implementing a project on cultivation of agricultural plants on carbonaceous farms in the sub-taiga zone of Western Siberia and, in addition to the range of traditional crops, offers amaranth as a promising introducer [21]. Thus, the interest in amaranth as a highly productive agricultural crop with a valuable protein composition has been growing rapidly in recent years.

The purpose of this work was the primary evaluation of a number of breeding and significant traits of plants of the amaranth genus to identify the most promising species and varieties for cultivation in the south of Western Siberia.

Experimental

The objects of the study were 7 amaranth cultivars of different origins: 1) *Amaranthus cruentus* L. — PK-318 (Russia), PK-391 (Brazil); 2) Amaranth hybrid (*A. hybridus* L. convar *erythrost*.) — PK-96 (Germany); 3) Amaranth caudatus (*A. caudatus* L.) — PK-146 (Germany), PK-150 (Greece); 4) Amaranth *tricolor* (*A. tricolor* L.) — PK-168 (Nepal); 5) Dark amaranth (*A. hypochondriacus* L.) — PK-429 (Mexico).

Seed material was obtained from the world collection of plant genetic resources of All-Russian Institute of Plant Industry named after N. Vavilov, St. Petersburg. To perform the experimental part of the work we used "Methodology of tests for distinctiveness, uniformity and stability of amaranth Federal State Center "State sort committee" (2007).

Pre-sowing tillage was carried out in spring using a gasoline cultivator Huter GMC-6.5. Sowing was carried out on June 3. Seed sowing rate was 0.5 kg/ha, sowing density was 20 plants/m^2. Repetition of the experiment was fourfold, experimental plot area was 1 m^2. Sowing was carried out manually in a wide-row method. Seeds were mixed with washed coarse sand. Later, we additionally thinned the seedlings and regularly loosened the soil during the growing season to break the soil crust and kill weeds. Starting from the emergence of seedlings, phenological phases were noted and morphological parameters were measured. Seeds were harvested and threshed manually.

Results and Discussion

In the vegetation period of amaranth there are 5 phenological phases: sprouting, growth, bottoming, flowering and fruiting. On average, the totality of all development periods is 110–140 days and varies depending on the variety and species. Seeds begin to germinate when the soil warms up to +10...+12℃, but the seedlings are extremely unstable to any frost. Therefore, sowing amaranth in the south of Western Siberia should be carried out when the threat of return frosts has finally passed — in the last decade of May or early June. Sprouts appear on the 6th-7th day and their development in the first three weeks is extremely slow due to a small supply of nutrients because of the size of the seeds. However, due to a special type of photosynthesis, the plants begin to grow rapidly after the start of the growth phase and the formation of green phytomass. The budding phase lasts 1-2 weeks on average, energy is redistributed to the formation of inflorescences — panicles, and growth in height is somewhat slower. Then, flower blossoming and seed ripening take place [22].

Amaranth plants have a fairly high seed production coefficient, but not every variety has seeds that reach physiological maturity before the onset of frost and cold weather. Therefore, breeding selection of this crop is aimed at developing early-ripening, cold- and drought-resistant varieties with high yield values. Among the species and varieties studied, Russian (PK-318, "Frant") and Brazilian (PK-391) amaranth varieties, as well as dark amaranth from Mexico (PK-429) showed excellent performance. The vegetation period for representatives of these species was 95–100 days, with the first seeds beginning to form on the 60–65th day (Fig.). Hybrid amaranth (PK-96, Germany) should be considered later maturing. In this species, the budding phase occurred on 93–95 days from seedlings, and the first seeds on single specimens matured on 105–110 days. *Amaranthus caudatus* (PK-146, Germany) had a similar growing season, but was twice affected by harmful insects and mold fungi. Tricolor amaranth (PC-168, Nepal) and Greek tail amaranth (PC-150) did not have time to form seeds before the first frosts and finished the vegetation at the budding and flowering stage. These species have too long vegetation period and their cultivation in local conditions is inexpedient.

Figure. Amaranth panicle (PK-318, Russia) during growth and flowering phases

In addition to the growing season, an important economic and valuable feature of amaranth is the low stature of plants. Private farms do not have special harvesting machines and use combines like KSK-100, KPKU-75, etc. For morphological description of the studied species we used the materials of "Methods of testing for distinctiveness, homogeneity and stability of amaranth" of Federal state center "State sort committee" (2007). The obtained data are presented in Table.

Table

Morphological traits of the studied amaranth breeding samples

PC-	Species name	Average plant height in the middle of vegetation, cm	Average plant height at the end of vegetation, cm	Presence of side shoots	Stem thickness at the end of vegetation, cm	Coloration of leaf lamina, presence of "spot"	Inflorescence coloration
318	*Amaranthus cruentus* L.	110	190	-	1,9	red, no.	red
96	*Amaranthus hybridus* L.convar *erythrost*.	136	223	-	2,2	green, V-shaped "spot" in the center	red
146	*Amaranthus caudatus* L.	126	190	-	1,9	green, no	green
150	*Amaranthus caudatus* L.	106,5	160	+	2,5	green, no	green
168	*Amaranthus tricolor* L.	57,5	100	-	1,2	green, egg-shaped "spot" in the center	red
391	*Amaranthus cruentus* L.	71	119	-	1,2	green, no	green
429	*Amaranthus hypochondriacus* L.	76,5	146	-	1	green, no	green with red spots
Statistical characteristics*							
ẋ		97.6	161.1				
σ		29.7	43.3				
Cv		30.4	26.9				
SDx		11.2	16.4				

Note. *ẋ — mean, σ — standard deviation, CV — coefficient of variation, %, SDx — standard error of the experiment

According to the results of the experiment of the first year, hybrid amaranth plants (PK-96, Germany) were the tallest — up to 223 cm. The average height of amaranth panicle PK-318 (Russia) at the time of harvesting was 190 cm, dark amaranth PK-429 (Brazil) — 146 cm. The lowest of the listed varieties was the height of Mexican amaranth panicle PC-391 (Mexico) — 119 cm.

All the studied samples with a vegetation period suitable for local conditions can be proposed for cultivation not only as food and fodder plants, but also for ornamental purposes. In addition, the leaves of the red-colored amaranth variety (PK-318, Russia) can be used to produce fermented tea, which is of great importance in functional nutrition [23].

Conclusion

Thus, at the primary stage of study of a number of samples from the amaranth collection of "All-Russian Institute of Plant Industry named after N. Vavilov" the most promising species, varieties and breeding samples for cultivation in climatic conditions of the south of Western Siberia were identified: amaranth panicle (PK-318, "Frant", Russia; PK-391, Brazil), dark amaranth (PK-429, Mexico).

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Амаранттың ресурстық әлеуеті және оны Батыс Сібірдің оңтүстігінде өсіру мүмкіндігі

Алпыстан астам түрі бар амарант Еуропаға XVI ғасырда енгізілген және қазіргі уақытта ақуыздың, витаминдердің және антиоксиданттардың көп болуына байланысты танымал болып келеді. Оның маңызы соңғы онжылдықтарда әлемдік масштабта да, Сібірде де өсті, онда ол селекциялық іріктеу объектісіне айналды. Мақалада Батыс Сібірдің оңтүстігінде амаранттың жаңа сорттарын зерттеу және өсіру туралы қысқаша тарихи очерк берілген. Сонымен қатар, амаранттың биологиялық ерекшеліктері (*Amaranthus* L.) және оның құнды азық-түлік және жем-шөп дақылдары ретіндегі маңызы қарастырылған. Селекциялық белгілерді талдау Батыс Сібірдің оңтүстігінде табысты өсіру үшін ең перспективалы үлгілерді анықтауға мүмкіндік берді: шашақты амарант (ПК-318 және ПК-391) және күңгірт амарант (ПК-42). Олар ең қысқа вегетациялық кезеңмен сипатталады және қолайсыз факторларға үлкен төзімділікке ие. Зерттеу нәтижелері амаранттың Батыс Сібір үшін маңызды ауыл шаруашылығы дақылына айналуы мүмкін екенін көрсетті, ол жоғары өнімділік пен күрделі климаттық жағдайларда бейімделуді қамтамасыз етеді.

Кілт сөздер: сквален, вегетациялық кезеңнің ұзақтығы, *Amaranthus cruentus* L., *Amaranthus hypohondriacus* L., *Amaranthus caudatus* L., *Amaranthus tricolor* L., жерсіндірілген түр, онтогенез кезеңдері.

К.С. Панченко, М.М. Силантьева, Д.В. Соколова

Ресурсный потенциал амаранта и возможности его выращивания в условиях юга Западной Сибири

Амарант, насчитывающий более 60 видов, завезен в Европу в XVI веке и в настоящее время набирает популярность благодаря высокому содержанию белка, витаминов и антиоксидантов. Его значение возросло в последние десятилетия, как в мировом масштабе, так и в условиях Сибири, где он стал объектом селекционного отбора. В статье приведен краткий исторический очерк по изучению и выведению новых сортов амаранта на юге Западной Сибири. Кроме того, рассмотрены биологические особенности амаранта (*Amaranthus* L.) и его значимость как ценной пищевой и кормовой культуры. Анализ селекционных признаков позволил выделить наиболее перспективные образцы для успешного возделывания в условиях юга Западной Сибири: амарант метельчатый (ПК–318 и ПК–391) и амарант темный (ПК–42). Они характеризуются наиболее коротким вегетационным периодом и обладают большей устойчивостью к неблагоприятным факторам. Результаты исследования показывают, что амарант может стать важной сельскохозяйственной культурой для Западной Сибири, обеспечивая высокую урожайность и адаптивность в сложных климатических условиях.

Ключевые слова: сквален, длина вегетационного периода, *Amaranthus cruentus* L., *Amaranthus hypohondriacus* L., *Amaranthus caudatus* L., *Amaranthus tricolor* L., интродуцент, стадии онтогенеза.

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Current state and ecological features of *Hippophae rhamnoides* L. cenopopulations in Northern Kazakhstan

Hippophae rhamnoides L. (sea buckthorn) is an important resource for agriculture, landscaping, and medicine due to its beneficial properties, high winter hardiness, and adaptability to various soil conditions. These factors make the study of the current state and ecological-cenotic characteristics of sea buckthorn populations in Northern Kazakhstan particularly relevant. The research conducted in the North Kazakhstan and Kostanai regions covers eight key populations of *H. rhamnoides* and their plant communities. The study found that sea buckthorn thrives and can be successfully used for reclamation in technogenically disturbed areas with moderate moisture. Sea buckthorn forms a shrub layer in forests and creates thickets on the edges of birch groves. In flatland landscapes, sea buckthorn dominates plant communities, particularly in dry steppe and meadow conditions, indicating ecological and phytocenotic plasticity. The species composition of the studied communities involving sea buckthorn depends on the ecological and cenosis conditions of their habitats. The herbaceous layer is predominantly composed of mesoxerophytic species. The studied sea buckthorn populations are mainly composed of pre-generative and generative individuals and require further monitoring and research.

Keywords: Hippophaer hamnoides L., North Kazakhstan, plant communities, populations, herbaceous layer, phytocenotic conditions.

Introduction

Currently, there is heightened attention to issues of food security and sustainable use of genetic resources [1, 2], which includes ensuring the conservation and rational use of agro-biodiversity in their habitats.

Sea buckthorn, known for its beneficial properties for the body [3, 4], is well adapted to harsh soil and climatic conditions, as evidenced by its ability to thrive in poor, sandy, and rocky soils, as well as withstand extreme temperatures and severe frosts. Additionally, its resistance to drought and saline soils contributes to its spread in arid and semi-arid regions [5].

These adaptive characteristics render sea buckthorn (*Hippophae rhamnoides* L.) particularly valuable for ecosystem restoration and agricultural utilization in regions with harsh climates. Sea buckthorn is a deciduous shrub predominantly distributed across Asia and North America, with occurrences in Europe, particularly along riverbanks in Finland, Sweden, Poland, and Germany [6–8].

In the countries of the former Soviet Union, the range of *H.rhamnoides* is characterized by a discontinuous nature. Sea buckthorn is found in almost all mountainous areas that border the southern edge of the CIS, including the Caucasus, the mountains of Central Asia, Kazakhstan, and Siberia. At low and medium elevations in these regions, it forms extensive thickets, thrives well, and produces abundant seed yields, which allows us to consider these territories as key areas for this species.

The range of sea buckthorn in Kazakhstan [9] covers the following floristic regions: 11. Eastern Sary-Esik, 12. Zaisan, 18. Balkhash — Alakol, 22. Altai, 23. Tarbagatai, 24. Dzhungarsky Alatau, 25. Zailiysky Kunghey Alatau, 25a. Ketmen Terskey Alatau, 27. Kyrgyz Alatau, 28. Karatau, 29. Western Tien Shan.

The North Kazakhstan region is characterized by a rather harsh sharply continental climate with hot summers and frosty winters. The diversity of geomorphological, climatic, and soil-vegetation conditions in North Kazakhstan determines the variety of landscapes, which correspond to well-defined natural zones in the latitudinal direction — forest-steppe, steppe, and semi-desert (desert steppes and grass-covered deserts).

A significant part of the region consists of flat steppes, with hilly fragments covered by pine forests. To the south, it borders the Kazakh Upland [10]. This region is also known for its mining activities, with several iron ore deposits being mined via open-pit methods. These operations lead to changes in geological landscapes and increase the areas of disturbed land that are prone to erosion. Treshchevskaya et al. (2018)

[11] note that sea buckthorn (Hippophae rhamnoides) is the most promising species for the reclamation of waste heaps.

Sea buckthorn (*H.rhamnoides*) is indifferent to soil conditions and can thrive on chestnut soils that are poor in nutrients and have significant salinity; however, it is very sensitive to the physical properties of the soil, preferring well-aerated substrates [12].

Thus, *H. rhamnoides* represents a valuable resource for agricultural use, landscaping, and medicine, owing to its beneficial properties, winter hardiness, and adaptability to soil conditions. This underscores the relevance of studying the current status and ecological-cenotic characteristics of *H.rhamnoides* populations in Northern Kazakhstan.

Experimental

Field botanical studies were conducted in the autumn-spring period of 2023-2024 in the territory of the State National Nature Parks “Borovoe” and “Kokshetau” in the North Kazakhstan region, as well as in the forests of the Kostanay region in Northern Kazakhstan. The research was carried out on 8 key plots measuring 10x10 m, 10x15 m, and 20x20 m [13]. Field expedition studies were conducted using a route reconnaissance method with the help of a GPS navigation device, specifically the GPS Garmin Montana 750i. The mathematical processing of the research results was carried out according to the methodology of G.N. Zaytsev [14].

The surveyed routes encompassed a variety of habitats where the studied species were found, including pine and birch forests of different forest type groups, forest edges, clearings, glades, areas along roads, and more. The collected herbarium of encountered species was identified using floristic compilations [15]. Additionally, the taxonomic status of the species was determined and verified using the international web system POWO [16]. Geobotanical descriptions included: coordinates, geographical location, absolute elevation, micro relief; description of the community involving sea buckthorn (name and species composition of the community, origin, number of shrubs, density, height, age, trunk diameter, phenophase, condition); for the herbaceous layer: projected cover, grassiness, abundance according to Drudae [17–19], height and phenophase, placement according to Bykov [20]. Age states were identified according to the methodological guidelines of L.B. Zaugolnova and O.V. Smirnova (1978) [21-22]. Taxonomic characteristics used in forestry and forest geobotany were noted. An analysis of the spatial distribution of individuals was conducted. Shrub counting was carried out across the entire sample plot using a complete count method. Their species, height, and frequency of occurrence were determined. The plant community was identified based on the proportion of dominants.

Descriptions of communities with *H. rhamnoides* L. are given in ascending order of the absolute height of their place of growth.

Results and Discussion

Plot 1. *Pine-sea buckthorn-herbaceous community.* Sea buckthorn grows in the lower part of the quarry pit (quarry location from the 1980s) on the boundary of compartment 62 of the Prigorodny Forest District, Kostanay Forestry. The area of the site is approximately 30 hectares. It is a forest-steppe zone. Coordinates: N 53°09'06.22", E 063°38'55.24", 147 meters above sea level. Sea buckthorn is in a tree-like life stage with a single trunk (average height — 4-5 meters; trunk diameter — 5 cm). Within the 10x10 meter sample plots, the number of sea buckthorn plants totals 20 units. The average distance between trees is 2-3 meters. The tree stand is represented by *Pinus sylvestris* L. (average height — 4–6 meters), *Ulmus pumila* L. (average height — 5-6 m), *Acer negundo* L. (average height — 6 m), *Populus* sp. (average height — 5-6 m). The shrub tier is not rich and is represented by *Lonicera tatarica* L. Regeneration is good. Succession is observed. The substrate is sandstone.

The cenoflora consists of *Pinus sylvestris* L, *Ulmus pumila* L., *Acer negundo* L., *Betula pendula* Roth, *Elaeagnus angustifolia* L., *Hippophae rhamnoides* L., *Lonicera tatarica* L, *Salix* × *fragilis* L., *Euphorbia virgata* Waldst. ex Kit., *Achillea millefolium*L., *Polygonum aviculare*L., *Veronicaincana* L., *Koeleria cristata (L.) Pers., Artemisia dracunculus* L, *Artemisia sericea* Weber ex Stechm., *Plantago media* L., *Vicia sepium* L., *Vicia cracca* L., *Medicago falcata* L., *Lathyrus pratensis* L., *Cirsium setosum* (Willd.) Bes, *Phleum phleoides* (L.). Karst., *Poa angustifolia* L., *Agropyron pectinatum* (M.Bieb.) Beauv., *Calamagrostis epigeios* (L.) Roth, *Melilotus officinalis*(L.) Lam., *Potentilla humifusa* Willd. ex Schltdl., *Helictotrichon desertorum* (Less.) Nevs.

Plot 2. *Pine-sea buckthorn-herbaceous-sedge community*, 175 meters above sea level. The population of H. rhamnoides L. is located along the Big Chebachye Lake on the northwestern lakeside terrace, 500 meters from the lake, within the Borovsky Forestry area, GNP "Borovoe". The area of the compartment is 27 hectares. It is a lake-alluvial plain. Coordinates: N 53°06'69,66, E 070°18'79,61. Within the 10x15 meter sample plots, there are about 70 sea buckthorn shrubs. The tree stand consists of Scots pine (*Pinus sylvestris* L., average height 6–8 m) and a few silver birches (*Betula pendula* Roth., average height 6 m). The shrub tier is represented by *H. rhamnoides* L. and *Crataegus sanguinea* Pall. The height of the sea buckthorn shrubs averages 2-3 meters. Trunk diameters range from 1 cm to 10 cm. The age of the shrubs is 15–20 years. The age spectrum of *H. rhamnoides* L. includes generative and pre-generative individuals of the species. Regeneration is present. Five forms of sea buckthorn are described, differing in the morphometric characteristics of the fruits. *Thymus serpyllum* L. is found in the herbaceous tier.

Plot 3. *Sea buckthorn-willow-onobrychis-herbaceous community* with pines. This plant community is located within the Kostanay Forestry area of the Prigorodny Forest District, at the boundary of compartment 66. The area of the community is 20 hectares. Coordinates: N 53°09'28.57", E 63°41'24.06", 181 m above sea level. Within the 20x20 meter sample plot, sea buckthorn is diffusely distributed, with the shrubs being 20 years old. Sea buckthorn is predominantly represented by generative individuals. Regeneration is good (35 saplings). The distance between sea buckthorn shrubs is 3–5 meters. The average trunk diameter is 10 cm. The tree stand consists of *Pinus sylvestris* L., *Betula pendula* Roth., and *Salix × fragilis* L.

The herbaceous layer includes the following species: *Euphorbia virgata* Waldst. ex Kit., *Achillea millefolium* L., *Koeleria cristata (L.) Pers.*, *Artemisia dracunculus* L., *Artemisia sericea* Weber ex Stechm., *Carex polyphylla* Kar. & Kir., *Dianthus versicolor* Fisch. ex Link, *Astragalus onobrychis* L., *Onobrychis arenaria*(Kit.) DC., *Onobrychis viciifolia* Scop., *Plantago media* L., *Vicia sepium* L., *Vicia cracca* L., *Medicago falcata* L., *Lathyrus pratensis* L., *Cirsium setosum* (Willd.) Bes, *Phleum phleoides* (L.) H.Karst., *Poa angustifolia* L., *Agropyron pectinatum* (M.Bieb.) Beauv., *Agropyron kazachstanicum* (Tzvelev) Peschkova, *Calamagrostis epigeios* (L.) Roth, *Plantago media* L., *Veronica incana* L.

Plot 4. *Elaeagnus-sea buckthorn-herbaceous community*. *Hippophae rhamnoides* thickets were found in the Prigorodny Forest District of Kostanay Forestry, Compartment 68. The area of the plot is 11.8 hectares. It is a lowland meadow. The site is seasonally inundated by meltwater during the spring. Coordinates: N 53°10'10.05", E 63°42'61.98", 190 m above sea level.

Within the 10x10 meter sample plots, approximately 50 sea buckthorn shrubs are present. The shrub layer includes *Elaeagnus angustifolia* L., *H. rhamnoides* L., *Lonicera tatarica* L., and *Salix × fragilis* L. The height of the sea buckthorn shrubs averages 3–5 meters. Trunk diameters range from 1.5 cm to 15 cm. The age of the shrubs is 15–20 years. The cenopopulation of *H. rhamnoides* comprises immature, generative, and post-generative individuals. Regeneration is good.The cenoflora consists of the following species: *Elaeagnus angustifolia* L., *Hippophae rhamnoides* L., *Lonicera tatarica* L, *Salix × fragilis* L., *Euphorbia virgata* Waldst. ex Kit., *Achillea millefolium* L., *Koeleria cristata (L.) Pers., Artemisia dracunculus* L, *Artemisia sericea* Weber ex Stechm., *Polygonum aviculare* L., *Dianthus versicolor* Fisch. ex Link, *Astragalus onobrychis* L., *Sedum telephium* L., *Vicia sepium* L., *Vicia cracca* L., *Medicago falcata* L., *Lathyrus pratensis* L., *Cirsium setosum* (Willd.) Bes, *Phleum phleoides* (L.) H. Karst., *Poa angustifolia* L., *Agropyron pectinatum* (M. Bieb.) Beauv., *Agropyron kazachstanicum* (Tzvelev) Peschkova, *Calamagrostis epigeios* (L.) Roth, *Plantago media* L., *Trifolium repens* L.

Plot 5. *Sea buckthorn-herbaceous community*, 196 meters above sea level. Prigorodny Forest District, Kostanay Forestry. Located at the edge of an old quarry. Coordinates: N 53° 10' 94.84", E 063° 43' 44.40".

Within this plot, sea buckthorn is distributed in clumps (thickets), with shrub ages ranging from 10 to 15 years. Sea buckthorn is predominantly represented by generative individuals. Regeneration is good, with 35 saplings present. The distance between sea buckthorn shrubs ranges from 1 to 3 meters. The average trunk diameter is 5 cm. Dominant species of the herbaceous layer include: *Artemisia dracunculus* L, *Artemisiasericea* Weber ex Stechm., *Vicia sepium* L., *Achillea millefolium*L., *Phleum phleoides* (L.) H. Karst., *Lathyrus pratensis* L., *Medicago falcata* L., *Euphorbia virgata* Waldst. ex Kit. et al.

Plot 6. *Sea buckthorn-bluegrass-strawberry community*. Coordinates: N 53°24'25.51", E 68°01'77.19", 290 m above sea level. (GNP "Kokshetau", Aiyrtausky Branch, Syrymbet-Tyukhtinsky Forestry, Compartment 28. The area of the plot is 0.01 hectares. It is a floodplain meadow. Sea buckthorn is diffusely distributed in the shrub life form. The species is 15–20 years old. The ontogenetic spectrum is incomplete. The tree stand consists of *Betula pendula* Roth (average height = 8 m), *Sorbus aucuparia* L. (average height = 6 m), and occasionally *Malus baccata* (L.) Borkh. (average height = 5 meters). The shrub layer is

exclusively represented by *H. rhamnoides* L. The herbaceous layer includes: *Fragaria viridis* (Duchesne) Weston (cop1), *Fragaria vesca* L. (cop3), *Euphorbia virgata* Waldst. ex Kit., *Plantago urvillei* Opiz, *Vicia cracca* L., *Urtica urens* L., *Bromopsis inermis* (Leyss.) Holub, *Melica nutans* L., *Calamagrostis neglecta* (Ehrh.) Gaertner, Meyer et Schreber, *Agrostis gigantean* Roth, *Elytrigia repens* (L.) Nevski, *Achillea millefolium* L., *Artemisia sericea* Weber ex Stechm., *Stellaria graminea* L., *Convolvulus arvensis* L., *Artemisia sericea* Weber ex Stechm., *Ranunculus polyanthemos* L., *Koeleria cristata* (L.) Pers.

Plot 7. *Birch-shrub-herbaceous community*. Coordinates: N 52°53'36.42", E 68°58'63.03", 349 m above sea level. The cenopopulation of *H.rhamnoides* is located on the left bank of a spring stream in the understory of a birch grove west of the settlement of Bayterek. Within the 10x15 meter sample plots, approximately 45 sea buckthorn shrubs are recorded. Regeneration is satisfactory. The tree stand consists of silver birch (*Betula pendula* Roth, average height = 9 meters). The shrub layer is diverse and includes *H. rhamnoides* L., *Rosa canina* L., and *Cerasus* sp. The height of the sea buckthorn ranges from 1 to 3 meters, with trunk diameters of 5–10 cm. The age of the shrubs is 15–25 years. The herbaceous tier consists of: *Artemisia dracunculus* L, *Artemisia sericea* Weber ex Stechm., *Polygonum aviculare* L., *Dianthus versicolor* Fisch. ex Link, *Astragalus onobrychis L., Sedum telephium L., Vicia sepium* L., *Vicia cracca* L., *Medicago falcata* L., *Lathyrus pratensis* L., *Cirsium setosum* (Willd.) Bes, *Phleum phleoides* (L.) H. Karst. and other forest-meadow species.

Plot 8. *Birch-sea buckthorn community*. The cenopopulation of *H. rhamnoides* is located on the right bank of a spring stream at an elevation of 349 meters above sea level. Coordinates: N 52°53'29.46", E 68°58'30.59', 349 v above sea level. The birch grove is situated west of the settlement of Bayterek. In this plot, sea buckthorn is represented in a tree-like life form, reaching up to 5 meters in height; with trunk diameters of 8–15 cm. Regeneration is excellent. The ontogenetic spectrum is complete. The sea buckthorn fruits exhibit distinct morphometric characteristics. The tree stand of the plant community is represented by *Betula pendula* (average height = 6–8 meters). The understory consists of *H. rhamnoides*, *Rosa canina* L., and *Ribes aureum* Pursh. The cenoflora of the herbaceous layer includes: *Euphorbia virgata* Waldst. ex Kit., *Achillea millefolium* L., *Koeleria cristata* (L.) Pers., *Artemisia dracunculus* L., *Artemisia sericea* Weber ex Stechm., *Carex polyphylla* Kar. &Kir., *Plantago media* L., *Vicia sepium* L., *Vicia cracca* L., *Medicago falcata* L., *Cirsium setosum* (Willd.) Bes, *Phleum phleoides* (L.) H. Karst., *Poa angustifolia* L., *Agropyron pectinatum* (M. Bieb.) Beauv., *Agropyron kazachstanicum* (Tzvelev) Peschkova.

In the habitats of *Hippophae rhamnoides* with adequate soil moisture and aeration, the herbaceous layer is dominated by *Fragaria viridis, Fragaria vesca, Euphorbia virgata, Plantago urvillei, Calamagrostis epigeios*, and other typical forest and meadow herbaceous species (Plots 2, 3, 4, 6, 7). In drier ecological and cenotic conditions, the abundance of xerophytic and mesoxerophytic species increases (*Artemisia dracunculus, Artemisia sericea, Polygonum aviculare, Dianthus versicolor*, etc.) (Plots 1, 5, 8).

Research has shown that *Hippophae rhamnoides* thrives and is successfully reintroduced in industrially disturbed areas with medium-steppe moisture. However, the herbaceous cover in these areas is not rich in species and is significantly sparse.

Conclusion

Thus, we found and studied 4 populations in the North Kazakhstan region, and 4 populations of *H.rhamnoides* were also found in the Kostanay region.

H.rhamnoides serves as an understory species in birch and pine forests, forming a shrub layer in tree plantations and occasionally creating impenetrable thickets at forest edges. Under such conditions, it exhibits high morphometric values of its fruits. In plain landscapes, sea buckthorn is primarily a dominant species in plant communities and is associated with dry-steppe and meadow ecological and cenotic conditions. In the cenopopulations of sea buckthorn we studied, generative and pre-generative individuals predominated, with post-generative individuals being rare. Sea buckthorn primarily regenerates vegetatively and successfully contributes to the process of afforesting disturbed lands. The data we obtained indicate that the studied populations of sea buckthorn are young and require further stationary research and regular monitoring of their current condition.

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Солтүстік Қазақстанның *Hippophae rhamnoides* L. ценопопуляцияларының қазіргі жағдайы және экологиялық ерекшеліктері

Hippophae rhamnoides L. (итшомыр шырғанағы) жемісінің пайдалы қасиеттерімен, әртүрлі топырақ жағдайларына бейімделу қабілетімен белгілі, аязға жоғары төзімділігі мен ауылшаруашылығында, ортаны көгалдандыруға және медицинада пайдалануда құнды ресурс. Аталған факторларға байланысты Солтүстік Қазақстан жағдайында шырғанақ популяциясының қазіргі жағдайы мен экологиялық-ценотикалық ерекшеліктерін зерттеу өзекті. Солтүстік Қазақстан және Қостанай облыстарында жүргізілген зерттеу итшомыр шырғанағының (*H. rhamnoides*) негізгі сегіз популяциясын және олардың өсімдіктер қауымдастықтарын қамтиды. Жүргізілген жұмыстардың

нәтижесінде итшомыр шырғанағы орта далалық ылғалдылығы бар техногендік бұзылған аймақтарда жақсы өсетіні және қалпына келетіні анықталды. Итшомыр шырғанағы қарағай ормандарында бұталы қабат түзіп, қайың тоғайларының шетінде қалың тоғай құрайды. Құрғақ далалы және шалғынды жағдайдағы жазық ландшафттарда итшомыр шырғанағы өсімдіктер қауымдастығында доминантты түр ретінде таралған, бұл олардың экологиялық-фитоценотикалық икемділігін көрсетеді. Итшомыр шырғанағының қатысуымен зерттелген қауымдастықтардың түрлік құрамы олардың тіршілік ету ортасының экологиялық және ценотикалық жағдайларына байланысты. Шөп қабатының негізінде мезоксерофильді түрлер басым болды. Итшомыр шырғанағының зерттелген популяциясы негізінен прегенеративті, генеративті дарақтардан тұрады және одан әрі бақылаумен зерттеуді қажет етеді.

Кілт сөздер: *Hippophae rhamnoides* L., Солтүстік Қазақстан, өсімдіктер қауымдастығы, популяция, шөпті деңгей, фитоценотикалық жағдайлар.

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Современное состояние и экологические особенности ценопопуляций *Hippophae rhamnoides* L. Северного Казахстана

Hippophae rhamnoides L. (облепиха крушиновидная) представляет собой важный ресурс для сельского хозяйства, озеленения и медицины благодаря своим полезным свойствам, высокой зимостойкости и способности адаптироваться к различным почвенным условиям. Эти факторы делают особенно актуальным изучение современных состояний и эколого-ценотических особенностей популяций облепихи крушиновидной в условиях Северного Казахстана. Исследование, проведенное в Северо-Казахстанской и Костанайской областях, охватывает восемь ключевых популяций облепихи (*H. rhamnoides*) и их растительные сообщества. В результате данной работы выявлено, что облепиха крушиновидная успешно растет и рекультивируется на техногенно-нарушенных территориях при среднестепном увлажнении. Облепиха формирует кустарниковый ярус в лесах и образует заросли на опушках березовых рощ. В равнинных ландшафтах облепиха доминирует в растительных сообществах, преимущественно в сухостепных и луговых условиях, указывающая на их эколого-фитоценотическую пластичность. Видовой состав изученных сообществ с участием облепихи зависит от эколого-ценотических условий их местобитаний. В основе травяного яруса преобладают мезоксерофильные виды. Изученные популяции облепихи состоят преимущественно из прегенеративных, генеративных особей и требуют дальнейшего мониторинга и исследований.

Ключевые слова: *Hippophae rhamnoides* L., Северный Казахстан, растительные сообщества, популяция, травянистый ярус, фитоценотические условия.

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Introduction of rare species of the genus Allium L. of the Kazakhstan Altai in the Altai Botanical Garden

The aim of this work was to study the biological characteristics of three introduced rare onion species of the Kazakh Altai flora, to assess the sustainability and prospects of their cultivation in the Altai Botanical Garden. The article presents the results of a long-term study of the seasonal rhythm of development, biometric parameters and seed productivity of *Allium ivasczenkoae* Kotuch., *A. ledebourianum* Schult. et Schult., *A. schoenoprasum* L. in the exposition of natural flora of the Altai Botanical Garden. These onions are combined into the subgenus *Rhizirideum* (Koch) Wendelbo and combined into the section *Schoenoprasum* Dumort. It was found that all three species in the introduction have a stable phenological rhythm, during the growing season they annually undergo a full cycle of shoot development and form seeds. According to the phenorhythmotype, they belong to spring-early summer-green with an average flowering period. They grow in April, bloom mainly in early June, seeds ripen in July, vegetation ends naturally in late August — early September. Vegetation lasts from 128.33 ± 2.58 days (*A. ledebourianum*) to 146.8 ± 7.24 days (*A. schoenoprasum*). The studied onion species differ in biometric parameters: height, number of flowers in inflorescence, inflorescence diameter. In culture, biometric parameters vary in the studied species mainly at a low level, which indicates the stability of these indicators in culture. High reproductive rates were established in culture for all three species, the productivity coefficient varies at the level of 56.75–69.26 %. At the same time, a low coefficient of variation in the weight of seeds and flowers in inflorescence was recorded for all three species, which indicates an insignificant degree of data dispersion in the introduction.

Keywords: Allium, introduction, seasonal rhythm of development, seed productivity.

Introduction

Genus *Allium* L. (Amaryllidaceae), which includes from 650 to 920 species according to various sources, is one of the most diverse and largest genera of monocotyledonous plants in the Northern Hemisphere [1]. Almost a third of the species grow in mountainous Central Asia, the world's largest center of onion diversity [2–4]. According to the latest data, the genus includes at least 127 species in Kazakhstan [5], found almost everywhere, but with greater species diversity in the steppe and semi-desert regions of the lowlands and mountains. Five new endemic onion species for the flora of Kazakhstan have already been described in 2021 [6–8]. Yu.A. Kotuhov [9] For the Kazakh Altai, 41 species are found. At the present stage, the introduction of representatives of the genus *Allium,* known for its many useful properties — food, medicinal, decorative and fodder, as well as rare ones that require protection, is also relevant in connection with the fact that the species of this genus belong to the wild relatives of cultivated plants [10–12].

An analysis of the introduction studies in phenological journals for 1983–2023 showed that out of 41 species of wild onions of the Kazakh Altai, 26 (or 63.4 %) were tested in the culture of the Altai Botanical Garden, including 9 (or 34.6 %) rare species (*Allium altaicum* Pall., *A. caespitosum* Siev. ex Bong. & C.A. Mey., *A. ivasczenkoae* Kotuch., *A. ledebourianum* Schult. et Schult., *A. microdictyum* Prokh., *A.schoenoprasum* L., *A. pskemense* B. Fedtsch. *A.polyrhizome* Turcz. ex Regel, *A. robustum* Kar. &Kir.).

The aim of the research conducted in the exposition of natural flora of the Altai Botanical Garden on the introduction of species of the genus *Allium* is to study the biological characteristics and identify their resistance to new growing conditions.

Currently, the collection fund of the genus *Allium* from the flora of the Kazakh Altai in the Altai Botanical Garden is formed from 68 species and form taxa, of which 10 are rare species in need of protection. This article provides information on the study of the seasonal rhythm of development, morphometry, reproductive biology and reproduction features in culture, the definition of three rare onion species of the flora of the Kazakh Altai that are resistant to the conditions of the introduction area: *Allium ivasczenkoae* Kotuch., *A. ledebourianum* Schult. et Schult., *A. schoenoprasum* L. These onions are biologically close to each other, belong to the Subgenus *Rhizirideum* (Koch) Wendelbo) and are united in the section *Schoenoprasum* Dumort [13].

Allium ivasczenkoae is a narrow-local endemic of the southwestern periphery of Western Altai, a relict. A new species for the flora of Kazakhstan, described by Yu.A. Kotukhov, from the Ubinsky Ridge (Kazakhstan Altai). In the nature of the Kazakh Altai, the species was discovered by the author in the south-eastern foothills of the Ubinsky ridge, in the vicinity of the village of Butakovo and the south-eastern foothills of Listvyazhnaya Mountain, as well as on the south-western slope of the Koksinsky ridge. It grows in open, well-lit, excessively moist meadows [14, 15].

Allium ledebourianum is a narrow-local endemic, indicated for the Kazakhstan Altai on the ridges of the southwestern and southeastern periphery of the Western Altai (Ivanovsky, Ulbinsky, Ubinsky, Lineisky, Kholzun, Koksinsky ridges), the mountain-forest part of the Southern Altai ridge (Kurchumsky, Southern Altai, Sarym-Sakty, Southern Altai Tarbagatai ridges). It grows in well-lit, moist meadows [16].

Allium schoenoprasum is boreal holarctic, polymorphic species, its range is wide, found in Japan, Korea, Siberia, Europe. It grows in damp meadows, river floodplains, forest edges, except for swamps. Morphologically, this plant can easily adapt to dry and sunny habitats [17–19]. In the territory of the Kazakhstan Altai, the species is widespread on the ridges of the Southern and Western Altai. Within the Kalbinsky Highlands, one location has been noted, where the species is apparently a relic of the Ice Age [13]. Since *A. schoenoprasum* has medicinal and edible functions, it is widely cultivated throughout the world [20].

Experimental

The Altai Botanical Garden is located in the city of Ridder in the East Kazakhstan region, in the mountain-forest zone between the Ubinsky (1967 m) and Ivanovsky (2776 m) ridges, with absolute heights from 700 to 900 meters. The distance from the oceans and the mountainous relief determine the degree of continentality, humidity and temperature conditions. According to the humidity coefficient, the Altai Botanical Garden is located in the GTK -1.2 indicators, which indicates humid conditions of existence [21].

The climate is sharply continental. According to the Ridder meteorological station, the winter period begins in the third ten days of October and lasts 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 to 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 hydration throughout the growing season [22].

The garden soils are mountain chernozems. Humus content fluctuates between 6 and 8 (10 %) with a high percentage of nitrogen and potassium. In the upper horizons the soil reaction is neutral or slightly acidic; in the lower tiers it acquires an alkaline reaction. The soil-forming rocks are loess-like loams of various genesis [23].

The limiting factors of introduction into the Altai Botanical Garden are large amplitudes of daily and annual temperatures, humidity, limited frost-free and vegetation periods. Hence, the leading indicators for the selection of introduced species are high winter- and frost-resistance, shortened growth and development rhythm, which allows them to pass the main phases of seasonal development. Introduction site of the genus *Allium.* The natural flora exposition is located in the southwestern part of the garden. The floral material is placed in a free landscape style, taking into account the biology and ecology of the species.

Objects of study: *A. ivasczenkoae, A. ledebourianum, A. schoenoprasum* were introduced as live plants from natural habitats of the Kazakh Altai in 2015. Thus, samples *of A. ivasczenkoae* were collected in the foothills of the ridge. Ubinsky, Kozlushka, location coordinates of the natural population: 50.27639 N, 83.28917 E, 625 m above sea level; sample *A.ledebourianum* — foothills of the ridge. Ivanovsky, northwestern slope, coordinates: 50.3201 N, 84.19694 E, 980 m above sea level; sample *A.schoenoprasum* — foothills of the ridge. Kalbinsky (Sibinskaya depression), coordinates: 49.43417 N, 82.56194 E, 911 m above sea level (Fig. 1–3).

The following methods were used in the introduction experiments: when studying the seasonal rhythm of growth and development, the method of phenological observations of I.N. Beideman was used [24], classification of phenorhythmotypes — according to the method of E.S. Fomin et al. [25]. Winter hardiness, resistance to unfavorable environmental factors and seed productivity were determined using generally accepted methods [26, 27]. The names of species were adopted according to Plants of the World Online (POWO, 2024) [28]. Statistical analysis was performed using the Excel software application. The mean values of the indicators, the coefficient of variation, and the accuracy of the experiment were determined.

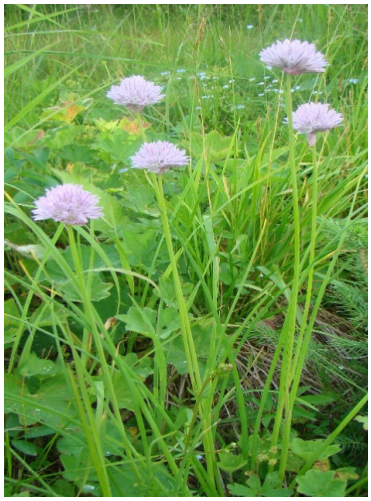

Figure 1. Allium ivasczenkoae

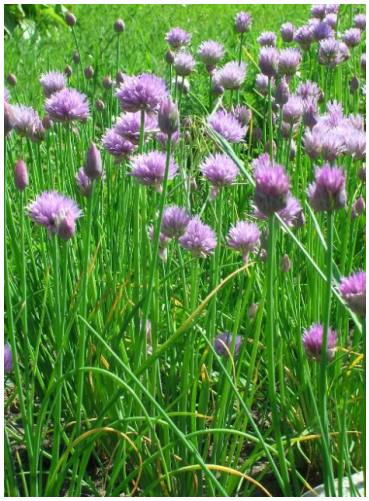

Figure 2. Allium ledebourianum

Figure 3. Allium schoenoprasum

Results and Discussion

One of the visually recorded indicators of plant adaptation to new growing conditions is their seasonal rhythm of growth and development. Many years of cultivation experience have shown that from under the snow *A. ledebourianum* and *A.schoenoprasum* always emerge without signs of sub snow growth, *A. ivasczenkoae* has a regrowth phase in some years. No losses were observed during the winter period and *they* are not damaged by spring frosts. The results of phenometry observations revealed that during the growing season the plants go through a full shoot development cycle and form seeds. The phenological rhythm is stable. Based on the analysis of the obtained phenodata data, phenorhythmotypes were determined, according to which all three species are classified as spring- early summer green with an average flowering period. Table 1 presents the average annual calendar dates of the main phenophases of the studied onions for an 8-year observation period (2016–2023).

Table 1

Average annual phenodates *Allium ivasczenkoae, A.ledebourianum* and *A.schoenoprasum* in the exposition of the Altai Botanical Garden

Name of phenodate	Statistical indicators	Phenodates of the studied onions		
		Allium ivasczenkoae	*Allium ledebourianum*	*Allium schoenoprasum*
Beginning of spring regrowth	(M± m) P %	17.04±4.34 4.33	16.04 ±4.06 4.10	18.04±4.84 4.72
Beginning of budding	(M± m) P %	22.05±3.94 2.16	28.05±4.45 2.16	04.06±5.62 2.79
Beginning of flowering	(M± m) P %	05.06±5.12 2.53	10.06±2.47 1.16	12.06±3.97 1.82
Mass flowering	(M± m) P %	16.06±3.00 1.33	15.06±2.78 1.24	19.06±3.96 1.43
End of flowering	(M± m) P %	02.07±5.99 4.24	01.07±3.68 1.43	02.07±4.21 1.62
Beginning of seed maturation	(M± m) P %	25.07±12.21 3.96	18.07±12.30 4.19	08.07±5.06 1.86
End of seed maturation	(M± m) P %	02.08±6.46 1.99	02.08±6.46 1.99	22.07±4.35 1.44
End of the growing season	(M± m) P %	05.09±10.28 2.6	21.08±8.61 2.36	22.09±10.86 2.52
Note – M — average value of the indicator; P% — accuracy of the experiment				

As practice has shown, in the spring after the snow melts from the site, all three species under observation begin to grow in the second half of April. The flowering phase begins in late May–early June. The seeds ripen in July. Vegetation ends naturally in late August–early September for *Allium ledebourianum* and *A. ivasczenkoae,* in September — *Allium schoenoprasum.*

During the introduction, the duration of the seasonal development phases was determined (Table 2). It was experimentally revealed that the duration of the seasonal development phase in all three species fluctuates depending on the weather conditions of the growing season. The duration of the interphase "beginning of spring regrowth — beginning of flowering" was set at 52–55 days with minor fluctuations from the average long-term. Comparison of the flowering start date in the experimental onion species over several years, at least 5 of which were atypically hot years with a dry growing season, moderately warm and humid, and also atypically cool, showed that one of the main factors determining the timing of flowering is the air temperature. Deviation of air temperature in the first half of the growing season from the average long-term upwards by 1-2° accelerates the onset of the flowering date. 3–5 days before the average perennial date. Duration of flowering in *A. ivasczenkoae* individuals is 24.4±1.77 days, *A.ledebourianum* and *A.schoenoprasum* almost the same, respectively 20.90±2.63 and 20.40±2.44 days. The seeds of all three species ripen simultaneously within 14–18 days with minor deviations from the average long-term indicator. The seeds fall out of the capsules as they ripen, but single self-seeding was noted only in *A. ledebourianum.* The vegetation period varies from 128.33±2.58 days (*A. ledebourianum*) up to 146.8±7.24 days (*A. schoenoprasum*). The studied species are characterized as winter-hardy, since no losses during the wintering period were noted during the observation period. No damage to plants from spring frosts was found, which indicates their frost resistance. In some years, in late August–early September, a single repeated flowering of *A. schoenoprasum.*

Table 2

Duration of seasonal development phases *Allium ivasczenkoae, A.ledebourianum* and *A.schoenoprasum* in the exposition of the Altai Botanical Garden

Name of the period of seasonal development	Statistical indicators	Duration of the seasonal development period, in days		
		Allium ivasczenkoae	*A.ledebourianum*	*A. schoenoprasum*
The beginning of spring growth, the beginning of flowering	(M± m) C% P %	52.30 ± 4.60 13.31 4.21	55.33 ±1.89 5.68 1.64	53.80 ±3.14 8.84 2.79
Beginning of flowering — end of flowering	(M± m) C% P %	24.40 ±1.77 10.96 3.47	20.90 ±2.63 19.07 6.03	20.40 ±2.44 18.08 5.72
Beginning of seed maturation — end of seed maturation	(M± m) C% P %	18.70 ±3.50 28.30 8.95	14.92 ±2.08 23.13 6.67	14.83 ±1.91 21.29 6.14
Beginning of vegetation — end of vegetation	(M± m) C% P %	130.40 ±6.54 7.58 2.39	128.33 ±2.58 3.33 0.96	146.80 ±7.24 7.46 2.36
Note – M — average value of the indicator; C% — coefficient of variation; P% — accuracy of the experiment				

In statistics, if the variation coefficient is less than 12 %, the degree of variability of the trait is considered low; from 13 % to 20 % — average; from 21 % to 40 % — high; more than 40 % — very high [29]. In our studies, the level of variability of the studied indicators of average annual phenodates established in all 3 species mainly at a low level of variability, rarely at an average level in *A. ivasczenkoae* and *A.ledebourianum,* single in *A. schoenoprasum.* High degree of variation in the seasonal rhythm of development is the fruiting phase, where this indicator varies at a high level in all three species. Such indicators of variability Phenodate confirms the good adaptation of the three studied species in culture.

Table 3 presents the results of morphometric parameters of experimental onion samples. According to the obtained parameters*, A. ledebourianum* distinguished by the height of generative shoots and leaves. The shortest is *A.schoenoprasum,* in which the height of the generative shoot and leaf are 37.46 ±1.79 and 30.85 ±1.74, respectively. At the same time, a high coefficient of variation of the leaf width was established in *A. schoenoprasum,* medium-*A. ivasczenkoae* and *Allium ledebourianum.* The remaining parameters vary

at a low level, which indicates the stability of these indicators in the culture over a long period of introduction.

Table 3

Morphometric parameters *Allium ivasczenkoae, Allium ledebourianum, Allium schoenoprasum* in the exposition of the Altai Botanical Garden

Parameters	Statistical indicators	Name of the species		
		Allium ivasczenkoae	*Allium ledebourianum*	*Allium schoenoprasum*
Height of generative shoot, cm	(M± m) C% P %	58.9±1.81 10.05 2.79	91.85±2.54 4.76 1.32	37.46±1.79 8.27 2.29
Length, cm	(M± m) C% P %	45.3±2.03 11.71 3.25	78.77±3.18 12.24 3.39	30.85±1.74 9.71 2.69
Sheet width, cm	(M± m) C% P %	1.2±0.06 17.71 4.91	1.2±0.06 19.44 5.39	0.67±0.06 27.94 7.75
Inflorescence height, cm	(M± m) C% P %	3.08±0.14 7.92 2.19	3.43±0.18 9.01 2.50	3.58±0.17 8.28 2.29
Inflorescence width, cm	(M± m) C% P %	3.06±0.16 9.09 2.52	3.01±0.12 6.71 1.86	3.43±0.17 8.36 2.32
Note – M — average value of the indicator; C% — coefficient of variation; P% — accuracy of the experiment				

The ability of a species to produce full-fledged seeds when transferred from natural habitats to culture is considered one of the most important criteria for its adaptation to changed living conditions. At the same time, as R.E. Levina notes [30], seed productivity indicators are difficult to predict, since their formation is influenced by many biological and abiotic external factors in addition to internal causes. The more favorable the growing conditions, the smaller the difference between potential and actual seed productivity [30]. For all species *Allium* box three-celled, each cell contains exactly 2 ovules, the ovary contains 6 ovules. Determination of potential seed productivity and the degree of its implementation characterizes the reproductive capabilities of the species, its ability to self-reproduce in the introduction and can serve as a test for assessing the degree of acclimatization [31]. In the course of the study, high reproductive rates were established in culture for all three species (Table 4).

Table 4

Reproductive indices *of Allium ivasczenkoae, A.ledebourianum, A.schoenoprasum* in the exposition of the Altai Botanical Garden

Indicators	Name of the species		
	Allium ivasczenkoae	*Allium ledebourianum*	*Allium schoenoprasum*
Number of flowers in inflorescence, pcs.	48.31±1.69	84.77±5.45	97.08±4.96
Number of fruits with seeds in inflorescence, pcs.	41.2±1.36	79.29±6.15	88.05±6.26
Number of seeds in fruit, pcs.	4.0±0.71	4.16±0.62	4.23±0.63
Potential seed productivity of inflorescence, pcs.	289.86±22.64	508.62±26.62	582.48±35.43
Actual seed productivity of inflorescence, pcs.	164.8±8.98	329.85±31.24	372.45±36.32
Productivity coefficient, %	56.75±8.39	64.76±10.24	63.92±12.52
Weight of 1000 seeds, g.	1.60±0.08	1.54±0.08	1.74±0.07
Laboratory germination of freshly collected seeds,%	42.88±6.49	69.26±10.34	67.82±9.35
Ground germination of freshly collected seeds,%	29.76±4.31	38.5 ±8.39	43.64±8.48

At *A.ivasczenkoae* on one inflorescence 48.31 ±1.69 pieces are formed, of which 41.2 fruits ±1.36 are set with the number *of* seeds in each being 4.0±0.71, in *A. ledebourianum* number of flowers in florescences — 84.77±5.45 pcs., seeds in a capsule — 4.1 ±0.62 pcs., *A. schoenoprasum* — 97.08±4.96 and 4.23, respectively. From these indicators it follows that the real seed productivity of the inflorescence in *A.ivasczenkoae* is on average 164.8±8.98, and potential — 289.86±22.64, in *A. ledebourianum*– 329.85±31.24 and 508.62±26.62 respectively. The productivity coefficient characterizes the actual implementation *of* the reproductive potential of introduced species. This indicator was recorded for *A. ivasczenkoae* — 56.75±8.39, *A. ledebourianum* — 64.76±10.24, *A. schoenoprasum* — 63.92±12.52 depending on the year of study.

In studies for all three species, a low coefficient of variation in the mass of seeds and flowers in an inflorescence was established, which indicates an insignificant degree of data dispersion (Fig. 4).

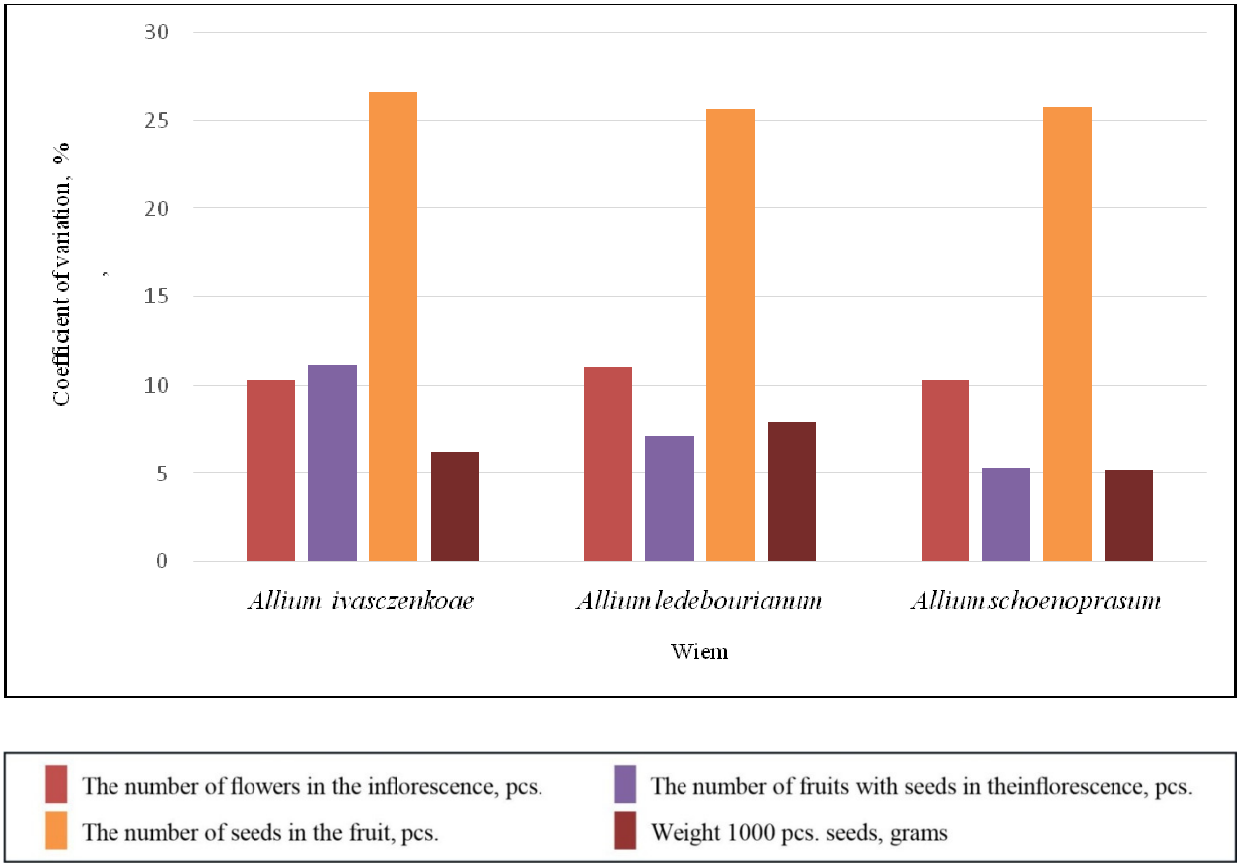

Figure 4. Coefficient of variation of some indicators of seed productivity *of Allium ivasczenkoae*, *A.ledebourianum, A.schoenoprasum* in the introduction

A high range of variability is established for the number of seeds in the fruit, where the coefficient of variation of the trait for all three species is recorded above 25 %.

The seeds are small, black, triangular, matte, without pubescence, oblong. In terms of weight of 1000 seeds, *A. schoenoprasum* is in the lead, the weight of which is 1.74±0.07 g. at *A. ledebourianum* and *A.ivasczenkoae* this indicator is 1.54±0.08 g and 1.6±0.08 g, respectively. The seeds do not have a dormant period. The germination of freshly collected seeds in laboratory conditions was recorded from 42.88±6.49 % to 69.26±10.34 %, in the ground — from 29.76±4.31 % to 43.64±8.48 % depending on the species and year of recording.

It has been established experimentally that with dry room storage in a dark room with daily temperature fluctuations in the mode from 18 °to 24, °the seeds retain their germination for 2 years. In the first two years of storage, the germination of seeds remains high, changes are insignificant. In the third year of storage, the laboratory germination of seeds drops sharply and remains, on average, at the level of *A. ivasczenkoae*– 8.7 %, *A. ledebourianum*–13.7, *A. schoenoprasum*–14.6 %.

In all three studied species, under laboratory conditions at room temperature of 15–17, water absorption by freshly collected seeds continues for 16–18 hours. At the same time, the length of the seed increases by 6 %–10 %, the width — by 10 %–14 %. Water enters the seeds most intensively during the first 2–4 hours. Good water permeability of the seed covers of the experimental onions eliminates the need for scarification.

Conclusions

Studied types of onions *A.ivasczenkoae, A.ledebourianum*, *A. schoenoprasum*in the Altai Botanical Garden have successfully adapted to new growing conditions, proving themselves in culture as winter-frost-resistant with a stable rhythm of seasonal development, according to the phenorhythmotype — spring-early summer-green with an average flowering period. Over a long period of introduction, they maintain stability of morphometric parameters with high reproductive rates, which made it possible *to classify A. ivasczenkoae, A. ledebourianum*, *A. schoenoprasum*to promising introduced species and include them in the landscaping assortment.

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Алтай ботаникалық бағына қазақстандық Алтайдың *Allium* L. тұқымдасының сирек кездесетін түрлерін енгізу

Жұмыстың мақсаты қазақстандық Алтай флорасының интродукцияланған, яғни 3 сирек кездесетін пияз түрінің биологиялық ерекшеліктерін зерделеу, оларды Алтай ботаникалық бағында өсірудің тұрақтылығы мен келешегін бағалау. Мақалада Алтай ботаникалық бағының табиғи флорасының экспозициясындағы *Allium ivasczenkoae* Kotuch., *A. ledebourianum* Schult. et Schult., *A. schoenoprasum* L. түрлерінің маусымдық даму ырғағын, биометриялық параметрлерін және тұқым өнімділігін көпжылдық зерттеудің нәтижелері келтірілген. Биологиялық жағынан бір-біріне жақын аталған пияздар *Rhizirideum* (Koch)Wendelbo) тұқым тармағына және *Schoenoprasum Dumort* секциясына біріктірілген. Интродукциядағы барлық үш түрдің де тұрақты фенологиялық ырғағы бар екені анықталды, вегетациялық кезеңде жыл сайын өркендер дамуының толық циклінен өтіп, тұқымдар түзіледі. Фенортмотип бойынша олар орташа гүлдену кезеңі бар көктемгі-ерте жазғы-жасыл түрлер болып саналады. Олар сәуірде өсіп шығады, негізінен маусымның басында гүлдейді, тұқымдары шілдеде піседі, вегетация тамыздың аяғында, қыркүйектің басында табиғи түрде аяқталады. Вегетация 128,33±2,58 күннен (*A. ledebourianum*) 146.8±7.24 күнге (*A. schoenoprasum*) дейін жүреді. Зерттелген пияз түрлері биіктігі, гүлшоғырындағы гүлдер саны, гүлшоғырының диаметрі сияқты биометриялық параметрлері арқылы ерекшеленеді. Дақылдың зерттелген түрлерінде биометриялық параметрлер негізінен төмен деңгейде өзгереді, бұл дақылдағы осы көрсеткіштердің тұрақтылығын көрсетеді. Дақылдың барлық үш түрінің репродуктивті көрсеткіштері жоғары, өнімділік коэффициенті 56,75–69,26 % деңгейінде өзгереді. Сонымен қатар барлық үш түр үшін тұқым массасының, гүлшоғырдағы гүлдердің төмен вариация коэффициенті тіркелді, бұл интродукциядағы деректердің таралуының шамалы дәрежесін көрсетеді.

Кілт сөздер: *Allium,* енгізу, маусымдық даму ырғағы, тұқым өнімділігі.

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Интродукция редких видов рода *Allium* L. Казахстанского Алтая в Алтайском ботаническом саду

Целью данной работы явилось изучение биологических особенностей интродуцированных 3 редких видов луков флоры Казахстанского Алтая, оценка устойчивости и перспективности их культивирования в Алтайском ботаническом саду. В статье приведены результаты многолетнего изучения сезонного ритма развития, биометрических параметров и семенной продуктивности *Allium ivasczenkoae* Kotuch., *A. ledebourianum* Schult. et Schult., *A. schoenoprasum* L. в экспозиции природной флоры Алтайского ботанического сада. Данные луки, биологически близкие между собой, объединены в подрод *Rhizirideum* (Koch) Wendelbo) и объединены в секции *Schoenoprasum* Dumort. Установлено, что все три вида в интродукции имеют устойчивый фенологический ритм, в период вегетации ежегодно проходят полный цикл развития побегов и формируют семена. По феноритмотипу относятся к весенне-раннелетне-зеленым со средним сроком цветения. Отрастают в апреле, цветут в основном в начале июня, семена созревают в июле, вегетацию заканчивают естественно в конце августа–начале сентября. Вегетация продолжается от 128,33±2,58 дней (*A. ledebourianum*) до 146,8±7,24 дней (*A. schoenoprasum*). Изученные виды лука отличаются по биометрическим параметрам: высоте, количеству цветков в соцветии, диаметру соцветия. В культуре биометрические параметры варьируют у изученных видов в основном на низком уровне, что свидетельствует о стабильности этих показателей в культуре. Установлены в культуре у всех трех видов высокие репродуктивные показатели, коэффициент продуктивности варьирует на уровне 56,75–69,26 %. При этом зафиксирован для всех трех видов низкий коэффициент вариации массы семян, цветков в соцветии, что свидетельствует о незначительной степени рассеивания данных в интродукции.

Ключевые слова: Allium, интродукция, сезонный ритм развития, семенная продуктивность.

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Water-holding capacity of *Ribes aureum* leaves in the conditions of Karaganda region

Study of fruit plants and selection of species resistant to local climatic conditions is an important task for nursery development. In conditions of Central Kazakhstan there is a limited assortment of fruit plants, so it is necessary to select crops resistant, first of all, to arid climate. A promising species is *Ribes aureum*, characterized by rapid growth, undemanding soil conditions and resistance to diseases and pests. Under the conditions of Karaganda city, studies were conducted to assess the water content and water-holding capacity of this crop during the growing season — from May to September. The results showed that the maximum values of water-holding capacity of *Ribes aureum* leaves are observed in May and June months, which is associated with the youth of leaves, their physiological activity, as well as cool and wet weather. In July, water-holding capacity starts to decrease, which can be attributed to hot conditions. However, in August and September, an increase in water-holding capacity can be observed due to abundant precipitation and cooler weather. Indicators of water regime show that the crop is highly resistant to water deficit.

Keywords: Ribes aureum, Karaganda, water content, water-holding capacity, water regime.

Introduction

The problem of preserving the genetic potential of fruit and berry plants, its practical introduction into culture, and its use in modern breeding is one of the basic foundations in the creation of new varieties, forms, and hybrids [1]. The necessity of work on the study of genetic potential of wild fruit and berry plants and creation of gene pool of new assortment is dictated by the fact that due to climate change, anthropogenic impact on biocenoses their habitats are sharply decreasing, up to the threat of complete extinction. The research is conditioned by the need of Kazakhstan to assess the current state of fruit and berry plants to solve the problem of food security, to carry out monitoring for scientifically based conservation measures [2].

In different regions of Kazakhstan there is a need to develop and create scientific and practical basis of regional collection funds and nurseries, which will allow meeting the growing demand for resistant crops to certain soil and climatic conditions of fruit and berry plants [3, 4]. *Ribes aureum*, characterized by high yield and undemanding to irrigation, soil fertility and resistant to diseases and pests, can be defined as a promising fruit crop in arid conditions of Central Kazakhstan [5].

To understand the levels of adaptation of different crops to local climatic conditions, it is necessary to study the water regime [6]. Based on the above mentioned, the aim of the present study was to investigate water content and water-holding capacity of promising fruit crop *Ribes aureum* Pursh (Grossulariaceae) in Karaganda city conditions.

Experimental

The studies were conducted at the fruit plant nursery of the Faculty of Biology and Geography of KarU in 2024. 3–5-year-old plants of *Ribes aureum* were selected to study water metabolism (Fig. 1).

Determination of total moisture content and water-holding capacity were performed according to the method of G.V. Eremin and T.A. Gasanova [7].

Total water content of leaves was calculated by the formula: $W=100\times(M-M2)/M$;

water-holding capacity of leaves: $R=100\times(M1-M2)/M$;

content of “mobile” moisture in leaves: $L=W-R$,

where: M — mass of fresh sample;

M1 — mass of the sample after 3 hours;

M2 — mass of sample after drying.

A B

Figure 1. Internal view of flowering (A) and fruitening (B) shoot of *Ribes aureum*

Leaves were weighed after 60, 120, 180 and 360 minutes. All measurements were carried out from May to September in 10-fold repetition.

The obtained numerical indices were analyzed using Statistica 6.1 and Microsoft Office Excel 2007 software packages.

Results and Discussion

Analysis of water content showed changes in *Ribes aureum* during the growing season (Fig. 2). The maximum water content was observed in May and amounted to 64.0 %, in the following months a steady decrease in water content can be observed. Thus, in June, this indicator amounted to 60.3 %, in June — 55.4 %, in August — 50.2 %, in September — 48.5 %.

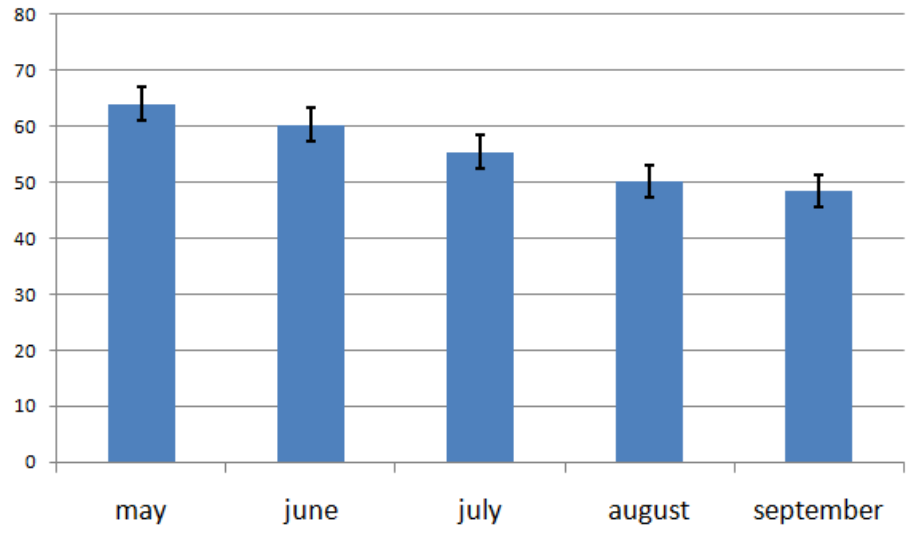

Figure 2. Water content of *Ribes aureum* leaves during 2024 vegetative period

High water content of currant leaves in spring is associated with their youth and relatively low temperatures and high humidity. With the onset of summer temperatures, the amount of free water in leaves decreases due to high transpiration. In the fall period, leaves physiologically senesce, which leads to a decrease in water content.

However, the water content of leaves cannot be a reliable sign of plant resistance to arid conditions, because under favorable watering this indicator can remain at a high level even in low drought-resistant plants.

Therefore, at the second stage, we analyzed the water-holding capacity of *Ribes aureum* leaves during the growing season.

Thus, in May leaves had maximum moisture content, which is due to lower temperatures and higher relative air humidity. However, plant water losses were higher in May than in June. This aspect is due to the fact that the leaves are young, not adapted to drought. In June, the water content of leaves was lower, but the loss in mass by desiccation was lower. Apparently, mature leaves adapted to drought more easily and retained it better in the pulp.

The results showed that in May currant leaves, leaves effectively retained free water for 60 and 120 minutes after cutting from the plant (Fig. 3). No significant difference was found between the water-holding capacity at these periods, 88.2 and 82.4 %. After 180 minutes, leaves begin to significantly reduce their water-holding capacity — 70.6 %. After 6 hours, this indicator decreases more than 2 times — till 41.1 %.

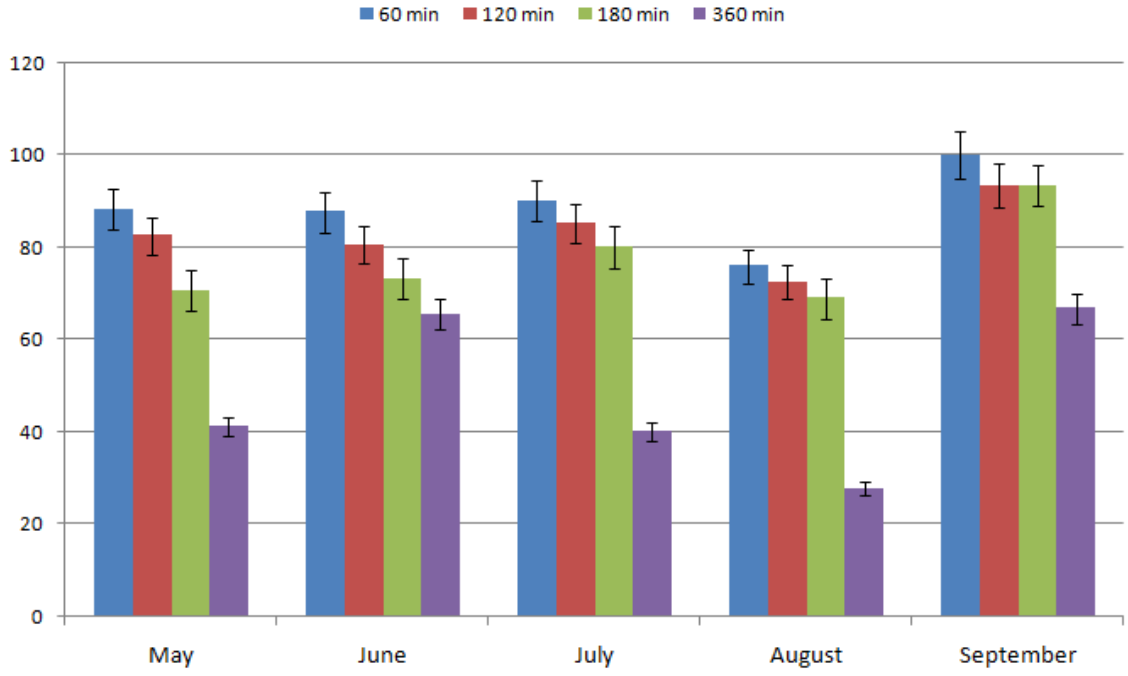

Figure 3. Indicators of water-holding capacity of *Ribes aureum* leaves during the 2024 vegetation period

In June, water loss by currant leaves decreases. Thus, after the 1st hour the water retention capacity was 87.6 %, after 2 hours — 80.4 %, after 3 hours — 73.2 %, after 6 hours — 65.4 %. Probably, currant leaves become mature and effectively use physiological mechanisms for water retention.

A similar situation is observed in the month of July. There is a slight loss of free water by currant leaves after 1, 2 and 3 hours, 90.0; 85.0 % and 80.0 %, respectively. However, after 6 hours, the water-holding capacity decreases sharply to 40.0 %. The same situation is with the indicators of water-holding capacity of *Ribes aureum* leaves in August. Thus, this indicator decreases insignificantly after 1, 2 and 3 hours — 75.8; 72.4 and 68.9 %, respectively, and after 6 hours — a sharp decrease to 27.6 %.

July and August were characterized by the highest temperatures during the growing season and minimum soil and air humidity, which makes plants retain water more actively, however, the lack of moisture reduces the efficiency of water-holding capacity after 6 hours.

The highest values of water-holding capacity were observed in September 2024. Thus, after 1 hour it was estimated at 100 %, after 2 and 3 hours — 93.3 %, after 6 hours — 66.7 %.

In general, the analysis of the obtained data shows maximum values of water-holding capacity in May and June months, which is associated with the youthfulness of leaves, their physiological activity, as well as cool and wet weather of the current year. In July, water-holding capacity starts to decrease, which can be ex-

plained by hot conditions. However, in August and September, an increase in water-holding capacity can be observed due to abundant precipitation and cool weather.

Conclusion

Thus, the study of water regime of *Ribes aureum* showed high adaptability to arid conditions of Karaganda region, which implies the ability to withstand periods of precipitation deficit and irrigation. Critical points for irrigation are July and August months, in which it is necessary to organize more active irrigation, in May, June and September this culture does not need intensive irrigation.

The results allow recommending *Ribes aureum* for more intensive application in fruit growing in Karaganda oblast.

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Қарағанды облысының жағдайындағы *Ribes aureum* жапырақтарының су ұстау қабілеті

Жеміс өсімдіктерін зерттеу және жергілікті климаттық жағдайларға төзімді түрлерді таңдау питомниктерді дамытудың маңызды міндеті. Орталық Қазақстан жағдайында жеміс өсімдіктерінің шектеулі ассортименті бар, сондықтан, ең алдымен, құрғақ климатқа төзімді дақылдарды таңдау қажет. *Ribes aureum* перспективалы түрлер болып табылады, ол тез өсуімен, топырақ жағдайына сәйкес келмеуімен және аурулар мен зиянкестерге төзімділігімен ерекшеленеді. Қарағанды қаласының жағдайында вегетациялық кезең ішінде — мамырдан қыркүйекке дейін осы дақылдың су басуы мен су ұстау қабілетін бағалау бойынша зерттеулер жүргізілді. Нәтижелер *Ribes aureum* жапырақтарының суды ұстау қабілетінің максималды мәндері мамыр және маусым айларында байқалатынын көрсетті, бұл жапырақтардың жас болуына, олардың физиологиялық белсенділігіне және 2024 жылғы салқын және ылғалды ауа-райына байланысты. Шілде айында суды ұстау қабілеті төмендей бастайды, оны ыстық жағдайлармен түсіндіруге болады. Алайда, тамыз және қыркүйек айларында жауын-шашынның көптігі мен салқын ауа-райына байланысты суды ұстау қабілетінің жоғарылауы байқалады. Су режимінің көрсеткіштері дақылдың су тапшылығына деген жоғары тұрақтылығын көрсетеді.

Кілт сөздер: Ribes aureum, Қарағанды, су басу, суды ұстау қабілеті, су режимі.

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Водоудерживающая способность листьев *Ribes aureum* в условиях Карагандинской области

Изучение плодовых растений и выбор видов, устойчивых к местным климатическим условиям, являются важной задачей для развития питомников. В условиях Центрального Казахстана существует ограниченный ассортимент плодовых растений, поэтому необходимо подбирать культуры, устойчивые, прежде всего, к аридному климату. Перспективным видом является *Ribes aureum*, отличающийся быстрым ростом, нетребовательностью к почвенным условиям и устойчивостью к болезням и вредителям. В условиях г. Караганды были проведены исследования по оценке оводненности и водоудерживающей способности данной культуры в течение вегетационного периода — с мая по сентябрь. Результаты показали, что максимальные значения водоудерживающей способности листьев *Ribes aureum* наблюдаются в мае–июне, что связано с молодостью листьев, их физиологической активностью, а также прохладной и влажной погодой 2024 года. В июле водоудерживающая способность начинает снижаться, что можно объяснить жаркими условиями. Однако в августе–сентябре можно наблюдать увеличение водоудерживающей способности из-за обилия осадков и прохладной погоды. Показатели водного режима свидетельствуют о высокой устойчивости культуры к дефициту воды.

Ключевые слова: Ribes aureum, Караганда, оводненность, водоудерживающая способность, водный режим.

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Accumulation of vitamin C and sugars in wild rose hips of Karaganda region

The study of wild fruit plant populations has a great potential in the selection of species and forms promising in terms of a number of economically valuable traits for introduction and industrial cultivation. Local species are more resistant to local climatic conditions and composition of pathogens. The aim of the study was to evaluate the accumulation of sugars and vitamin C in fruits of 3 wild rose hips collected in Karaganda region. The quantitative accumulation of vitamin C varied from 0.87 to 1.85 %, the sum of sugars from 6.8 to 15.8 %. Analysis of fruits for accumulation of sugars and vitamin C showed that *Rosa majalis* from the Nura River floodplain, Rosa *spinosissima* from Komissarovka tract, *Rosa acicularis* from the vicinity of Karagaily settlement are promising for selection in the introduction experiment.

Keywords: plants of *Rosa* genus, fruits, Karaganda region, vitamin C, sugars, quantitative accumulation.

Introduction

One of the most important factors ensuring harmonious development of the human body is nutrition. According to WHO experts [1], human health is determined by heredity by 10–15 %, by ecology by 10–20 %, and by 55–70 % by lifestyle, the most important component of which is nutrition.

The problem of preserving the genetic potential of fruit and berry plants, its practical introduction into culture, and its use in modern breeding is one of the basic foundations in the creation of new varieties, forms, and hybrids [2]. The need to study the genetic potential of wild fruit and berry plants and attract their gene pool into culture is explained by the potential for obtaining more resistant forms to local climatic conditions, diseases and pests [3, 4].

In Karaganda oblast, representatives of the genera rosehip (*Rosa*: *R.majalis, R.acicularis, R.spinosissima*), which can serve as valuable food and vitamin plants, are of interest for the introduction of wild species into culture [5].

The purpose of this study was to determine the accumulation of sugars and vitamin C in the fruits of wild rose hips of the flora of Central Kazakhstan for the selection of species and populations suitable for introduction according to this set of traits.

Experimental

Fruit sampling was conducted in August — September 2024 from different natural populations, at full ripeness.

The quantitative accumulation of sugars was evaluated on a refractometer [6], the content of vitamin C — by the method of potentialmetric titration [7]. The exact weight~ 3.00 g of raw material is thoroughly grinded in a mortar with distilled water (100 ml), infused for 10 minutes, then the mixture is stirred and filtered. 10 ml of the obtained filtrate is transferred into a 100 ml beaker, 1-2 drops of phenolphthalein are added and titrated with standardized NaOH solution until the appearance of a pale pink color, stable for 30 seconds and in the presence of a pH meter to determine the end point of titration, which is within 8.5 pH. Each measurement is carried out 3 times.

Calculate the mass of ascorbic acid using the following formula:

$$m(C_6H_8O_6),\ г = \frac{C(\text{NaOH})\cdot V(\text{NaOH})\cdot M_{equv.}(C_6H_8O_6)\cdot V_{к.}}{1000\cdot V_{al}}$$

Calculate the ascorbic acid concentration using the following formula:

$$\omega(C_6H_8O_6),\ \% = \frac{m\ (C_6H_8O_6)\cdot 100}{m\ \text{plant material}}$$

The obtained data were analyzed using the application software package Statistica 6.1 and Microsoft Office Excel 2007.

Results and Discussion

The diversity of natural reliefs, significant amplitude of temperatures, precipitation and humidity determined the diversity of vegetation of Central Kazakhstan. Thus, more than 1250 species of vascular plants belonging to 434 genera and 99 families grow on its territory [8]. As the preliminary analysis showed, the flora of Central Kazakhstan contains a significant number of species of economic value, including wild fruit plants. This group is represented by 31 species belonging to 14 genera and 7 families.

A review of species distribution over the territory of Central Kazakhstan shows their unevenness. Most species are confined to the northern, northwestern and central parts, characterized by higher annual precipitation, moderate summer temperatures and the presence of coniferous, mixed island forests and numerous shrub thickets. The southern, southwestern areas are characterized by extremely arid conditions, poor soils and high summer temperatures. Fruit crops in these habitats are mainly concentrated along river valleys, in the vicinity of springs. All described species are well adapted to the conditions of Central Kazakhstan and can be used for introduction into culture as fruit crops

It is known that the chemical composition of wild fruits depends on many factors, including soil and climatic conditions of the place of growth, composition and structure of soil under plant thickets, moisture availability, water quality, presence of microorganisms and other factors [8].

We found 3 species of rose hips in natural conditions.

Rosa spinosissima L. Habitat: interfold hollow; soils — meadow, dark chestnut. Communities — briar-briar-grass communities. *Rosa spinosissima* grows in small colonies, area 40x15 m. Shrub shape — oval, age — 8–12 years, height — 112,5±12,2 cm, diameter — 137,4±9,8 cm. Condition — average, winter hardiness — without damage, bark color — brown, length of annual shoots — 6.4±0.8 cm. Shoot-forming ability — medium, growth force — medium, vigor — medium. Degree of fruiting — medium. Yield — 0.5 kg per bush. The color of the upper side of the leaves is green. Shirredness — high. Fruit shape — oval. Hypanthium color — black, taste — sweet, slightly astringent. Pests and diseases — not identified.

Rosa acicularis Lindl. Habitats: under mixed forest canopy; soils — forest chernozem. Communities are boneset-grass, briar-grass, briar. *Rosa acicularis* grows in small patches, area 53x50 m. Shape of the bush — spreading, age — 10–14 years, height — 134,67±5,01 cm, diameter — 103,3±3,6 cm. Condition — average, winter hardiness — very weak damage, bark color — light gray, length of annual shoots — 9.7±1.8 cm. Shoot-forming ability — satisfactory, growth strength — average, vigor — average. Degree of fruiting — weak. Yield — 0.24 kg per bush. Coloring of the upper side of leaves — green. Foliage — moderate. Pests and diseases — chlorosis 25–40 %.

Rosa majalis Hermm. Habitats: mixed forest edge; under mixed forest canopy, soils — dark chestnut. Communities of thavolgovo-briar-briar-grass, briar-briar, briar-briar-honeysuckle. Rosehip grows in groups, area 77x120 m. Shape of the bush — spreading, age — 12–17 years, height — 142,3±5,45 cm, diameter — 100,3±3,79 cm. Condition — poor, winter hardiness — medium damage, bark color — light gray, length of annual shoots — 8,4±0,55 cm. Shoot-forming ability — poor, growth force — average, obliquity — average. Degree of fruiting — weak. Yield — 0.05 kg / bush. Coloring of the upper side of the leaves — light green. Fertility — high. Pests and diseases — not identified.

The results showed that phytochemical parameters can vary significantly among species under natural conditions.

The quantitative accumulation of vitamin C ranged from 0.87 to 1.85 %, and the sum of sugars — from 6.8 to 15.8 %. Thus, among representatives of the genus *Rosa* L., the best indicators of quantitative vitamin C content were observed for May rosehip in the floodplain of the Nura River — 1.85 %, the minimum — for prickly rosehip from the Komissarovka tract (Fig. 1).

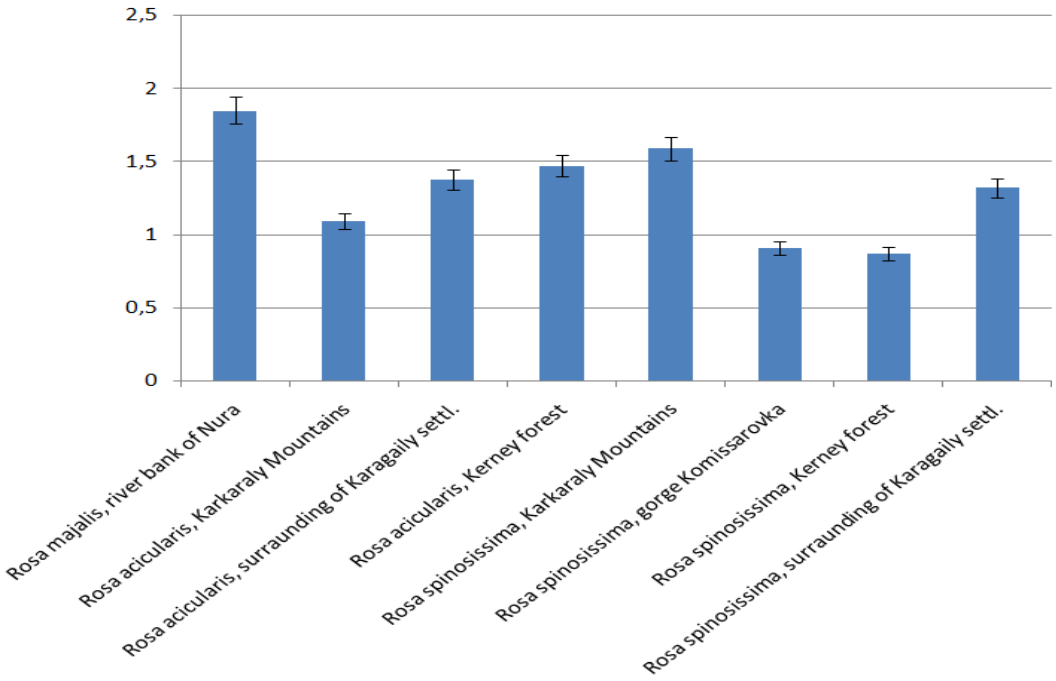

Figure 1: Quantitative accumulation of vitamin C in rose hips depending on species and place of growth

Fruit flavor depends on the sum of free sugars and acidity. For rose hips, the maximum accumulation of sugars was detected for prickly thorn from Komissarovka tract (15.8 %) and Karagaily settlement (14.8 %), and the minimum — for needle thorn from Karkaraly mountains (Fig. 2).

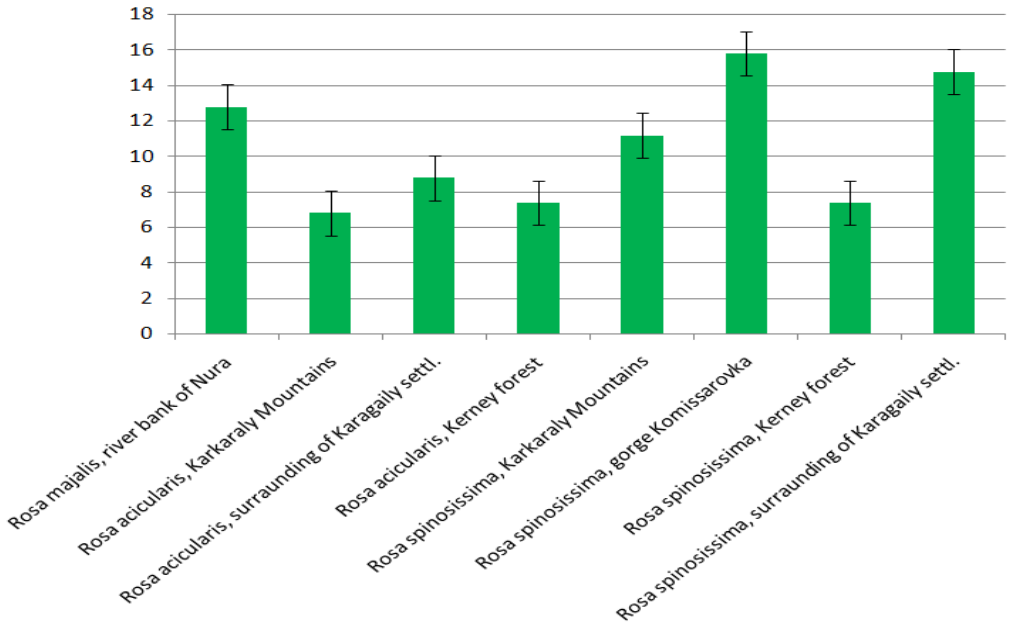

Figure 2: Quantitative accumulation of the sum of free sugars in rosehip fruits depending on species and place of growth

The obtained data allow selecting promising species and specimens with the best biochemical parameters for the introduction experiment.

Conclusion

Thus, on the territory of Karaganda oblast (Central Kazakhstan) a number of populations with 3 species of rose hips were found. Analysis of fruits for accumulation of sugars and vitamin C showed that *Rosa majalis* from the Nura River floodplain, Rosa *spinosissima* from the Komissarovka tract, *Rosa acicularis* from the vicinity of Karagaily settlement are promising for selection in the introduction experiment.

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Қарағанды облысындағы жабайы итмұрында *С* витамині мен қанттың жинақталуы

Жабайы жеміс өсімдіктерінің популяциясын зерттеу интродукциялық және өнеркәсіптік өсіру үшін бірқатар экономикалық құнды белгілер бойынша перспективалы түрлер мен формаларды таңдауда үлкен мүмкіндіктерге ие. Жергілікті түрлер жергілікті климаттық жағдайларға және патогендік құрамға төзімдірек. Зерттеудің мақсаты Қарағанды облысынан жиналған 3 жабайы итмұрынның жемістерінде қант пен *С* витаминінің жинақталуын бағалау. *С* витаминінің сандық жинақталуы 0,87-ден 1,85 %-ға дейін, қант мөлшері 6,8-ден 15,8 %-ға дейін өзгерді. Қант пен *С* витаминінің жинақталуына жемістерді талдау көрсеткендей, Нұра өзенінің жағалауынан жиналған *Rosa majalis*, Комиссаров шатқалынан жиналған *Rosa spinosissima*, Қарағайлы ауылының маңынан жиналған *Rosa acicularis* интродукциялық тәжірибеде іріктеу үшін перспективалы екенін көрсетті.

Кілт сөздер: Rosa тұқымдас өсімдіктер, жемістер, Қарағанды облысы, *С* витамині, қант, сандық жинақтау.

С.С. Тыржанова, Р.Т. Мусина

Накопление витамина *С* и сахаров в дикорастущих шиповниках Карагандинской области

Изучение популяций дикорастущих плодовых растений имеет большой потенциал в отборе перспективных по ряду хозяйственно-ценных признаков видов и форм для интродукции и промышленного выращивания. Местные виды являются более устойчивыми к местным климатическим условиям и составу патогенов. Цель исследования — оценить накопление сахаров и витамина *С* в плодах 3-х диких

шиповников, собранных на территории Карагандинской области. Количественное накопление витамина *С* варьировало от 0,87 до 1,85 %, сумма сахаров — от 6,8 до 15,8 %. Анализ плодов на накопление сахаров и витамина *С* показал, что перспективными для отбора в интродукционный эксперимент являются *Rosa majalis* из поймы р. Нура, *Rosa spinosissima* из урочища Комиссаровка, *Rosa acicularis* из окрестностей поселка Карагайлы.

Ключевые слова: растения рода *Rosa*, плоды, Карагандинская область, витамин *С*, сахар, количественное накопление.

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State of coenopopulations of wild berry plants in the territory of Kazakhstan Altai

In the article studies on the state of the coenopopulations: *Rosa acicularis* Lindl., *Rosa spinosissima* L., *Lonicera altaica* Pall., *Ribes nigrum* L., *Ribes petraeum* Wulfen, which have high resource indicators and significant areas were presented. The studies were conducted on the territory of the Kazakhstan Altai in the geographical areas of South-West Altai, South Altai. For each coenopopulation, data were obtained on the nature of distribution, occupied area, phytocenotic characteristics, general and age condition of plants and their biodiversity.

Keywords: coenopopulation, phytocenosis, area, productivity, variation.

Introduction

The problem of preserving the genetic potential of fruit-berry plants, its practical introduction into culture, use in modern breeding is one of the basic foundations in the creation of new varieties, forms and hybrids. The need to study the genetic potential of wild fruit-berry plants and create a gene pool of a new assortment is dictated by the fact that due to climate change, anthropogenic impact on biocenoses, their ranges are sharply reduced, up to the threat of complete extinction. The research is due to Kazakhstan's need to assess the current state of fruit-berry plants to solve the problem of food security, to carry out monitoring for scientifically substantiated security measures.

In various regions of Kazakhstan, there is a need to develop and create scientific and practical foundations of regional collection funds and nurseries, which will satisfy the growing demand for sustainable crops for certain soil and climatic conditions of fruit-berry plants. Earlier, the study concerned the introduction of foreign fruit-berry plants in various regions of Kazakhstan, while the species composition of the natural flora of wild fruit-berry plants is little studied and its resource potential is practically not assessed.

A comprehensive study of berry plants is essential for solving issues of ecology, phytocenology, floristry, population biology and environmental protection [1, 2].

Experimental

The objects of the research were coenopopulations of wild berry plants in the territory of the Kazakhstan Altai from the genera *Ribes*, *Lonicera*, *Rosa*. The locations with geographical reference of GPS coordinates and areas of 8 coenopopulations for 5 species of berry plants were established — *Rosa acicularis* Lindl., *Rosa spinosissima* L., *Lonicera altaica* Pall., *Ribes nigrum* L., *Ribes petraeum* Wulfen.

When assessing the current state of the studied plant species, the methodological guidelines developed by V.N. Golubev and E.F. Molchanov (1978) were used [3]. The description of phytocenoses was carried out using generally accepted geobotanical methods of T.A. Rabotnov [4]. In biomorphological studies, ecological-morphological classifications of life forms by I.G. Serebryakov [5] were used. During determining the projective cover, the method of determining the average projective cover, generally accepted in resource studies by S.N. Kozyakov [6] was used.

Results and Discussion

***Rosa acicularis* Lindl.** Two locations have been identified in the foothills of the Ubinsky ridge in the valley of the Zhuravlikha River, the vicinity of the village of Krolchatnik and the foothills of the Ubinsky ridge, Osinovsky pass, the vicinity of the village of Zimovye in the territory of the South-West Altai (Kazakhstan Altai).

1) Foothills of the Ubinsky ridge, valley of the Zhuravlikha river, environs of the village of Krolchatnik, area 95 ha, N50.33333; E88.183333, 913 m above sea level. Plant distribution over the area is single bushes

or separate groups of 12–17 individuals of different ages. Total projective cover is 04–06.The forest stand is represented by *Populus laurifolia* Ledeb., *Populus tremula* L. The shrub layer is formed by *Viburnum opulus* L., *Prunus padus* L., *Crataegus chlorosarca* Maxim., *Rosa acicularis* Lindl. The grass stand is thinned out and includes 25 species of vascular plants (*Angelica decurrens* (Ledeb.) B.Fedtsch., *Dactylis glomerata* L., *Festuca drymeja* Mert. & W.D.J. Koch, *Festuca rubra* L., *Poa palustris* L., etc.). Bushes are from 0.7 m to 1.8 m high with a large number of overgrowing shoots. Productivity is from 80 to 210 g/bush. Hypanthia color variation is revealed from yellowish-orange to dark cherry and crimson, with orange and orange-red colors predominating. A large spread in hypanthia weight is noted from 1.23 to 2.90 g, in length from 1.8 to 2.6 cm, in width from 1.0 to 2.0 cm. Fruit shape: bottle-shaped, oval, elongated; sweetish taste with a pleasant sourness. Juicy is pulp with mealy inclusions. A difference in the number of seeds in the fruit was revealed: from 24 to 48 pcs.

2) Foothills of the Ubinsky ridge, Osinovsky pass, vicinity of the village of Zimovye. The population is located in the foothills of the Ubinsky ridge, near the village of Zimovye, with an area of 20 hectares along the road of the long Osinovsky pass in front of the village of Zimovye, with a length of 3 km, N50.31422; E82.85234, 795 m above sea level. The total projective cover is 12 %. The distribution of rose hips is diffuse and in continuous clumps under the canopy of tall trees: *Abies sibirica* Lindl., *Populus laurifolia* Ledeb., *Betula pendula* Roth., *Sorbus aucuparia* L., *Sorbus aucuparia* subsp. *glabrata* (Wimm. &Grab.) Hedl. The dominants of the herbaceous cover are represented by *Dactylis glomerata* L., *Poa pratensis* L., *Festuca rubra* L., *Elymus repens* (L.) Gould. (Fig. 1, 2).

Figure 1. Fruiting of *Rosa acicularis*

Figure 2. Fragment of the *Rosa acicularis* phytocenosis

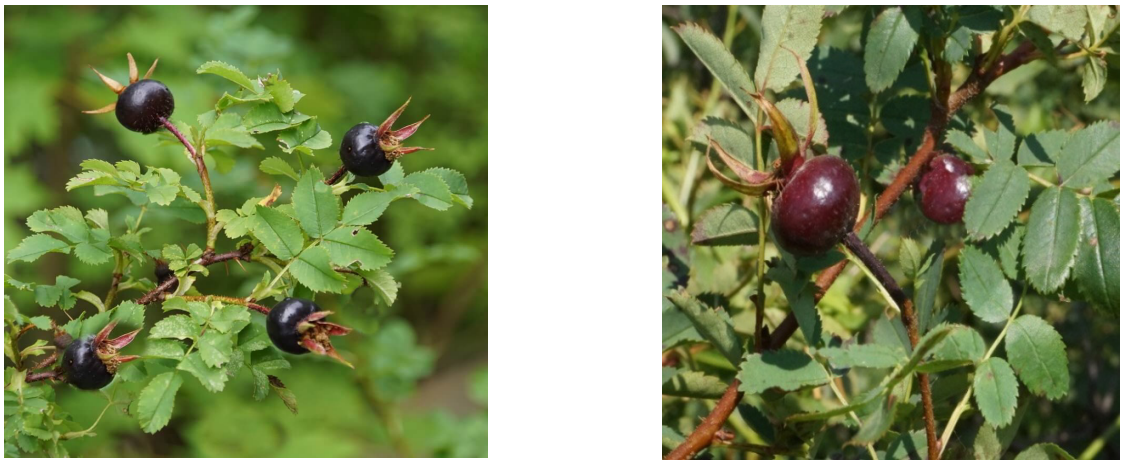
Rosehip bushes are from 0.1 m to 2.2 m high. The bushes are in excellent condition, the maximum shoot-forming capacity is 4-5 zero shoots. The following differences have been established in the size of the hypanthia: length from 2.2 cm to 2.7 cm, width from 1.1 cm to 1.6 cm, weight from 0.97 to 2.26 g.

Rosa spinosissima L. Two populations were examined in the foothills of the Ivanovsky ridge in the territory of Southwestern Altai (Kazakhstan Altai).

Foothills of the Ivanovsky Ridge, south-eastern slope of Belkina Mountain, N50.34222; E83.55111, 848 m above sea level. The population occupies 15 hectares, located mainly in open areas, in the area of the Ridder meteorological station. The spatial structure of the population is diffuse, less often diffuse-group, 1.7 m^2 — 25 m^2. The projective cover fluctuates from 18 to 23 %. The density of generative shoots per 10 m^2 is 30–60 pcs. The condition of the plants is good; there are no broken or dry shoots. Shoot growth is from 8 to 17 cm. The level of resistance to unfavorable factors of the winter period is quite high. Signs of freezing are practically not noted.

The accompanying plants are mainly shrubs: *Spiraea trilobata* L., *Cotoneaster melanocarpus* Fisch. ex Blytt. The herbaceous cover is represented by *Geranium pretense* L., *Potentilla aurea* L., *Bunias orientalis* L., *Fragaria viridis* Duchesne etc. The number of renewal shoots per bush is 2-3 pcs. The shape of the hypanthia is round and flat-round. The weight varies from 1.3 g to 3.57 g, hypanthia with a weight of 2.35 g

prevail. The variation coefficient was 20.4 %, the level of variability is average. The length and width of the hypanthia vary from 1.1 to 1.4 cm and from 1.4 to 1.9 cm, respectively. For the size of the fruits, the variation coefficient for length was 11.8 %, for width 8.0 %. The color is black and dark-brown (Fig. 3). The yield is from 70 to 220 g/bush. The beginning of ripening is noted in mid-September.



A B

Figure 3. Variation in fruit color; A — black, B — brownish

1) Foothills of the Ivanovsky Ridge, Gromatushinskoye Gorge, N50.30544; E83.55047, 935 m above sea level. The area is 33 hectares. It grows in open areas, reaching the border of the mixed forest. This population is characterized by good phytocenotic indicators for bush density, the number of generative shoots per 10 m^2 from 25 to 55 pcs. Maintenance and dispersal is carried out due to active root-sucker propagation, replacing old individuals with clonal young ones. The general condition of the plants is good; the increment of overgrowing shoots is quite high 10–21 cm. There are no signs of freezing. The number of renewal shoots per bush is 2-3 pcs. Productivity from 80 to 245 g/bush. Mass ripening of fruits is noted in mid-September. Hypanthia weight is 1.92 g.

The phytocenosis consists of coniferous (*Larix sibirica* Ledeb., *Pinus sylvestris* L.), deciduous (*Sorbusa ucuparia* subsp. *glabrata* (Wimm. &Grab.) Hedl.), shrub (*Sibiraea laevigata* (L.) Maxim., *Cotoneaster melanocarpus* Fisch. ex Blytt., *Ribes nigrum* L., *Ribes rubrum* L., *Rubus idaeus* L.) plants. From the herbaceous plants *Paeonia anomala* L., *Trollius altaicus* C.A. Mey., *Anemone altaica* Fisch. ex C.A. Mey., *Pulmonaria mollis* Wulfen ex Hornem., *Heracleum dissectum* Ledeb., *Rumex acetosa* L., *Equisetum arvense* L. and others are noted. There are 54 species of vascular plants in total.

***Lonicera altaica* Pall**. Two populations were examined in the territory of the Kazakh Altai (Southern Altai, Southwestern Altai).

1) Foothills of the Kurchumsky ridge, northwestern coast of Lake Markakol, environs of the abolished village of Verkhnyaya Yelovka, Kurchumsky district (Southern Altai), N48.80668; E85.66083, 1513 m above sea level. Area is 18 hectares. In the larch forest, plants are found singly, sparsely, in groups in open clearings. The age of plants in the population is 40–50 years, the vitality of individuals is satisfactory. Vegetative regeneration of plants is absent. In this population, forms with large fruits of 0.8-1.0 g, elongated-ovoid in shape with a yield of 1.1-1.6 kg/bush were identified. Ripening of fruits is extended.

The phytocenosis consists of conifers (*Larix sibirica* Ledeb., *Picea obovate* Ledeb., *Abies sibirica* Lindl), deciduous trees (*Populus laurifolia* Ledeb., *Populus nigra* L., *Betula pendula* Roth, *Sorbus aucuparia* subsp. *glabra* (Wimm. & Grab.) Hedl.), shrubs (*Rosa spinosissima* L., prickly *Rosa acicularis* Lindl., *Ribes atropurpureum* C.A. Mey., *Ribes nigrum* L.). The grass stand is mixed grass and cereal, formed by 47 species of vascular plants.

1) Ivanovsky Ridge, northwestern slope, Palevaya Yama tract, buffer zone of the West Altai State Nature Reserve, N50.36584; E83.93598, 1112 m above sea level. The area is 48 hectares in the mixed forest belt. Mountain-meadow soils, with a developed profile up to 40 cm. Plants are 1.4–1.6 m high. Productivity varies from 0.8–1.3 kg / bush. Plants with an average fruit weight of 0.5–0.7 g predominate. The age of

plants in this population is from 42 to 50 years, there are many plants with old branches with hanging bark in the bush. Vegetative renewal of plants is absent.

The tree layer is represented by *Populus laurifolia* Ledeb., *Sorbus aucuparia* subsp. *glabra* (Wimm. &Grab.) Hedl., *Betula pendula* Roth), shrub layer — *Cotoneaster melanocarpus* Fisch. ex Blytt., *Rosa acicularis*Lindl., *Rubus idaeus* L. The herbage is forb-grass, well developed, represented by 52 species of vascular plants (*Angelica sylvestris* L., *Dactylis glomerata* L., *Festuca altissima* All., *Festuca rubra* L., *Poa palustris* L., *Aconitum leucostomum* Worosch., *Filipendula ulmaria* (L.) Maxim., *Origanum vulgare* L., *Hypericum perforatum* L., etc.).

***Ribes nigrum* L.** The population was examined in the territory of the Southern Altai (Kazakhstan Altai) on the northwestern coast of Lake Markakol, N48.80668; E85.66083, 1513 m above sea level. The dispersal of plants on moist soils along streams flowing into the lake. It is found singly and in strips. The tree stand is represented by *Populus laurifolia* Ledeb., *Populus nigra* L., *Betula pendula* Roth, *Sorbus aucuparia* subsp. *glabra* (Wimm. & Grab.) Hedl., *Larix sibirica* Ledeb., *Picea obovata* Ledeb., *Abies sibirica* Lindl. Among the shrubs, *Rosa spinosissima* L., *Rosa acicularis* Lindl., *Rubus idaeus* L. are noted; the herbage is mixed grass and cereal, formed from 56 species of vascular plants (*Angelica sylvestris* L., *Dactylis glomerata* L., *Festuca rubra* L., *Festuca drymeja* Mert. & W.D.J. Koch, *Poa palustris* L., etc.).

The bushes are spreading, 0.7–1.0 m high. The cluster is medium-sized, 4–6 cm; the number of berries in it is from 3 to 8 pcs., on average 5 pcs. The population is dominated by individuals with average berry sizes from 0.3 g to 0.6 g, the weight of the largest berry is 0.8 g. The berries ripen in the first ten days of August. The yield is from 0.5 to 2.0 kg/bush (Fig. 4).

A B

Figure 4. Fruit-bearing blackcurrant bush (A), blackcurrant berry cluster in the vicinity of Lake Markakol (B)

***Ribes petraeum* Wulfen**. The population is located at the foot of the Ivanovsky ridge, in the area of the first forest cordon, 50.35472; 84.24833, m above sea level 1756 m. It grows under the canopy of dark coniferous forest as single bushes, in open clearings — in groups.

The forest stand is represented by *Abies sibirica* Lindl., *Pinus sibirica* Lodd., *Betula pendula* Roth, the shrub layer in this coenopopulation is represented by the following species: *Prunus padus* L., *Crataegus chlorosarca* Maxim., *Salix viminalis* L., *Rosa spinosissima* L., *R. acicularis* Lindl., *Cotoneaster melanocarpus* Fisch. The most widespread in the herbaceous cover are: *Origanum vulgare* L., *Bupleurum longifolium* L., *Hypericum perforatum* L., *Filipendula ulmaria* (L.), *Trollius altaicus* C.A. Mey., *Elymus repens* (L.) Gould, *Artemisia glauca* Pall. ex Willd., *Allium microdictyon* Prokh., *Aconitum leucostomum* Worosch. Plants of this population are characterized by erect bushes, 0.7 to 1.2 m high. Almost all forms have a compact, long brush, the number of berries is from 3 to 12 (8) pcs. The berries are not uniform, the ratio of large to small berries is 2.5-2.6. Most of the forms growing here have medium berries of 0.31 g, variations are from 0.26 g to 0.50 g. The weight of the largest berry is 1 g. The berries ripen later, in the third decade of August — early September. The yield is from 1.7 to 2.2 kg/bush.

Conclusion

As a result of the expedition work, the current state of the coenopopulations of *Rosa acicularis* Lindl., *Rosa spinosissima* L., *Lonicera altaica* Pall., *Ribes nigrum* L., *Ribes petraeum* Wulfen, *Rosa acicularis* Lindl. was obtained. The studies allowed us to conclude that they are stable in existence due to their resistance to unfavorable factors of the winter period, natural regeneration, the presence of individuals of different ages in good condition of plants, and morphological diversity.

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Т.А. Вдовина, О.А. Лагус, Е.А. Исакова, А.А. Винокуров

Қазақстандық Алтай аумағындағы жабайы жеміс өсімдіктерінің ценопопуляцияларының жай-күйі

Мақалада *Rosa acicularis* Lindl., *Rosa spinosissima* L., *Lonicera altaica* Pall., *Ribes nigrum* L., *Ribes petraeum* Wulfen ценопопуляция жағдайы туралы зерттеулер келтірілген, олар жоғары ресурстық көрсеткіштерге және айтарлықтай аудандарға ие. Зерттеулер Қазақстандық Алтай аумағының Оңтүстік-Батыс Алтай, Оңтүстік Алтай географиялық аймақтарында жүргізілді. Әрбір ценопопуляция үшін таралу үлгісі, алып жатқан аумағы, фитоценотикалық сипаттамалары, өсімдіктердің жалпы және жас жағдайы және олардың биоәртүрлілігі туралы мәліметтер алынды.

Кілт сөздер: ценопопуляция, фитоценоз, ауданы, өнімділігі, өзгергіштігі.

Т.А. Вдовина, О.А. Лагус, Е.А. Исакова, А.А. Винокуров

Состояние ценопопуляций диких плодовых растений на территории Казахстанского Алтая

В статье представлены исследования состояния ценопопуляций: *Rosa acicularis* Lindl., *Rosa spinosissima* L., *Lonicera altaica* Pall., *Ribes nigrum* L., *Ribes petraeum* Wulfen, которые имеют высокие ресурсные показатели и значительные площади. Исследования проводились на территории Казахстанского Алтая в географических зонах Юго-Западного Алтая, Южного Алтая. Для каждой ценопопуляции получены данные о характере распространения, занимаемой площади, фитоценотических характеристиках, общем и возрастном состоянии растений и их биоразнообразии.

Ключевые слова: ценопопуляция, фитоценоз, площадь, продуктивность, изменчивость.

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The effect of growth regulators on the multiplication of *Crataegus sanguinea* *in vitro*

This study focused on examining how plant growth regulators affect shoot proliferation on *Crataegus sanguinea*. Shoot multiplication treatments included benzylaminopurine (6-BAP) at different concentrations (0.25, 0.5, and 0.75 mg/l) combined with constant 0.5 mg/l gibberellic acid (GA3) and 0.01 mg/l Indole-3-butyric acid (IBA), in *Quoirin & Lepoivre* (QL) nutrient medium. The results showed that the highest number of shoots per explant (5.23) was achieved in a medium supplemented with 0.5 mg/l 6-BAP plus 0.5 mg/l GA3 and 0.01 mg/l IBA, while the greatest shoot length (12,77 cm) was obtained with 0.75 mg/l 6-BAP plus 0.5 mg/l GA3, and 0.01 mg/l IBA 35 days after transplantation. This study presents an efficient protocol for *in vitro* multiplication of *Crataegus sanguinea*, achieving the highest shoot proliferation rate.

Keywords: Axillary buds, QL medium, PGRs, Shoot proliferation, *Crataegus sanguinea*.

Introduction

Sexual reproduction in plants significantly contributes to the diversity of reproductive strategies. Mechanisms such as self-incompatibility and dioecy facilitate cross-pollination, which enhances genetic variability (genetic recombination) and adaptability by increasing the potential for adaptive responses to environmental changes [1].

Crataegus spp., which belongs to the subfamily *Maloideae* within the *Rosaceae* family [2], exemplifies the complex interplay of these reproductive strategies [1]. This genus is particularly notable for its extensive hybridization capabilities, a consequence of its sexual reproduction mechanisms [2].

Hybridization complicates traditional taxonomic and genetic works by introducing a range of unpredictable outcomes and intermediate traits. This process affects ploidy levels, leading to additional challenges related to fertility and genetic stability. It can also influence gene flow between species, impacting their evolutionary paths and potentially contributing to speciation or extinction events [3]. This complexity is partly attributed to its base haploid chromosome number of x=17, which contributes to the genetic diversity and variability within the genus [2].

The genus includes both shrubby species and others that can reach heights of up to 12 meters. Widely distributed across the temperate regions of the Northern Hemisphere, *Crataegus* comprises approximately 280 species [2].

Hawthorn, a wild edible plant, has played a vital role in human life for centuries. Historically, its fruits, seeds, leaves, flowers, roots, and branches have been utilized to fulfill various personal and societal needs, including as a food source, for medicinal purposes, and as an ornamental plant [4].

Various *Crataegus* species are listed in the pharmacopeias of Germany, Britain, France, Switzerland, the US [5], Canada and China [6].

Due to their antispasmodic, cardiotonic, diuretic, hypotensive, and antiatherosclerotic properties. In Europe and the USA, aqueous ethanol extracts of *Crataegus* are used clinically to manage heart failure. These extracts are also employed to address a range of health issues, including cardiovascular disorders and concerns related to the central nervous system, immune system, eyes, reproductive system, liver, and kidneys [5]. Additionally, *Crataegus* extracts exhibit cytotoxic effects, gastroprotective properties, anti-inflammatory mechanisms, and antimicrobial activity [2].

The leaves, flowers, and fruits of *Crataegus* species are particularly rich in antioxidants [4], containing phenolic compounds such as chlorogenic acid, epicatechin, and hyperoside, which help to reduce genetic damage in bone marrow cells [7].

However, pharmaceutical products containing secondary metabolites must meet specific phytochemical content requirements, including minimum concentrations of active components like flavonoids and procyanidins [6]. All above-mentioned benefits highlight the plant's potential to contribute to overall human health and well-being.

Characterization of secondary metabolites through mass spectrometry or nuclear magnetic resonance (NMR) spectroscopy offers an additional method for describing *Crataegus* [8]. However, this kind of dataset alone does align with the evolutionary pattern of the species Molecular analysis based on ITS and 5.8S ribosomal DNA sequences shows that *Crataegus* species are not monophyletic [8].

In horticultural practice, *Crataegus* species are extensively utilized for their beneficial properties. These species are valued not only for their role in rootstock but also for the nutritional content of their fruits. The fruits are rich in sugars (4–11 %), pectin (0.6-1.6 %), tannins, and pigment compounds (0.8-1.7 %). They also have significant amounts of ascorbic acid (vitamin C) and vitamin A, with concentrations ranging from 31 to 108 mg and 380 to 680 mg per 100 grams, respectively [9].

In horticulture, *Crataegus* species are extensively utilized as rootstocks for apple, pear, and quince trees. The fruits of these species are characterized by their content of sugars (4–11 %), pectin (0.6-1.6 %), tannins, and pigment compounds (0.8-1.7 %). In addition, these fruits are distinguished by their significant content of ascorbic acid (vitamin C) and vitamin A, with concentrations varying between 31 and 108 mg, and 380 and 680 mg per 100 grams, respectively [9].

In Kazakhstan, seven wild species are found: *Crataegus almaatensis*, *Crataegus ambigua*, *Crataegus cholorocarpa*, *Crataegus pontica*, *Crataegus sang uinea*, *Crataegus songarica*, *Crataegus turkestanica*. *Crataegus ambigua* is listed in the Red Book of Kazakhstan [9].

Morphologically, the stems of *these* species are covered in thorny spines that 3–6 cm in length. Initially smooth, the bark is gray with light or dark tints. Mostly, flowers of wild types, typically white, have an unpleasant aroma. Cultivars of *Crataegus* sometimes produce pink or red flowers. The fruit is a small pome containing 1–5 seeds, and it can be orange-yellow, red-purple, or black in color [9].

Crataegus sanguinea are thorny shrubs or small trees, 1–4 meters tall, found in forest, forest-steppe, and steppe zones. They have purple-brown, glossy branches with strong, red-brown thorns. A hundred grams of fruits contain 127 mg of vitamin C [9]. In their leaves, various compounds have been found, including flavonoids (such as hyperoside, vitexin, apigenin, luteolin, quercetin, and rutin), phenylpropanoids (like caffeic acid and chlorogenic acid), saponins, vitamins, and various other secondary and primary metabolites, all of which are highly valued for their medicinal properties [10].

Hawthorn trees are winter-hardy, light-demanding, and drought-resistant, requiring little in terms of soil quality. They propagate naturally through seeds or sprouts, while in cultivation they can be propagated by layering or grafting. These trees have a lifespan of 200 to 300 years [9]. Typically, attempts to propagate hawthorns using standard horticultural techniques have encountered significant challenges. Seed germination tends to be slow and has a low success rate, while cuttings from mature trees are difficult to root and rarely succeed [11]. Currently, the *in vitro* culture method is extensively employed to address issues related to *ex situ* preservation and the restoration of the gene pool of rare and endangered plant species. This technique allows for the production of a larger quantity of plant material and produces disease-free plants [12]. Moreover, the approach focuses on maintaining genetic stability of meterial [1].

Developed protocols may serve as an excellent starting point. *In vitro* techniques have been applied to *Crataegus aronia* L. [13], *Crataegus oxyacantha* [14], *Crataegus pseudoheterophylla* Pojark [15], *Crataegus monogyna* [16].

Crataegus sanguinea, along with other *Crataegus* species, is recognized for its medicinal properties and horticultural value. However, there is limited research focused solely on *Crataegus sanguinea*, in the context of propagation.

In our study, we aim to develop an applicable protocol for the shoot multiplication of medically important species of *Crataegus sanguinea* for conservation and reproduction.

Experimental

Sample collection and explants preparation

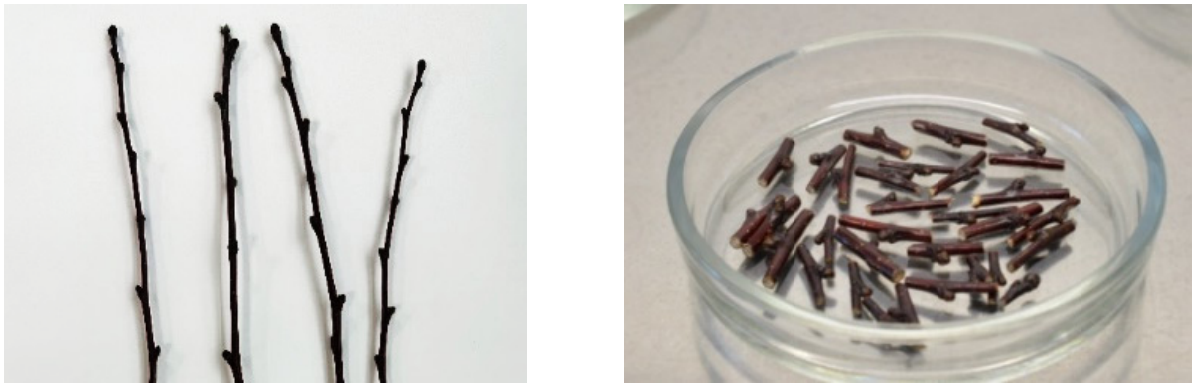
The stems of hawthorn were collected in 2023 from two regions, Karaganda (Korneevskiy Forests, Bukhar-Zhyrau District) and Aktau. The GPS data of the collected samples are given in Table 1. Axillary buds were stored at 4 °C until use.

Table 1

Coordinates of the collected plant materials

Species	Geographical location	Longitude	Latitude	Height above sea level, m
Crataegus sanguinea	"Korneevsky" forest, "Bukhar-Zhyrausky district, Karaganda region	E073°95.693'	N50°29.607'	552
	Aktau region	E51°9'39.337"	N43°39'1.969"	

Axillary buds (Fig. 1), excised from nodal segments, and 2-2.5 cm long segments were exposed to sterilization with soapy water three times and then washed under running tap water for 30 min. The effectiveness of hydrogen peroxide (H_2O_2) at various concentrations (5 %, 10 %, and 15 %) was studied for the establishment of *in vitro* culture, with sterilization duration of 5 minutes. Afterward, the explants were rinsed three times with sterile distilled water and dried on filter paper in Petri dishes for approximately an hour. The prepared axillary buds were cultured on QL medium to examine the viability of the donor plant.



A) Collected donor plants B) Prepared segments of plant material

Figure 1**.** Axillary buds of *Crataegus sanguinea*

Formation of the main shoot

After obtaining sterile and viable explants, the next stage was selecting the nutrient medium. The prepared axillary buds were cultured in QL, *Murashige and Skoog* (MS), and *Woody Plant Medium* (WPM).

In our experiment, nutrient mediums were supplemented with constant 0.25 mg/l 6-BAP and 0.5 mg/l GA3 to regenerate the main shoots. The number of shoots obtained at the sterilization and regeneration stages was recorded to calculate the percentage of viable explants.

Shoot multiplication

Regenerated shoots were cultured in glass jars containing QL medium, supplemented with 6-BAP at four concentrations in combination with constant IBA and GA3 for shoot multiplication. As a result, the following treatments were studied: I — PGR-free medium (control); II — 0.25 mg/l 6-BAP, 0.5 mg/l GA3, and 0. mg/l IBA in QL; III — 0.5 mg/l 6-BAP, 0.5 mg/l GA3, and 0.01 mg/l IBA in QL; IV — 0.75 mg/l 6-BAP, 0.5 mg/l GA3, and 0.01 mg/l IBA in QL. In our study, 30 explants were cultivated for each treatment, and data were collected 35 days after transplantation.

Statistical analyses involved subjecting the experimental results to ANOVA, with significant differences determined using Tukey's post hoc test in SPSS 25.0 (IBM Inc., New York, NY). The data represent means ± standard error from three independent experiments.

The cultures were incubated in a climate chamber at 24–26 °C, with a relative humidity of 60–80 %. The day length was maintained at 16 hours in a 24-hour light/dark cycle.

Results and Discussion

Culture establishment

The success of in vitro culture largely depends on several factors, including the genetic potential of the explants, their morphogenetic stages of development, and the establishment of aseptic conditions that ensure higher survival rates and low percentage of contamination. Therefore, selecting an effective (non-residual) sterilization agent is a crucial step [17].

Numerous studies indicate that H_2O_2 is a suitable sterilization agent for certain species in the Rosaceae family. By using the optimal concentration, H_2O_2 can effectively sterilize axillary buds, ensuring high explant viability while minimizing the risks of necrosis and contamination [18].

Based on the significant research findings of previous studies, our research tested different concentrations of H_2O_2 for sterilizing Crataegus explants. The 10 % H_2O_2 solution achieved the highest viability, with 73,3 % of hawthorn explants remaining sterile (22 explants out of 30).

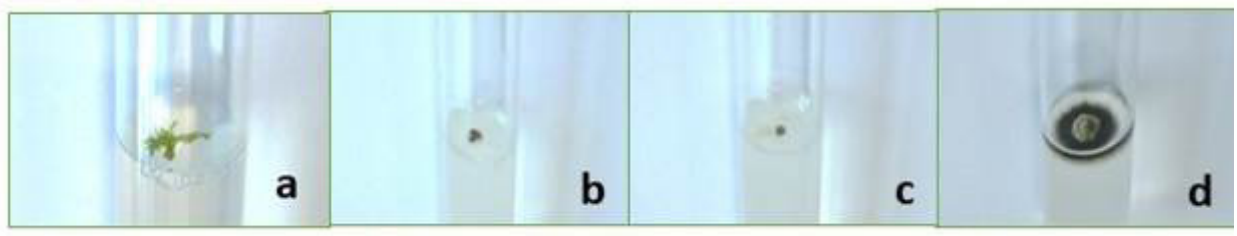
In contrast, the 5 % H_2O_2 solution resulted in a high infection rate of 86,6 % (26 explants out of 30) and lower viability 13.3 % (4 explants out of 30). The use of a 15 % H_2O_2 solution resulted in significant explant necrosis, affecting up to 66.6 % of the samples (Table 2).

Table 2

Results of sterilization of hawthorn (*Crataegus sanguinea*) explants

Treatment	Explant contamination		Explant necrosis		Viable explants	
	pcs.	%	pcs.	%	pcs.	%
I — 5 % H_2O_2	26	86.6	0	0	4	13.3
II — 10 % H_2O_2	6	20.0	2	6.6	22	73.3
III — 15 % H_2O_2	0	0	20	66.6	10	33.3

Therefore, the optimal concentration for axillary buds of *Crataegus sanguinea* is a 10 % H_2O2 solution (Fig. 2).



A) Sterile and viable explants B) Explant necrosis C, D) Explant contamination

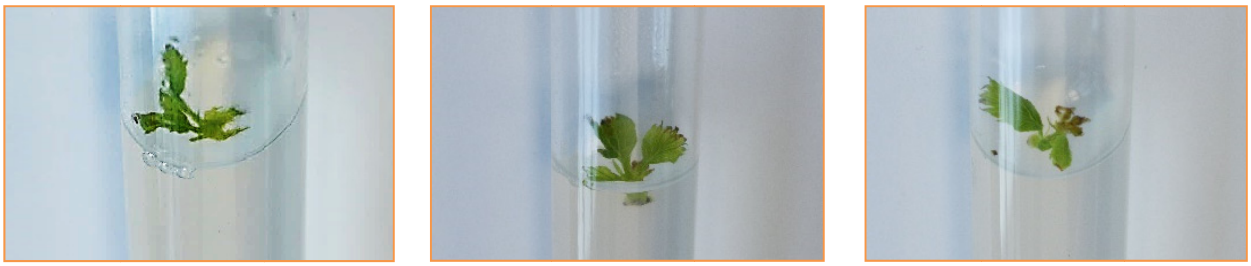
Figure 2. Sterilization of axillary buds of *Crataegus sanguinea*

Initial shoot formation

The initial shoot formation is one of the critical stages that determine the success of plant tissue culture. A suitable nutrient medium, proper balance and concentration of PGRs are essential for stimulating the explants to develop into shoots.

Successful shoot initiation of *Crataegus* species on MS, LP and WPM has been published. It was reported that the optimal concentration of growth regulators, specifically, 6-BAP and IBA in combination demonstrates a significant impact on the regeneration of the main shoot [19]. In *Crataegus monogyna*, 6-BAP was one of the essential PGRs [20].

In our study, we investigated the effects of QL, MS and WPM media supplemented with constant concentration 0.25 mg/l 6-BAP and 0.5 mg/l GA3 on shoot regeneration (Fig. 3). Applied treatments were found to be suitable for target species with some adjustments.



A) QL *B)* MS *C)* WPM

Figure 3. Explants of Crataegus sanguinea germinated after 2 weeks of culture on different nutrient mediums supplemented with 6-BAP and GA3

The leaf lamina of the formed shoots was well developed on all nutrient media. However, based on visual observations, explants cultured in MS and WPM media exhibited signs of drying (Fig. 3). Thus, QL medium proved to be the most effective for the development of primary microshoots of *Crataegus sanguinea*.

This underscores the critical role of choosing the right nutrient medium for the main microshoot regeneration based on observed quantitative data (Table 3, Fig. 4). The highest regeneration rate was 76.6 %, with 23 out of 30 explants on QL medium. In contrast, the initial shoot formation rates were lower on both MS and WPM media, 66.6 % and 60 %, respectively.

Table 3

The effect of nutrient media on shoot regeneration

Treatments	Total number of cultivated explants, pcs.	Number of regenerated explants, pcs.	Percentage of regeneration, %
I — QL 0.25 mg/l 6-BAP and 0.5 mg/l GA3	30	23	76.6
II — MS 0.25 mg/l 6-BAP and 0.5 mg/l GA3	30	20	66.6
III — WPM 0.25 mg/l 6-BAP and 0.5 mg/l GA3	30	18	60.0

A study on Crataegus pinnatifida showed that successful regeneration of the main shoot occurred with 6-BAP in the range of 0.5 to 1.5 mg/l [21].

However, our experiment demonstrated that QL medium supplemented with 0.25 mg/l *6-BAP and 0.5* mg/l *GA3 yielded sufficient results for initial shoot formation of Crataegus sanguinea.*

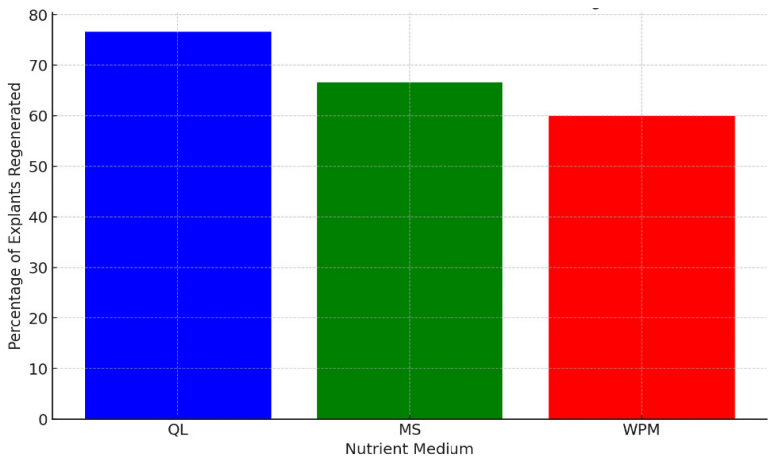


Figure 4. *Effect of nutrient media on shoot regeneration*

Shoot multiplication

In this study, we optimized a protocol for the *in vitro* multiplication of *Crataegus sanguinea* via the cultivation of regenerated explants in QL medium with 6-BAP, GA3 and IBA. We examined the effects of 6-BAP at different concentrations (from 0.25 to 0.75 mg/l) in combination with 0.5 mg/l GA3 and 0.01 mg/l IBA in QL medium. The results of the analysis of variability in morphometric characteristics in the observed *Crategus sanguinea* plants are presented in Table 4, which contains the summary data for all the studied treatments.

Table 4

The effect of 6-BAP concentrations on shoot proliferation of hawthorn (*Crataegus sanguinea)*

Treatments	PGR (mg/l)			35 Days after transplantation		
	6-BAP	GA3	IBA	Average number of shoots per explant, pcs.	Mean shoot height, cm	Number of leaves per explant, pcs.
I (Control)	-	-	-	3.26±0.11	1.50±0.09	13.07±0.24
II	0.25	0.5	0.01	2.34±0.08*	4.33±0.22*	10.33±0.17*
III	0.5			5.23±0.07*	6.77±0.18*	10.97±0.23*
IV	0.75			2.96±0.06	12.77±0.48*	11.87±0.35
Note – *The average difference is significant at the 0.05. Data are expressed as means ± standard error.						

It was found that the QL medium supplemented with 0.5 mg/l 6-BAP, 0.5 mg/l GA3, and 0.01 mg/l IBA resulted in high multiplication, with an average number of shoots per explant being 5.23 ± 0.07 (Table 4, Fig. 5). The plants appeared visually healthy, with an average shoot height and number of leaves per explant being 6.77 ± 0.18 cm and 10.97 ± 0.23, respectively.

The collected data suggest that the concentration of the cytokinin 6-BAP has a significant impact on the height, number, and quality of the developing plants of *Crataegus sanguinea*.

A) PGRs-free culture medium; B) 0.25 mg/l 6-BAP, GA3 0.5 mg/l, IBA 0.01 mg/l QL medium; C) QL 6-BAP 0.5 mg/l, GA3 0.5 mg/l, IBA 0.01 mg/l; D) QL 6-BAP 0.75 mg/l, GA3 0.5 mg/l, IBA 0.01 mg/l

Figure 5. Optimization of 6-BAP concentration for shoot proliferation of *Crataegus sanguinea*

Auxin and cytokinin are pivotal in regulating key stages of plant development in tissue culture. This is exemplified by research on *Allium cepa*, which has provided insights into the molecular mechanisms through which PGRs interact with *CDK* genes, influencing their activity and thereby regulating plant growth phases [22].

It was reported that the combination of cytokinins and auxins significantly influenced both the average number of shoots per explant and shoot length in sweet cherry (*Lapins Prunus avium L.*), where 6-BAP supplementation proved effective in promoting shoot multiplication [23]. This is consistent with our observations on *Crataegus sanguinea.* Additionally, it also was reported that the significant influence of 6-BAP supplementation on other *Crataegus* species [20]. The investigation on *Crataegus aronia* L. showed that media supplemented only with 6-BAP yielded the highest shoot production by promoting both shoot proliferation

and elongation. Higher shoot numbers were observed at 5.0 and 7.5 μM 6-BAP, while TDZ (Thidiazuron) caused significant callus formation [13]. Assessed shoot production among *Crataegus aronia, Crataegus pseudoheterophylla,* and *Crataegus meyeri* demonstrated variability in response to different combinations of PGRs. Notably, the combination of 1 mg/l NAA (Naphthaleneacetic acid) and 4 mg/l 6-BAP (6-Benzylaminopurine) was particularly effective, generating the highest average number of shoots after 6 weeks of cultivation [24].

Among the studied species, *Crataegus aronia* produced the highest percentage of successful explants, achieving 89.67 % success rate under this PGR combination. This indicates a strong propensity for shoot regeneration in *Crataegus aronia*, suggesting its potential for efficient shoot proliferation [24].

In contrast, *Crataegus meyeri* exhibited the longest average shoot length, reaching 22.67 mm. This was achieved under a different PGR concentration of 1 mg/l NAA and 1 mg/l 6-BAP, highlighting the species-specific response to growth regulators [24].

By considering above mentioned information we highlight the importance of optimizing PGR concentrations to each *Crataegus* species to maximize growth parameters.

Conclusion

The method employed in this experiment enabled effective shoot multiplication using auxiliary buds, bypassing the germination barrier and significantly reducing the propagation time. This approach facilitated the rapid and mass production of plant materials. Our findings insights are valuable for improving shoot proliferation protocols and enhancing the efficiency of *in vitro* cultivation of *Crataegus sanguinea*, which is valuable for its high fruit quality and ornamental, pharmaceutical, ecological, and rootstock importance. The use of QL media supplemented with certain concentrations of 6-BAP, GA3, and IBA can be recommended to enhance the multiplication of *Crataegus* spp. *In vitro* collection of *Crataegus sanguinea* has been created and will be used for further research.

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Өсімдік гормондарының *Crataegus sanguinea* *in vitro* жағдайындағы көбеюіне әсері

Зерттеу жұмысы өсімдік гормондарының *Crataegus sanguinea* микроөркендерінің көбеюіне қандай әсер ететінін зерттеуге бағытталған. Ол үшін бензиламинопуриннің келесі концентрациясы (6-БАП) 0,25, 0,5 және 0,75 мг/л, 0,5 мг/л гибберелл қышқылымен (ГҚ) және 0,01 мг/л индол-3-май қышқылымен (IBA) *Quoirin & Lepoivre* (QL) қоректік ортада зерттелді. Зерттеу нәтижелері бір эксплантқа ең көп өскіндер (5,23) ГК3 регенерациялық қоректік ортаға 0,5 мг/л, 0,5 мг/л 6-БАП, 0,5 мг/л GA3 және 0,01 мг/л IBA концентрациясында қосылу арқылы түзілетінін көрсетті. Алайда культивациялаудың 36-шы күнінде 0,75 мг/л 6-БАП, 0,5 мг/л GA3 және 0,01 мг/л IBA пайдалану арқылы эксплантағы өркеннің орташа ұзындығы (12,77 см) алынды. Атқарылған жұмыс негізінде *Crataegus sanguinea* өсімдігінің микроөскіндерін *in vitro* жағдайында көбейту үшін тиімді протокол ұсынылды. Бұл өз кезегінде микроөскіндердің саны мен ұзындығын жоғары деңгейде қамтамасыз етеді деп болжанады.

Кілт сөздер: қолтық бүршік, QL қоректік *ортасы*, өсімдік гармондары, микроөркендерді көбейту, *Crataegus sanguinea*.

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Влияние регуляторов роста на мультипликацию *Crataegus sanguinea* в культуре *in vitro*

В данном исследовании было изучено влияние регуляторов роста растений на пролиферацию дополнительных микропобегов у *Crataegus sanguinea*. Для этого были изучены следующие концентрации бензиламинопурина (6-БАП) 0,25, 0,5 и 0,75 мг/л, в комбинации с 0,5 мг/л гиббереллловой кислоты (ГК) и 0,01 мг/л индол-3-маслянной кислоты (IBA) на питательной среде *Quoirin & Lepoivre* (QL). Результаты исследований показали, что наибольшее количество побегов на эксплант (5,23) образовано добавлением в питательную среду регенерации ГК3 в концентрации 0,5 мг/л, 0,5 мг/л 6-БАП, 0,5 мг/л GA3 и 0,01 мг/л IBA. Однако средняя длина побегов на эксплант (12,77 см) была получена при использовании 0,75 мг/л 6-БАП, 0,5 мг/л GA3 и 0,01 мг/л IBA, на 36 день культивации. Настоящая статья представляет собой эффективный протокол для мультипликации микропобегов *Crataegus sanguinea*.

Ключевые слова: пазушные почки, питательная среда QL, регуляторы роста, мультипликация, *Crataegus sanguinea*.

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Oat yield with organic fertilizer Guminatrin

Currently, the oats are cultivated in almost all regions of Russia. The aim of our research is to study the formation of oat yield according to the application of growth stimulator Guminatrin under the conditions of Priobskaya zone of Altai Krai. The work was conducted on the basis of the training plots of Altai State Agricultural University in 2020-2021. The objects of research were oaks cultivars "Korifej", "Pegas", "Argument", "Vektor", "Rusich". Working solution was prepared at the rate of 2 l of Guminatrin to 8 l of water. The consumption of working solution for treatment: seeds — 10 l per 1 t; plants by vegetation — 1.5-2 l per 1 ha. During the research the following records and observations: the yield structure, the yield of oats, the mass of 1000 seeds. The most responsive cultivarto the growth stimulant Guminatrin was "Rusich". Preseeding treatment of seeds and then the plants by vegetating with the Guminatrin contributed to an increase in the yield structure elements of the investigated oats cultivars, and as a consequence resulted in an increase in yield compared to control by 0,38-0.65 t/ha.

Keywords: oats, cultivars, Guminatrin, yield, yield structure elements, yield gain.

Introduction

Oats are one of the most common crops in world agricultural production. Under to various literary sources, the genus *Avena* is up to 70 species. According to the data presented by the "Plantarium. Plants and lichens of Russia and neighboring countries: open online galleries and plant identification guide", 30 species belong to this genus, of which more than half are native to countries on the European continent [1].

The primary centers of origin of cultural oats ancestors were determined by researchers — these are Mongolia and the north-eastern provinces of China. The spread of oats to all continents of the world, thanks to the many positive qualities of the crop, has allowed oats to occupy one of the leading positions in the cereal crop ranking [2].

The quality of grain oats is of great importance. Protein is one of the most important indicators for grain quality in any crop. The protein content in oats grains fluctuates at a level of 12-13 % and is characterized by the presence in its composition of essential amino acids — histidine, arginine, lysine and tryptophan. Scientists Burtseva E.V. and Ternenko I.I. [3] note the presence in oatsgrains up to 60 % offast-breaking starch, vitamin C, fats, sugars, saponins, flavonoids, fitinic acids [4]. The chemical composition of the straw extract showed a high content of silicon acid, iodine, avenin. The analysis of the oats seedlings revealed the presence of large quantities of peptides [5]. The oats grains contain high levels of iron, calcium and phosphorus; the crop has a high content of Al, Fe, As, Sn, Hg salts; the leaves accumulate Cu, Zn, Bi salts; the stems concentrate the Br, Rb, Sr, Cd, Ba salts [2, 6].

According to biological indicators, oatis a crop that develops well under the temperate climates. It is quite resistant to high humidity, low temperature, low soil fertility [2]. It is therefore not surprising that the Russian Federation is the largest producer of oats in the world, with a production volume of 3,775,686 tons per year (Fig. 1). Canada is second in terms of production — 2,808,109 tons/year, followed by Australia — 1,897,989 tons/year, and Poland — 1,625,100 tons/year [7–9].

In 2022/2023, the global production of oats was approximately 25.13 million tons. In the 2023-2024 seasons, Russia ranked second in the world production of grain of this crop (2.6 million tons, which is 17.2 % of all global production of grain of oat).

Despite the fact that Russia is one of the leading places in the world for grain production of oats, recent years have seen a decrease in the size of the areas planted, a reduction in gross harvest, and a decline in the yield in 2023 (Fig. 2).

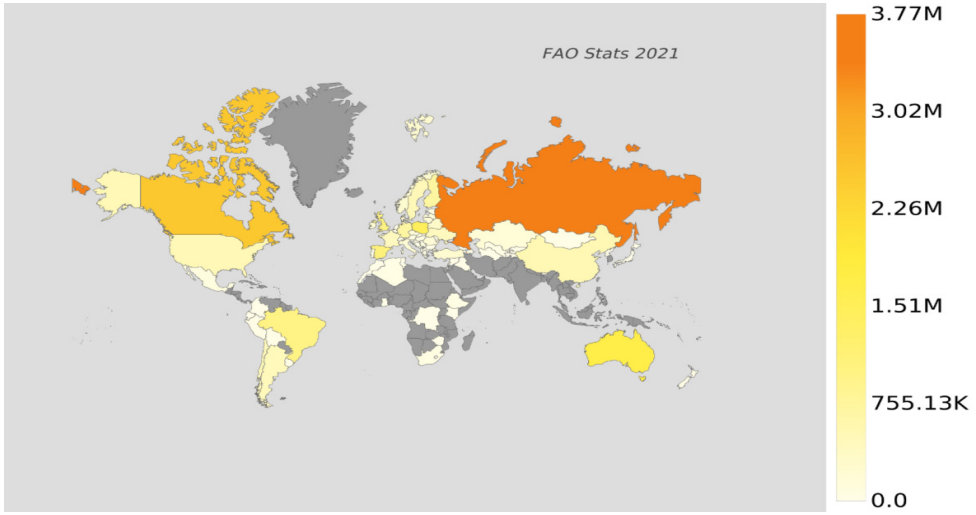

Figure 1. World oat production by country, 2021 (source: Rosstat)

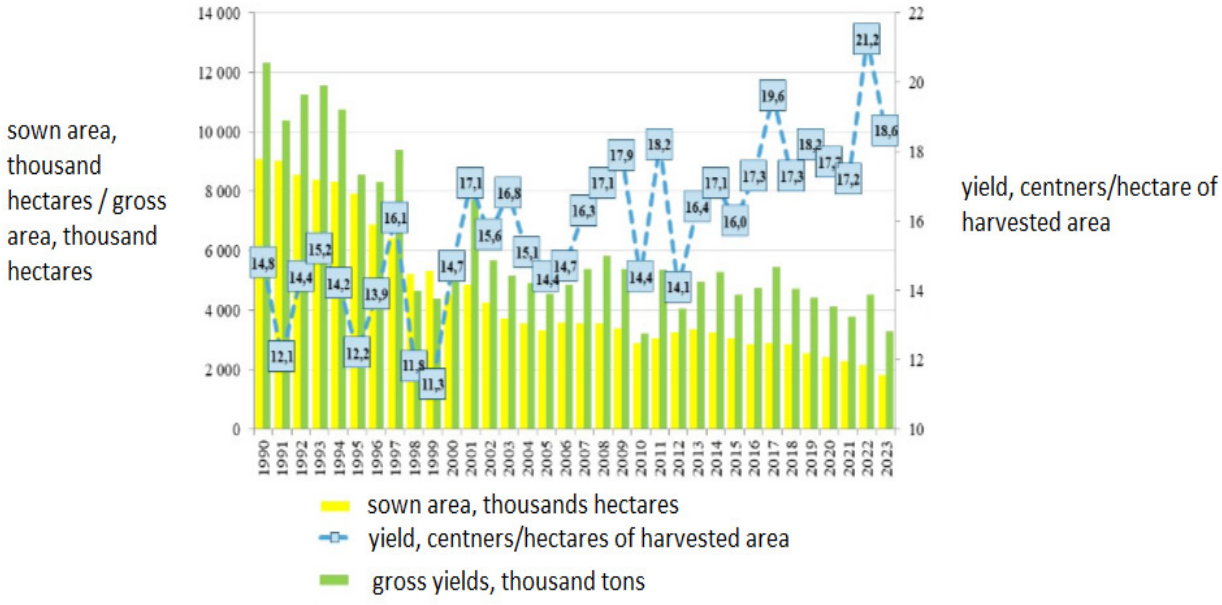

Figure 2.The area planted, gross yield and yield of oats in Russia in 1990–2023 (source: Rosstat)

In 2023, the oat area decreased by 79.9 % over the period under analysis and reached the target. Gross revenues in 2023 were 3,300 thousand tons, which is 27.1 % lower than in 2022. Such a sharp drop in the figure was observed in Russia and in 2010, when due to drought 3,225.2 thousand tons were obtained. The oat yield has increased by 7.5 % in the past five years, 13.4 % in 10 years, 8.8 % to 2001 and 25.7 % to 1990 [10].

Currently, the oats are cultivated in almost all regions of Russia. In 2023, 29.2 % of all oat harvest from regions included in the TOP-5, to share of the TOP-10 was 45.3 %. The maximum volume of oat production from regions included in the TOP-10 are noted from such municipalities as Altai Krai, Krasnoyarsk Krai, Tyumen Oblast, Republic of Bashkortostan, Novosibirsk, Irkutsk, Nizhnygorodskaya, Omsk, Kirov and Kemerovo regions (Fig. 3) [10].

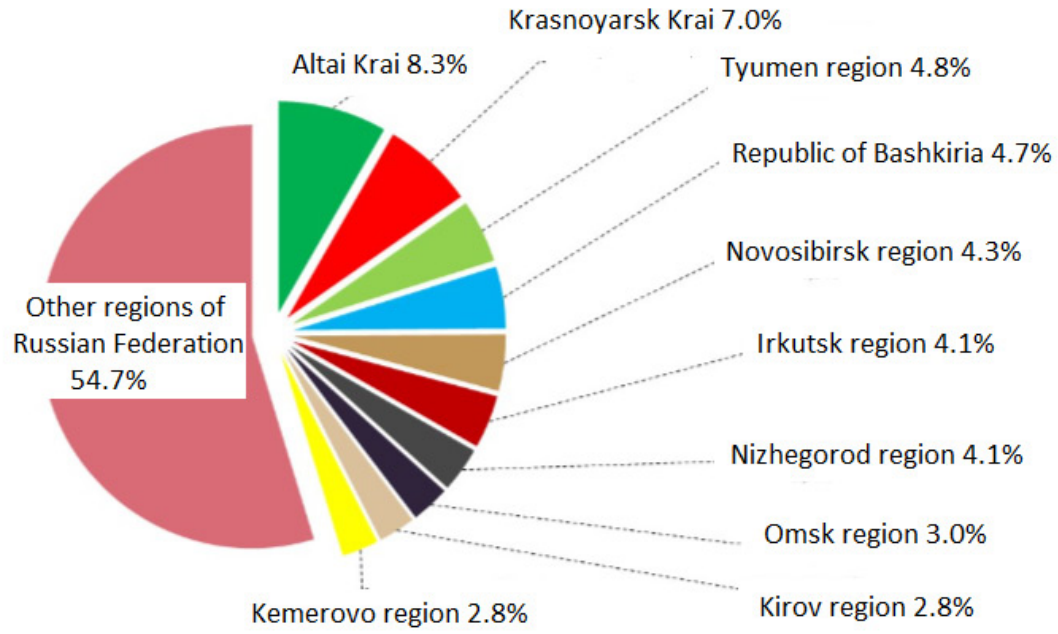

Figure 3. Share of regions in total production of oats in Russia in 2023, in % (source: Rosstat)

The importance of growing oats in modern agricultural production is undeniable. Oats occupies an honorable place among cereal crops. Oats contain a high protein, starch and fat content. This makes the oat a very important food and feed. The crop is used to make cereals, cookies, biscuits, coffee. It is also used as animal feed.

Oat is the good forecrop for other crops, because it is weakly damaged by lodging infections. Due to the short harvesting time, blotchy ripening and high propensity for falling grain, oats are difficult to harvest and require additional measures to obtain simultaneously ripening crops [11].

The application of growth regulators allows obtaining changes in plant metabolism and development identical to those that occur under certain environmental conditions [12]. Plant growth regulators are now an excellent way to solve many problems in crop farming practice. They are improving the agricultural techniques of growing selected crops. The application of growth regulators is becoming more and more relevant and demanded for agricultural producers every year. The use of physiologically active substances in the production of oats allows controlling the individual stages of growth and development of plants in order to improve their yield and grain quality [13, 14].

Many different biological preparations are currently being developed and used in agricultural production. One of these is Guminatrin. The humic acid salts in it are a complex mixture of high molecular natural organic compounds. It is natural growth stimulator, which improves the penetration of mineral nutrients through plant roots, actively participate in oxidative-restorative processes of plant cells, mobilize the phosphorus content into bioavailable forms. Humic acids are able to bind and safely transfer radionuclides, heavy metals, pesticide residues, accelerate the intensity of photosynthesis and chlorophyll synthesis. Boron, manganese, copper, zinc, molybdenum, iron, cobalt, which are included in “Guminatrin”, stimulate the growth and development of plants. Under their action, plants are increasingly resistant to bacterial and fungal diseases, to adverse environmental factors [14].

The aim of our research is to study the formation of oat yield according to the application of growth stimulator Guminatrinunder the conditions of Priobskaya zone of Altai Krai.

Experimental

The research was conducted on the basis of the training plots of Altai State Agricultural University in 2020-2021. Test plots soil — leached medium-thicksemi-loammedium-humic chernozem. The objects of research were oaks cultivars “Korifej”, “Pegas”, “Argument”, “Vektor”, “Rusich”. The fore crop was a

spring wheat, sowing made by hand. The seed rate was 500 pcs. germinating seeds per 1 m^2. The plot area was 2 m^2, repetition was 3-times (Fig. 4).

The Guminatrin is a liquid fertilizer consisting of humic and fulvic acids, it also contains live agrobacteriums (Agrika, Rizotorfin B, Rizoagrin B) and amino acid complex. The product has a stimulating effect, increasing the resistance of plants to diseases, extreme climatic factors: drought, excess moisture, soil salinity. Enhances the ability of plants extract macro- and micro-nutrients from soil. Increases seed germination and gives plants favorable starting conditions due to the rich complex of micronutrients, together with soil bacteria [15].

Experiment options:

- pre-seeding treatment of seeds, and then of plants in the stage of tillering with Guminatrin;
- non-treated control.

Working solution was prepared at the rate of 2 l of Guminatr into 8 l of water. The consumption of working solution for treatment: seeds — 10 l per 1 t; plants by vegetation — 1.5-2 l per 1 ha.

Figure 4. Experimental plots, 2020

During the research conducted the following records and observations: counted the yield structure, recorded yield of oats, counted the mass of 1000 seeds. The experiments and studies were conducted in accordance with the guidelines [16]. Mathematical processing of data was carried out according to the methodology of Dospekhov B.A. [17].

Results and Discussion

Positive reaction of plants to the treatment with growth stimulator on seed germination was noted for all cultivars. However, responsiveness was mixed. The highest increase in field germination (and excess of control) was obtained by the cultivars “Korifej” (16,7 %), “Argument” (12,2 %), “Pegas” (14,3 %), “Rusich” (11,8 %), “Vektor” (7,6 %).

The study of yield structure elements of crops allows highlighting those of them that are paramount in determining its valueunder specific soil-climatic conditions (Tables 1, 2).

Table 1

Yield structure elements, 2020

No.	Cultivar	Experiment option	Plant height, cm	Number of stems on one plant, pcs	Panicle			Mass of 1000 grains, g
					Length, cm	Number of grains, pcs	Mass of grain from one plant, g	
1	Pegas	Control	80	1.3	11	25	1.59	26.2
		Guminatrin	82	1.4	10	26	1.64	27.4

Continuation of Table 1

No.	Cultivar	Experiment option	Plant height, cm	Number of stems on one plant, pcs	Panicle			Mass of 1000 grains, g
					Length, cm	Number of grains, pcs	Mass of grain from one plant, g	
2	Korifej	Control	81	1.2	13	24	1.51	26.7
		Guminatrin	83	1.2	11	28	1.64	29.4
3	Argument	Control	86	1.3	14	24	1.87	24.6
		Guminatrin	87	1.4	11	26	1.93	26.9
4	Vektor	Control	86	1.3	14	22	1.56	23.2
		Guminatrin	87	1.3	13	26	1.64	25.7
5	Rusich	Control	80	1.1	14	22	1.55	29.1
		Guminatrin	83	1.1	13	25	1.59	30.6
Statistics								
Mean			83.5	1.3	12.4	24.8	1.65	27.0
σ			2.7	0.1	1.4	1.8	0.13	2.1
Cv, %			3.2	8.1	11.5	7.2	7.94	7.9
SEM			0.9	0.03	0.5	0.6	0.04	0.7

Table 2

Yield structure elements, 2021

No.	Cultivar	Experiment option	Plant height, cm	Number of stems on one plant, pcs	Panicle			Mass of 1000 grains, g
					Length, cm	Number of grains, pcs	Mass of grain from one plant, g	
1	Pegas	Control	84	1.2	11	31	1.78	27.6
		Guminatrin	85	1.2	12	32	1.81	29.6
2	Korifej	Control	76	1.1	12	29	1.72	25.2
		Guminatrin	86	1.1	13	27	1.83	26.2
3	Argument	Control	84	1.1	9	24	1.35	21.9
		Guminatrin	92	1.1	10	29	1.54	22.6
4	Vektor	Control	76	1.1	13	29	1.27	23.3
		Guminatrin	85	1.1	13	33	1.41	24.7
5	Rusich	Control	83	1.1	11	26	1.14	26.8
		Guminatrin	92	1.1	14	31	1.28	29.2
Statistics								
Mean			84.3	1.1	11.8	29.1	1.51	25.7
σ			5.1	0.0	1.5	2.7	0.24	2.5
Cv, %			6.1	1.9	12.5	9.2	16.10	9.8
SEM			1.7	0.01	0.5	0.9	0.08	0.8

Under the 2020 conditions, all the yield structure elements studied except for the panicle length were higher on the Guminatrin option. So, the height of plants was on average 1.8 cm higher, the maximum obtained in the “Argument” and “Vector” cultivars — 87 cm. “Rusich” surpassed the control more than others, by 3 cm, with its average height of 83 cm. Average height was 83.5 cm.

The number of stems on one plantin the processed option exceeded the control only in cultivars “Argument” and “Pegas”, and that by only 0.1 pcs. Average number of stems on one plant was 1.3 pcs.

The panicle length was maximum at the control, exceeding the experimental option by an average of 1.6 cm. The shortest — 10 cm — was obtained from the “Pegas”. Average panicle length was 12.4 cm.

The number of grains from one panicle led by the “Korifej” cultivar — 28 pcs. on the Guminatrin variant, the lowest number obtained from “Vector” and “Rusich” cultivars was 22 pcs. The average excess over control was 2.8 pcs. Average number of grains from one panicle was 24.8 pcs.

The mass of grain from one plant in the processed option exceeded the control on average by 0.07 g. Maximum was obtained from the “Argument” — 1.93 g with Guminatrin and 1.87 g by control. Average mass of grain from one plant was 1.65 g.

The mass of 1000 grains were also higher on the Guminatrin option. “Rusich” cultivar showed the best result with 30.6 g, and the second place had “Korifej” cultivar with 29.4 g. The average excess over control was 2.04 g. Average mass of 1000 grains was 27.0 g.

The “Korifej” cultivar showed the great receptivity to treatment — the mass of 1000 grains after it increased by 2.7 g. The “Pegas” cultivar showed the lowest dependence, the increase was only 1.2 g. The “Vector” cultivar showed a 2.5 g increase, the “Argument” cultivar showed an increase of 2.3 g, the “Rusich” showed a 1.5 g increase.

Under the 2021 conditions, all the yield structure elements studied except for the number of grains from one panicle were higher on the Guminatrin option.

The “Pegas” cultivar showed the lowest responsiveness too. Plant height and panicle length has hardly changed, the increase was only 1 cm. The number of grains per plant has increased by 1 pcs., but “Pegas” showed a slight increase in the mass of grains from one plant, and as a consequence — an increase in the mass of 1000 grains by 2.0 g.

The “Korifej” cultivar showed the rise in plant height by 10 cm on the Guminatrin option — the first place among all studied cultivars. Its mass of grains from one plant increased by 0.11 g, the mass of 1000 grains — by only 1.0 g.

The “Argument” cultivar showed a rise in plant height by 8 cm, panicle length by 1 cm, number of grains from one panicle 5 pcs., the mass of grains from one plant in 0.19 g, the mass of 1000 grains has increased by only 0.7 g.

The “Vector” cultivar showed a rise in the plant height by 9 cm, in the number of grains from one panicle by 4 pcs., in the mass of grains from one plant by 0.14 g, and the mass of 1000 grains increased by only 1.4 g.

The “Rusich” cultivar showed a rise in the plant height by 9 cm, in the panicle length by 3 cm, in the number of grains from one panicle by 3 pcs., in the mass of grains from one plant 0.14 g per plant, and the mass of 1000 grains increased by 2.4 g.

Crop yield is a very important indicator, it shows how much production was obtained from one unit of the area. To increase the yield, it is necessary that optimal conditions for the growth and development of the plant are created. When the optimum is deviated, the yield decreases, so the use of growth stimulators allows not only to reduce the impact of adverse factors on the plant, but also to increase the yield at the expense of increasing resistance to external factors. Table 3 shows the yield of oats for 2020-2021.

Table 3

Yield of oats, t/ha

No.	Cultivar	Experiment option	Yield, t/ha			Yield gain	
			2020	2021	Mean	t/ha	%
1	Pegas	Control	1.56	1.85	1.71	-	-
		Guminatrin	1.75	2.42	2.09	0.38	22.2
2	Korifej	Control	1.60	1.77	1.69	-	-
		Guminatrin	2.20	2.08	2.14	0.46	27.0
3	Argument	Control	1.35	1.33	1.34	-	-
		Guminatrin	1.84	1.83	1.84	0.50	36.9
4	Vektor	Control	1.51	1.62	1.57	-	-
		Guminatrin	1.99	2.15	2.07	0.51	32.3
5	Rusich	Control	1.56	1.64	1.60	-	-
		Guminatrin	2.01	2.49	2.25	0.65	40.6
Statistics							
Mean			1.74	1.92	1.83	0.50	31.8
σ			0.25	0.35	0.28	0.09	6.6
Cv, %			14.64	18.10	15.38	17.57	20.8
SEM			0.08	0.12	0.09	0.04	3.3

Yield growth was between 22 and 40 percent. Based on the harvest data, it can be concluded that in 2021 the average yield was higher both on control and on the experiment, the exception being only the “Korifej” cultivar.

The yield of “Pegas” cultivar in 2021 was significantly higher than in 2020. At the control, the difference was 0.29 t/ha, at the experiment — 0.67 t/ha. Despite the significant change in crop yields in 2021, the trend of increased the yields with Guminatrin was maintained and stands at 12.2 % in 2020 and 23 % in 2021.

The “Korifej” cultivar also had an increase in the yield by control in 2021 compared to 2020, this increase was 0.17 t/ ha, the option with Guminatrin had a negative growth dynamic and it was 0.12 t/ ha. The average increase in control over two years was 0.46 t/ha or 27.0 %.

The average of the “Argument” cultivar over two years was almost identical and the difference was only 0.02 t/ha. But if we compare the options of the experiment, it turns out that the application of Guminatrin increased yield by 0.5 t/ha or 36.9 %.

The “Vector” cultivar had the same positive dynamics of yield growth in 2021 compared to 2020, it was 0.11-0.16 t/ha. The experiment with fertilizer gave an increase in yield of 0.51 t/ ha, which was an increase in yield by 32.27 %.

The “Rusich” cultivar showed the highest response to the use of Guminatrin, an increase of yield was 0.65 t/ha, which corresponds to a record increase in yields of 40.63 %.

The highest yield was generated by the use of Guminatrin in 2020 by the cultivars “Rusich” (2.01 t/ ha) and “Korifej” (2.20 t/ ha), in 2021 — by the cultivars “Pegas” (2.42 t/ ha) and also “Rusich” (2.49 t/ ha). On average for 2 years of the research, the yield of more than 2.0 t/ ha was formed at the background of Guminatrin by the “Pegas”, “Korifej”, “Vector” and “Rusich”.

Pre-seeding treatment of seeds and then the plants in the growing phase with Guminatrin fertilizer with a stimulating effect contributed to increased yields compared to control in both years of studies for all test options. In 2021, the increase of oats yields at the background of the treatment was higher than in 2020 by 0.01-0.47 t/ha. The average yield gain by 2 years was from 22.2 % to 40.6 %. The most responsive cultivar to the growth stimulant Guminatrin was “Rusich”.

Conclusions

Pre-seeding treatment of seeds and then the plants by vegetating with the stimulant Guminatrin contributed to an increase in the yield structure elements of the investigated oats cultivars, and as a consequence resulted in an increase in yield compared to control by 0,38-0.65 tons/ha.

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С.В. Жаркова, Н.И. Шевчук, Л.В. Соколова

Органикалық гуминатрин тыңайтқышы бар сұлы өнімділігі

Қазіргі уақытта сұлы Ресейдің барлық дерлік аймақтарында өсіріледі. Зерттеудің мақсаты — Алтай өлкесінің Приобская аймағы жағдайында гуминатрин өсу стимуляторын қолдануға байланысты сұлы өнімділігінің қалыптасуын зерттеу. Жұмыс Алтай мемлекеттік аграрлық университетінің оқу учаскелері базасында 2020-2021 жылдары жүргізілді. Зерттеу объектілері «Корифей», «Пегас», «Аргумент», «Вектор», «Русич» сорттарының емен ағаштары болды. Жұмыс ерітіндісі 8 л суға 2 л гуминатрин мөлшерінде дайындалды. Өңдеу үшін жұмыс ерітіндісінің шығыны: тұқымдар — 1 тоннаға 10 л; өсімдіктер вегетациялық кезеңге сәйкес — 1 га-ға 1,5-2 л. Зерттеу барысында келесі жазбалар мен бақылаулар жүргізілді: өнімнің құрылымы, сұлы өнімділігі, 1000 тұқымның салмағы. Гуминатриннің өсу стимуляторына ең сезімтал сорт «Русич» болды. Тұқымдарды, содан кейін өсімдіктерді вегетациялық кезеңде гуминатринмен егу алдында өңдеу зерттелетін сұлы сорттарының өнімділік құрылымының элементтерінің жоғарылауына ықпал етті және нәтижесінде бақылаумен салыстырғанда өнімділіктің 0,38-0,65 т/га өсуіне әкелді.

Кілт сөздер: сұлы, сорттар, гуминатрин, өнімділік, дақыл құрылымының элементтері, өнімділіктің өсуі.

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Урожайность овса с органическим удобрением Гуминатрин

В настоящее время овес возделывается практически во всех регионах России. Цель наших исследований — изучить формирование урожайности овса в зависимости от применения стимулятора роста — Гуминатрина в условиях Приобской зоны Алтайского края. Работа проводилась на базе учебных участков Алтайского государственного аграрного университета в 2020–2021 гг. Объектами исследований служили дубравы сортов «Корифей», «Пегас», «Аргумент», «Вектор», «Русич». Рабочий раствор готовили из расчета 2 л Гуминатрина на 8 л воды. Расход рабочего раствора на обработку: семян — 10 л на 1 т; растений по вегетации — 1,5–2 л на 1 га. В ходе исследований проводились следующие учеты и наблюдения: структура урожая, урожайность овса, масса 1000 семян. Наиболее «отзывчивым» на стимулятор роста Гуминатрин оказался сорт «Русич». Предпосевная обработка семян, а затем растений по вегетации Гуминатрином способствовала увеличению элементов структуры урожая исследуемых сортов овса и, как следствие, привела к увеличению урожайности по сравнению с контролем на 0,38–0,65 т/га.

Ключевые слова: овес, сорта, Гуминатрин, урожайность, элементы структуры урожая, прирост урожайности.

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Study of the distribution range of species of the genus *Adonis* L.

In the article data on the distribution of species of the genus *Adonis* L. in Kazakhstan were presented. In order to further clarify the places of distribution and inventory of modern growth of species of the genus Adonis, the main herbarium fund of botanical organizations was studied. The conducted analyses show that the highest occurrence of species is noted in Almaty region. To clarify the distribution in Kazakhstan and to compile the points of occurrence of species of the genus Adonis, 148 herbarium sheets (1843–2021) from Al-Farabi KazNU, Institute of Botany (AA), DAPO and KIR and digital herbarium of Moscow State University (MW) were reviewed and processed. Collections from 1843 are presented. The largest number of collections is from 1940–1972, and the main collectors are S.A. Arystangaliev, B. Bykov, N.V. Pavlov, and A.A. Ivashchenko. 148 actual places of growth for 8 Adonis species from the flora of Kazakhstan were identified: *Adonis aestivalis* L., *Adonis apennina* L. (*Adonis sibirica* Patr.ex Ledeb.), *Adonis chrysocyathus* Hook.f. & Thomson., *Adonis parviflora* Fisch., *Adonis tianschanica (*Adolf.*)* Lipsch., *Adonis vernalis* L., *Adonis villosa* Ledeb., *Adonis volgensis* Steven ex DC. Species diversity of *Adonis* L. is established in Dzungarian Alatau, Western Altai, Tarbagatai and Ile-Kungei Alatau, which are classified as rare and whose numbers are decreasing. Geographically, the most common are Adonis *Adonis aestivalis* L., *Adonis parviflora* Fisch. & *Adonis tianschanica (*Adolf.*)* Lipsch. The conducted research allowed systematizing, clarifying and supplementing information about species diversity and distribution of genus *Adonis* in the flora of Kazakhstan.

Keywords: distribution, herbarium, floristic regions, inventory, Kazakhstan.

Introduction

The genus *Adonis* L. includes 20 species growing in Europe and Asia. In Kazakhstan 8 species grows and [1] all of them are noted for the flora of Kazakhstan.

Adonis tianschanica (Adolf) Lipsch. is a rare species with decreasing abundance in the north-central Tianshan range [2, 3]. The species is included in the Red Data Book of Kazakhstan (1981) [4] and the List of Rare Species (2006) [5]. The above-ground part of the plant contains alkaloids, cardeonolides, saponins, nitrogen-containing compounds, flavonoids, vitamins. It is used as a cardiotonic agent (Grudzinskaya et al., 2014) [6]. *A. tianschanica* is a rhizomatous herbaceous perennial. By the time of flowering it reaches up to 35 cm in height. The number of stems is from 1–5. The stems are branched from the base, covered with many curly hairs. Leaves are scaly, twice pinnately divided into lanceolate lobes. At the beginning of vegetation, shoots and leaves are strongly curly-hairy; by fruiting, they are almost glabrous. Flowers are solitary, 3.5–5 cm in diameter, located at the ends of shoots. Petals are lemon-yellow, slightly irregular. The root system is represented by a shortened vertical rhizome up to 6 cm long with numerous straight cord-like roots of dark brown color up to 30 cm long. Lateral roots of the 2nd order are not numerous. In August, during the fruiting period, buds of renewal of next year's shoots are formed at the base of the rhizome. The number of buds depends on the size and age of the plant — from 1 to 5 (6) pieces. The fruit is a polycarp. Seeds are 3-4 mm long and 2-3 mm wide, finely wrinkled, scattered-hairy with a small, hook-shaped downward bent spout. The weight of 1000 seeds is 4.405 g [7].

Adonis apennina L. *(=Adonis sibirica* Patr. ex Ledeb.*)* — perennials. 20–30 cm tall, with fruits up to 60 cm; naked, with short, thick rhizome; stem smooth, simple or with short, slightly inclined branches; root and lower stem leaves scaly. sessile, middle and upper sessile, large, grayish underneath, twice or thrice pinnately divided, oval or triangular in outline, glabrous, terminal lobes linear-lanceolate, up to 12 mm long and 1 mm wide; flowers large, bright yellow, 4–6 cm. in dia. sepals yellow-tomato-greenish, glabrous, roundish-ovate, narrowed at the end, 10–15 mm long and 8–10 mm wide; petals oval, overlapping edges, 20–30

mm long and 10–15 mm wide; fruits shortly and sparsely pubescent, 4.5 mm long and 4 mm wide, their spout is short, bent downwards. Blossoms V-VI. Grows in dry meadows, forest edges, glades and light forests [1, 8].

Adonis villosa Ledeb. — perennials, 5–25 cm tall, with fruits up to 45 cm; stems solitary, with spreading branches; entire plant scattered-hairy; lower leaves brown, scaly, subsequent stem leaves twice pinnate, sessile, with 2 shortened lobes at the base, ovate or triangular in outline, their terminal lobes lanceolate, acuminate, young leaves strongly pubescent, later becoming less pubescent; flowers from 2 to 5 cm. in diameter, on a hairy pedicel; calyx purplish, its lobes oval, acuminate, pubescent, much shorter than the length of petals; petals pale yellow, oblong, narrow, narrowed at the ends, sometimes slightly toothed, 1-1.5 cm long and 0.5-1 cm wide; sop-lodia globular or ovoid, sometimes drooping; fruits 3-4 mm long, ovate, slightly wrinkled, pubescent, spout small, hooked downwardly bent. Blossoms V-VI. Grows on the edges of birch forests and in mountain steppes [1, 9].

Adonis chrysocyathus Hook.f. & Thomson — perennials, 12–40 cm tall, with fruits higher; rhizomes dark brown; stems straight, often curved at the top, ovate, with large, brown, scaly leaves below, lower green leaves long petiolate, large, sometimes exceeding the height of the stem, petioles 2-3 times longer than the lamina, upper leaves are sessile, the laminae are thrice pinnately incised into lanceolate or ovate-robic, acuminate lobes at the apex, young leaves are covered with fine, curly hairs on the underside, in old leaves they are strongly reduced; flowers are solitary, up to 4 cm. in dia. sepals are 6–8, purplish, ovate, unequally toothed at the apex, hairy on the outside, 12–15 mm long; petals are 16–24, golden-yellow, 25–27 mm long, 5–8 mm wide, obovate-lanceolate, blunted; copulose globular, about 10 mm in dia.; fruit 5–7 mm long, glabrous, with a long, inwardly twisted spout, almost twice as short. Blossoms VI-VII, fl. VIII. Grows on fine-grained slopes of the alpine belt of mountains and meadows like snow patches [1, 10].

Adonis vernalis L. — perennials, 5–20 cm, with fruits up to 40 cm tall.; rhizome thick, short, brownish-black; stems 3-4 in number, smooth, erect or slightly deflected, usually low branched, with oppressed branches, brownish in the lower part, with brown scaly leaves, stem leaves sessile, ovate or rounded in outline, dissected into lobes: lower palmately divided, upper lobes twice palmately divided, terminal lobes linear, entire-edged, 1-2 cm long. and 0.5-1 mm wide, glabrous; flowers bright yellow, 4 4.5 cm. in dia.; sepals green, finely pubescent, blunted at the top, up to 2 cm. long and 1.2 mm. wide, petals 12–20, oblong-elliptic, slightly narrowed and finely serrate at the apex, 1.5–3.5 cm long and 0.5-1.2 cm wide; fruit ovoid, 3.5–5.5 mm long and 3 mm wide, wrinkled, hairy, with a short, hook-shaped spout wrapped downwards, collected in ovoid heads about 2 cm long and 1.2 cm wide. Blossoms IV-V. It grows in steppes, along the margins of steppe coniferous forests and in shrubs [1, 11].

Adonis volgensis Steven ex DC. — perennials, 15–30 cm tall, with fruits up to 35 cm; rhizome thick, short, brownish-black; stems solitary or several of them, sparsely branched, almost glabrous at the lower part, with brownish scaly leaves; stem leaves sessile, ovate in outline, twice palmately divided into broadly linear lobes, wrapped at the bottom, more than 1.5 mm wide, young leaves rather densely pubescent, pubescence becomes sparse at flowering; flowers pale yellow, 3.5 4.5 cm. in dia.; sepals purplish, slightly pubescent; petals 1.7-2 cm. long and 6-7 mm. wide; fruits numerous, rounded, densely assembled into a head, finely indistinctly wrinkled, sometimes smooth, hairy, up to 4 mm. wide, their spout bent downward, tightly pressed to the surface of the fruit. Blossoms III-IV. It grows in grassy-typchak and grassy steppes, and occasionally in forest meadows [1, 12].

Adonis parviflora Fisch. ex DC. — small-flowered, 6–50 cm tall, with straight, branched or simple stem, glabrous or thinly pubescent in the lower part; leaves sessile, glabrous, only the lowest ones on petioles, twice or thrice pinnately dissected into linear lobes; flowers orange or fiery red, with a black spot at the base of petals; sepals 5–8, flat, ovate, glabrous, half the size of the corolla; corolla petals oblong-ovate or lanceolate, in the same or larger number; sapodule dense, oblong, up to 2 cm long and 0.6-0.7 cm long. and 0.6-0.7 cm wide; seeds broadly ovoid, 3.5 mm long and 3 mm wide, narrowed at the apex into a slightly bent spout with a toothed projection under it, glabrous, reticulate-tupomorphic over the whole surface, with a ridged-toothed margin and 2 small teeth. Blossoms V-VI. Grows on storages, saline and wet meadows [1, 13].

Adonis aestivalis L. — 3. summer, coal on fire, 10–50 cm tall; stem straight, branched or simple, glabrous or diffusely hairy; lower leaves petiolate, twice or thrice dissected into linear lobes; flowers few, 1 each at the top of the stem and branches, 1.8–3 cm dia. sepals flat, ovate, glabrous, rarely hairy from below; petals twice as large as sepals, bright fiery-red, rarely yellow, with a black spot at the base; seeds, collected in a dense oblong head, wrinkly-cellular in surface, elongated into a straight spout, below its middle bordered

by a scalloped-toothed margin, with one sharp projection and 2 teeth. Blossoms IV-VI. It grows as an invasive weed in crops, on fallow lands and old cattle camps [1].

Experimental

The work was based on materials stored in the herbarium funds (AA) of the Institute of Botany and Phytointroduction, in herbarium collections of the Kazakh National University named after Al-Farabi of the Department of Biodiversity and Bioresources and Department of agrochemical, soil surveys and integrated survey work DAPO (DAPO and KIR), as well as in the digital herbarium of Moscow State University (MW) of red-listed and rare species of the genus Adonis L. (*A. aestivalis*, *A. apennina* (*A.sibirica*), *A. chrysocyathus, A. parviflora, A. tianschanica*, *A. vernalis*, *A. villosa*, *A. volgensis*) to identify the exact locations of populations in the territory of Kazakhstan.

To further clarify the species composition and modern distribution of the genus Adonis L., an inventory of herbarium material dated 1842–2021 was conducted. Latin names of species are given according to the international platform POWO [14]. The names of floristic regions are based on botanical zoning of the flora of Kazakhstan. The following basic reference materials were used to compile systematic and geographical analyses of the genus Adonis L.: "Flora of Kazakhstan" (1961) [1], "Illustrated identifier of plants of Kazakhstan" (1972) [15], Handbook of plants of Central Asia (1993) [16]. In the process of work in the herbarium data contained in the herbarium were indicated without change on the labels, where the name of collectors, date of collection, geographical and administrative location of the point. In the work, the Latin names of *Adonis* L. species were checked in accordance with the reports of POWO [14].

Results and Discussion

Based on literature and herbarium data, a list of the flora of the genus *Adonis* L. growing in Kazakhstan was compiled, which includes 8 species of perennial herbaceous plants. As a result of the analysis of herbarium materials, 118 actual growing places were identified in herbarium funds of the Institute of Botany and Phytointroduction (AA). It was found 8 species of genus Adonis L. from the flora of Kazakhstan, and further we will present the list of herbarium sheets of plants growing in Kazakhstan:

Identified 50 herbarium sheets of storage, species *A. aestivalis*: Western Melkosopochnik, locus Tersakkan, 27.05.1842, Schrenk A. G.; Pri-Balkhash steppe, Arganatinskiye mountains closer to Lake Balkhash, rocky slopes, 12.04.1902, Sapozhnikov V. V.; Zailiyskiy-Kungei Alatau, Talgar River, foothills, 25.05.1925, Popov M. G.; Pre-Caspian region, Ural province Guryevsky district, Lake Inder, Gypsum sinkhole, 09.06.1927, Ilyin M. M., Grigoriev Yu. S.; Balkhash-Alakul district, Eastern Pribalkhashie, Area between the Karatal river and Uch-Kul lakes, 3 km west of Sarybulak station, wormwood steppe, 08.06.1928, Shipchinskiy N. V.; Zailiyskiy-Kungei Alatau, vicinity of the city. Alma-Ata, slopes of hills on the right bank of the Almatinka River outside the city, 28.05.1928, Lipshits S. Yu.; Zailiyskiy Alatau, Alma-Ata gorge, slopes of stalls outside the city of Almaty, 28.05.1928, Pavlov N. B.; Karatau, Syr-Darya district, Kara-Tau town, Jong Plateau, 17.06.1930, Volkova P. A.; Karatau, Syr-Darya district, east of Bijli Kul lake, 27.05.1930, Volkova P. A.; Karatau, Syr-Darya district, Kara-Tau town, low places of Jong plateau, pasture, 15.06.1930, Volkova P. A.; Karatau, Syr-Darya district, Juvalynsky area, spurs of Kara-Tau ridge, slightly hilly intermountain valley in the upper reaches of Chimbulak, south-west of Ber-Kara gorge about 1 km, 22.06.1931, Kornilova V.S.; Zailiyskiy-Kungei Alatau, Burunday urzhishche, Alma-Ata oblast, Kalininsky district, 25.05.1931, Mukhlya A.V.; Zailiyskiy Alatau, the vicinity of the city. Alma-Ata., Botanical garden, stalls, 25.05.1933, Geld A. I.; Zailiyskiy Alatau, vicinity of Alma-Ata mountain, southern slopes of Zailiyskiy Alatau foothills, light-chestnut soils, 06.06.1933, Kazgiprozem; Kirghiz Alatau, Aulietinsky district, north of Aigulak station — 5-6 km, plain, old deposits 8–10 l., on sierozem, 14.05.1933, Kornilova V.S.; Balkhash-Alakul district, Alma-Ata oblast, Ili station, sands, 09.05.1934, Geld A.I.; Priaralie district, Aral Sea, Barsa-Kelmes island, 1935, Nazarov M. V.; Zailiyskiy Alatau, Zailiyskiy Alatau ridge, Kastek gorge, 25.05.1936, Dmitrieva A. A.; Chu-Iliyskiye mountains, Utyugun river vicinities, shallow soils, 01.06.1936, Kubanskaya Z. V.; Zailiyskiy Alatau, Alma-Ata, on slopes on foothills, 17.05.1936, Shishkin B.K.; Zailiyskiy-Kungai Alatau, vicinity of Alma-Ata, Poganki river gorge, near the path on the slope, 06.06.1936, Shishkin B. K.; Zailiyskiy Alatau, Kastek district, closer to Kastek river gorge, near Dzhilda-Saya, 24.05.1936, Linchevsky O. A.; Dzungarian Ala Tau, Southern slope of Dzungarian Ala Tau, Keityn tract, stony slope, 13.06.1937, Rubtsov N. I.; Zailiyskiy Ala Tau, Syugaty mountains, stony slopes, 14.06.1937, Gorbunova E. P. P.; Dzungarian Ala Tau, Southern part, spurs of Dzungarian Ala Tau, May-Tyube station, about 53 passages, in shallow soils, 14.05.1937, Kubanskaya Z. V.; Karatau Mountains,

meadow slopes of foothills in the Mingelke Mountains, 08.05.1939, Pavlov N. V.; Betpak-dala, Central Betpak-dala, tract Kok-Ashik among caragannik, 21.05.1940, Rubtsov N. I.; Western Tien-Shan, western spur of Talas Alatau, Aksu-Dzhabagly reserve, overlog adjoining from the north to Aksu canyon, 30.05.1942, Karmysheva N. H.; Priaralie district, Aral Sea, Barsa-Kelmes Island, 06.05.1946, Platonov Y. G.; Chu-Ili Mountains, gorge Kulfiya-Basy tract, near old sheep barn, 13.05.1946, Fisyun V. V.; Djambul obl. V.; Djambul oblast, in a chiwnik on the Chu-Iliyskie Mountains schlefs near Kulakshino station, 23.05.1948, Pavlov N. V.; Chu-Ili Mountains, Chu-Ili watershed, Kopa River basin, near Targap settlement, intermountain valley, 03.06.1949, V. P. Goloskokov; Zailiyskiy-Kungei Alatau, on steppe slope of foothills, 11 km east of Alma-Ata, 22.05.1950, Polyakov P. P.; Djambul oblast, Chu-Iliyskiye mountains, in a thicket of chia near Otar station, 07.05.1951, Pavlov N. V.; Dzungarian Ala Tau, Southwestern spurs of Dzungarian Ala Tau, Chulak Moncha-sai mountains, on slopes among weedy places, near cattle herds, 29.05.1955, V. P. Goloskokov; Dzungarian Ala Tau, Southwestern spurs of Dzungarian Ala Tau, Matay mountains, foothill plain in the upper reaches of Kara-Kaska river near Koyankoz, 17.06.1956, Goloskokov V. P.; Dzungarian Alatau, Southern spurs of Dzhugar Alatau, Altyn-Emel ridge, Tyulkuli Mountains, along the southern stony slopes in the gorge of the Tyulkuli River, 30.06.1956, Goloskokov V. P.; Dzungarian Ala Tau, Southern part, Southwestern spurs of Dzungarian Ala Tau, Karakaska River basin, on deposits near Shanghai MTS, 24.05.1959, Goloskokov V. P.; Dzungarian Ala Tau, Southwestern spurs of Dzungarian Ala Tau, hill 1107 n.a. of the highway near Krasnogorovka, along the slope of the hill, 25.05.1959, Goloskokov V. P.; Dzungarian Ala Tau, Northern spurs of Dzungarian Ala Tau, along plumes near Antonovka, in wheat crops, 08.06.1959, Goloskokov V. P.; Dzungarian Ala Tau, Southern part, Western spurs of Dzungarian Ala Tau, on plumes near Sary-Agach settlement, in weedy places, 06.06.1959, Goloskokov V. P.; Dzungarian Alatau, Southern part, Western spurs of Dzungarian Alatau, near the pass saddle to Mukry village, on steppe slope, 17.06.1960, Roldugin I. I.; Balkhash-Alakul district, east Pribalkhashie, Akrkarly mountains, near Shengeldy village, on dry slopes, 25.06.1960, Roldugin I. I.; Zailiyskiy Alatau, Southwest extremity of Zailiyskiy Alatau, middle course of Karakunuz river (Chu river basin), along northern grassy slopes, 14.06.1963, V.P. Goloskokov; Zailiyskiy Alatau, Eastern spurs of Zailiyskiy Alatau, Syugatinskiye mountains, gorge near cordon, among bushes, 10.06.1963, Goloskokov V. P.; Kirghiz Alatau, foothill loess plain of Kirghiz ridge, ephemeral desert between Lugovaya and Dzhambul, 15.05.1963, Goloskokov V. P.; Karatau, plateau of Syrdarya Karatau, along grassy slopes, 26.05.1963, V. P. Goloskokov; Zailiyskiy-Kungei Alatau, eastern margin of Talgar, altitude 950 m, strongly dissected loess foothills, wormwood communities, 11.05.1994, M. P. Danilov; Zailiyskiy-Kungei Alatau, Almaty region, before Uzynagach on the highway Almaty-Bishkek, h~322 m., 18.05.2018, Sjedina I. A., Otradnykh I. G., Bilibayeva B. K., Zhumadilova A. M.; Kyrgyz Alatau, Zhambyl obl, Zhambyl district, behind the camp “Ruslan”, Nogaisai gorge on the stony eastern slope, altitude 1100 m, 14.05.2021, Kudabaeva G. M., Veselova P. V., Kerdyashkin A. V., Bilibaeva B. K., Osmonali B. B.;

15 herbarium sheets of storage, species *A. apennina (A. sibirica*) were revealed: Altai, Western Altai, Ivanovsky ridge, East Kazakhstan region, Ridder district, northern slope of Mount Kretovaya, 26.06.1937, Kuznetsov N. M.; Altai, Western Altai, north west of Ridder, on rocks of unnamed peak close to Mount Golukha, at a height of 1650 m. elevation, 31.07.1947, Polyakov P. P.; Saur-Tarbagatai, Tarbagatai ridge, foothills of the northern slope, in a hollow at an altitude of h~1600 m, 15.07.1948, Stepanova E. F.; Saur-Tarbagatai, Tarbagatai ridge, foothills of the northern slope, in a hollow at an altitude of 1600 m, 15.07.1948, Stepanova E. F.. F.; Saur-Tarbagatai, ridge, Tarbagatai, northern slope north of Khabar-Asu pass, 5 km, tipchak steppe, 15.08.1948, Stepanova E. F. F.; Altai, South Altai, Altai Tarbagatai, Bukhtarma basin, Urylka river near Uryl village, tract “Bakanaz”, altitude 1300 m, forest belt of north-western slope, 01.06.1955, Razlivalov G. M.; Saur-Tarbagatai, East Kazakhstan region, Tarbagatai district, Monrak ridge, northwest spurs, Tuyuk gorge, 26.05.1981, Rakityanskaya T. M.; Altai, South Altai, East Kazakhstan region, Tarbagatai ridge, Monrak ridge, northwest spurs, Tuyuk gorge, 26.05.1981. M.; Altai, Southern Altai, East Kazakhstan Region, Sarymsakty Ridge, southwest spurs, Tuyuk Gorge, 26.05.1981, Rakitianskaya T. Sarymsakty, south-eastern slope, Tekeli river valley, h~1600 m., 02.08.1985, Bialieva R. A.; Altai, Southern Altai, VKO, South Altai ridge, western part, northern slope, lower forest border, h~1800 m., 20.08.1986, Ivashchenko A. A. A.; Altai, Southern Altai, Chindagatui River on the way to the headwaters, near the 1st hut, h~1820 m., thin coniferous forest, with meadow-steppe grass and rock outcrop, 28.07.1986, Ivaschenko A. A.; Altai, Southern Altai, VKO, Southern Altai ridge, northern slope of the lower border of the forest, left bank of Kara-Kab, depression h~1840 m, 03.07.1987, Ivaschenko A. A. A.; Altai, Southern Altai, VKO, Southern Altai Ridge, 3 km east of the Pronikha River, forest, h~1300 — 1400 m, 27.07.1987,

Ivashchenko A. A. A., Isaev E. B.; Altai, Southern Altai, East Kazakhstan Region, Southern Altai Range, upper reaches of the Kara-Kaba River, left bank, in coniferous forest, 30.06.1987, Isaev E. B.; Altai, Southern Altai, East Kazakhstan Region, Southern Altai Range, upper reaches of the Kara-Kaba River, meadow glades in forest, 30.06.1987, Isaev E. B.; Altai, Central Altai, Berel, valley of the right bank of the Bukhtarma River, h~1500 m., reedgrass meadow at the top of the meadow of Kainar Mountain, 04.06.1999, Kudabaeva G. M.; Altai, Central Altai, left bank of the Bukhtarma River, h~1100 m., roadside scree on the road to Rakhmanovskie Klyuchi, 30.05.1999, Kudabaeva G. M.;

7 herbarium sheets of storage, species *A. chrysocyathus* were found: Zailiyskiy Alatau, East Talgar River, northern slopes under rocks, margins h~2600 m., 14.06.1936, Bykov B. A.; Zailiyskiy Alatau, Karga-Uldy river basin (Aksai-Kaskelen interfluve), moistened soils of subalpine belt, 05.07.1936, Goloskokov V. P.; Zailiyskiy Alatau, Malaya Almatinka, straight slot, upper reaches, 30.06.1936, Popov M. G.; Zailiyskiy Alatau, Issyk River, upper reaches of eastern sai (at the pass to Turgenskaya Tesken-su), grassy slopes, 2700 m. a.s.l., the river is located in the upper reaches of the river, 14.07.1937, Popov M. G.; Ketmen-Terskey Alatau, Tien Shan, Ketmen ridge, Karatau, upper reaches of the Sumbe river, 19.07.1962, Arystangaliev S.A.; Ketmen,- Terskey Alatau, Tien-Shan, Ketmen ridge, tract of Three Slits, alpine belt near snowfields, 19.07.1963, Arystangaliev S. A.; Ulutau, Kovylypolyno-typchak community, on light-chestnut soils of interfold plain, Dzhezkazgan region, Ulutau agriculture, 28.04.1979, Kazgiprozem;

13 herbarium sheets of storage, *A. parviflora* species were identified: Eastern Melkosopochnik, Songaria, in desertis fl. Ajagus djac., 31.05.1840, Schrenk A. G.; Western Melkosopochnik, Atassu, 05.1843, Dzungarian Alatau, Songaria, in vallibus montium Maitass, 1.06.1843, Schrenk A. G.; Schrenk A. G.; Mugodzhary mountains, Aktobe province, Bayurubai mountain, upper part of a gully falling from the mountain to the slope, small terrace on the slope falling to the gully, 21.05.1927, Rusanov F. N.; Chu-Ili mountains, vicinity of the Utyugun river, shallow hollow, 01.06.1936, Kubanskaya Z. V.; Zailiyskiy Alatau, Syugaty mountain, western stony slopes, 14.06.1937, Gorbunova E. P.; Betpak-dala, Central Betpak-dala, Kok-Ashik tract, among caragannik, 21.05.1940, Rubtsov N. I.; Dzungarian Alatau, Southern part, Southwest spurs of Dzungarian Alatau, Chulak, Moncha-sai mountains, on weedy places, near cattle camps, 31.05.1955, Goloskokov V. P.; Western Tien-Shan, Karjantau, Churgunus gorge at the place of former cattle camp, 31.05.1983, Samoilova V. A.; Kyrgyz Alatau, Western part of Kyrgyz Alatau, foothills at the entrance to the Aspara gorge, grasses, 17.05.1984, N. V. Nelina; Kyrgyz Alatau, southern macroslope, Kara-Archa valley, talweg, 28.05.1984, N. V. Nelina; Karatau, Karatau ridge, Birisek gorge, stony slope of southern exposure, 08.05.1989, Samoylova V. A.; Karatau, Turkestan ridge, Isfana and Lyaylek interfluves, Shaldybaldy tract, north-western slope, orange flowers, 23.04.2007, Tanybaeva M. R., Lazkov G. A.;

There were 9 herbarium sheets of *A. tianschanica* species: Dzungarian Alatau, Northern part, Lepsin district, 24.05.1940, Polyakov P. P.; Kungei Alatau, northern slopes of mountains above Kurmekty river, 15.05.1942, Lazarenko A. S.; Kungei Alatau, Kurmekty, southern slopes in exposition, among bushes, h~1800 m., 04.05.1942, Lazarenko A. S. S.; Kungei Alatau, Kurmekty, southern slopes in the exposition, among bushes, h~1800 m., 04.05.1942, Lazarenko A. S. S.; Ketmen-Terskey Alatau, area of the middle course of the river Kegen, western extremity of the mountains Shol-Adyr, among cereal-grass steppe, 15.08.1946, Rubtsov N. I., Stepanova E. F. F.; Dzungarian Alatau, western spurs of Dzungarian Alatau, Katurkain Mountains, upper reaches of Karagaily River, along northern steppe slopes, 27.05.1959, V. P. Goloskokov; Zailiyskiy-Kungai Alatau, Eastern extremity of Kungai Alatau ridge, Karkara river valley, hills along Iri-su river in 3 km from the highway to Kegen, 01.06.1966, Borjaev K. G. G.; Kungai Alatau, Eastern extremity of Kungai Alatau ridge, Karkara river valley, along Iri-su river 3-4 km from ford through Karkara river, 01.06.1966, Boryaev K.; Zailiyskiy-Kungai Alatau, Eastern spurs of Kungai Alatau ridge, hills and foothills along Irsu river, 03.06.1975, Lushpa O. U.; Kyrgyz Alatau, Eastern spurs of Kungai Alatau ridge, hills and foothills along Irsu river, 03.06.1975, Lushpa O. U. U.; Kyrgyz Alatau, Kyrgyz Alatau ridge, Toguzbulak tract (between Alamedin and Issyk-Ata rivers), grassy slopes up from the highway, 12.05.1976, Karmysheva N. H.;

Identified 2 herbarium storage sheets, species *A. vernalis*: Semipalatinsk hog, Semipalatinsk district, in a forest, 1931, Dmitrieva A. A.; Centr. Kazakhstan. Celinograd region, Lake Kurgaljin, Karazhar tract on the way to Kurgaljino settlement, 01.06.1976, A. Turganbekova;

There are 3 herbarium storage sheets of *A. villosa* species: Karkaraly, Songaria, in montibus Arkalyk et Arkat, 1841, Schrenk A. G.; Karkaraly, Songaria, in montibus Karkaraly, 06.1843, Schrenk A. G.; Altai, East Kazakhstan oblast, Zyryanovsky region, vicinity of Berezovka village, northern gentle, shrubby slope, 17.05.2004, Grebenyuk A., Ankova A.;

19 herbarium sheets of storage, species *A. volgensis* were identified: Spurs of the Common Syrt, Uralskaya province, Uralsk, vicinity of Bannov's garden in the steppe, 04.1918, Larin I. V.; Tobolo-Ishimsky, Akmolinsky vicinity, Sovenkovsky experimental site, steppe, 20.05.1920, Sheludyakova V. A.; Tobolo-Ishimsky, Akmolinsky vicinity, Sovenkovsky experimental site, on slopes and depressions, 26.04.1920, Sheludyakova V. A.; Spurs of the Common Syrt, Ural Province, Uralsk vicinity, Stepanov garden blooms, in steppe, bloomed, 03.05.1924, Larin I. B.; Aktobe province, Wil-Emba interfluve, ascent to Turkestan watershed between the rivers Wil and Temir, sandy grassy steppe, 28.05.1926, Rozhevits R. Yu, Avramchik M. N.; Aktobe province, Wil-Emba interfluve, 20 ver. south of Temir not reaching the watershed, sandy grassy steppe, 31.05.1926, Knorring O. E.; Spurs of General Syrt, Ural district, Teplovsky district, vicinity of farm Dzharykin, sandy sagebrush steppe, 05.06.1929, Dmitrieva A. A.; Spurs of the Common Syrt, Ural district, Teplovsky district, vicinity of Dzharykina farm, grassy steppe, 17.06.1929, Dmitrieva A. A.; Pre-Caspian, Ural district, Dzhambeity district, grassy steppe, 09.05.1930, Dmitrieva A. A.; Tobolo-Ishimsky, Kustanay district, Kel-Aralskaya volost, area of Zhukova farm, sandy chernozem, abundant, 04.1930, Dmitriev G.; Karaganda region, closer to Chechen-mountain settlement, sagebrush-typchak steppe, 24.04.1939, Linchevskiy O. A..; Northern Kazakhstan, Akmola region, Atbasar district, 3 km north-west of the central farmstead of Kiev state farm, 15.05.1954, Kurochkina L. Y.; Western Melkosopochnik, Akmola region, Atbasar district, right bank of the river Kayrakty, on slopes to the bank, 22.05.1954, Lushpa O. U.; Akmola region, Atbasar district, Malogum, black earth of type plains steppe north of the river Kayrakty, 14.05.1954, Kisykov U. U.; Akmola region, Atbasar rayon, Malogum, chernozem type plains steppe north of the river Kayrakty, 14.05.1954, Kisykov U. K.; Western Melkosopochnik, Akmola region, Atbasar district, Ostrovsky State Farm. Kovilnaya steppe, 10.05.1954, Lushpa O. U.; Tobol-Ishimskiy, Northern Kazakhstan, Kustanay city vicinity, soil station of the Institute of Soil Science, Tselina, 09.06.1968, Sokolov S. A.; Aktobe region, Aktobe district, floodplain of Butak river, 05.1991, Aipeisova S.; Akmola region, vicinity of Korgalzhyn village, h~343 m., 06.2019, Kubentayev S.; Akmola region, vicinity of Kara egin village, altitude h~381 m., 29.04.2019, Kubentayev S.

In the funds of the Al-Farabi Kazakh National University herbarium specimens were from 18 actual place of growth. There were found 5 species of genus *Adonis* L. from the flora of Kazakhstan:

7 herbarium storage sheets, species *A. aestivalis* were identified: Alma-Ata vicinity, Botanical Garden, counters, 17.05.1933, Geld A.; Zailiyskiy Alatau, Talgar vicinity, southern tip, northern slope, 06.06.1936, Belousova; KSSR, Aral Sea, Barsa Kelmes Island, north-east of the factory, 27.05.1940, Demchenko L.; Alma-Ata vicinity, Kauchukpromkhoz, No. 13, Krym-sagyz crops, 29.04.1942, Kornilova; Almaty region, Uigur district, Aksu village, 25.05.1954, Mansurova, Kibirova; Alma-Ata region, Kegen district, collective farm named after Gorky, Kuluk-tau, Dalayty-say gorge, 06.07.1954, Terekhov; Ketmen-tau ridge, Bolshoy Kirgizsky gorge, steppe slopes, south-western slope, 20.07.1972, Ospanova, Yereshika (Fig. 1).

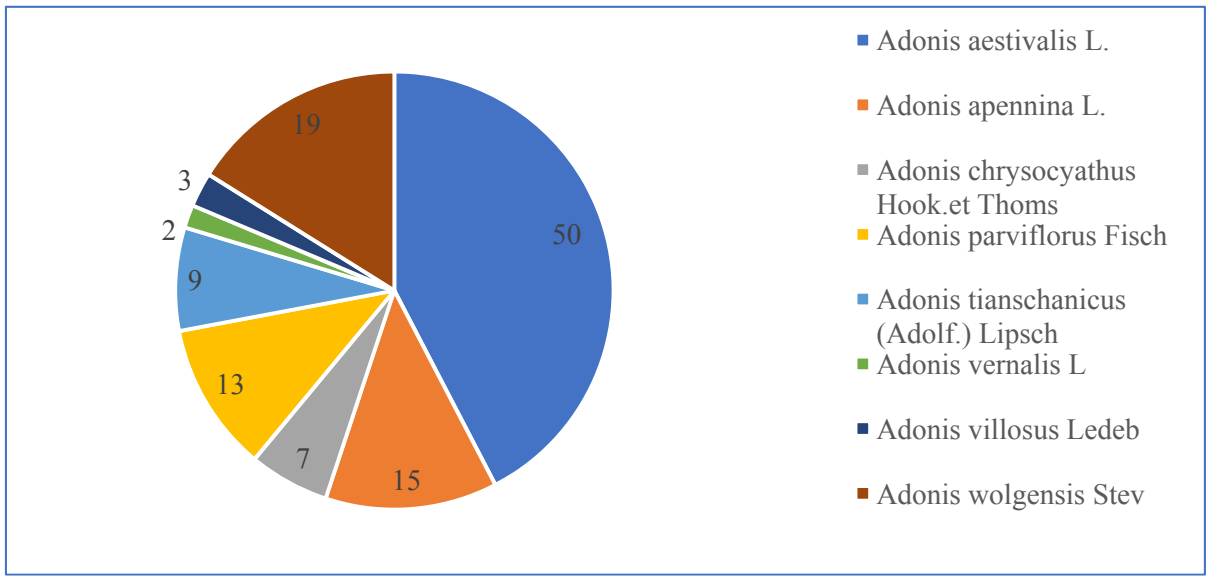

Figure 1. Herbarium collections of *Adonis* L. species, Institute of Botany and Phytointroduction (AA)

3 herbarium sheets of storage, species *A. chrysocyathus* were found: Eastern Talgar, h~2600 m, 14.06.1936, Bykov B.; Zailiyskiy Alatau, Kargauyldy, moistened slopes of subalp, 05.07.1938, Bykov B.; Zailiyskiy Alatau, Issyk Gorge, northern slope h~2800, near rocks, 17.06.1938, Bykov B.;

4 herbarium sheets of storage, species *A. parviflora* were found: KazSSR, Aral Sea, Barsa-Kelmes Island north-east of the factoria, 27.05.1940, Demchenko L.; KazSSR, Aral Sea, Barsa-Kelmes Island, gray earth loam, 27.05.1940, Demchenko L., Pavlov U.V.; KazSSR, Dzhambul obl., in chievnik on Chu-Ili mountains shleiv near Kulakshina station, 23.05.1948, Pavlov N.V.; KazSSR, Right bank of Ili river 5–10 km south of Tash-Murun, sandy valley, 11.05.1962, Iksanov N.V., Iksanov N.V.; KazSSR, Ili river, 5–10 km south of Tash-Murun, sandy valley, 11.05.1962, Iksanov N.V.; KazSSR, Ili river, 5–10 km south of Tash-Murun;

3 herbarium sheets of storage, species *A. tianschanica* were revealed: Kungei Alatau, Kegensky Alatau, steppe, 11.06.1935, Kornilova V.S., Bykov B.; Kegensky district, 11.06.1935, Kornilova V.S., Bykov B.; Alma-Ata region, Narynkol district, Akbiet village, Southern slope of Akbiet tract, 19.07.1954, Terekhov V.I.;

Identified 1 herbarium sheet of storage, species *A. villosa*: KazSSR, East-Kazakhstan oblast, neighborhood of Shemonaikha, in hollows of slopes among shrubs, 04.05.1946, Solomchenka (Fig. 2).

The herbarial leaves of the species *A. apennina* (*A. sibirica*), *A. wolgensis* and *A. vernalis* are absent.

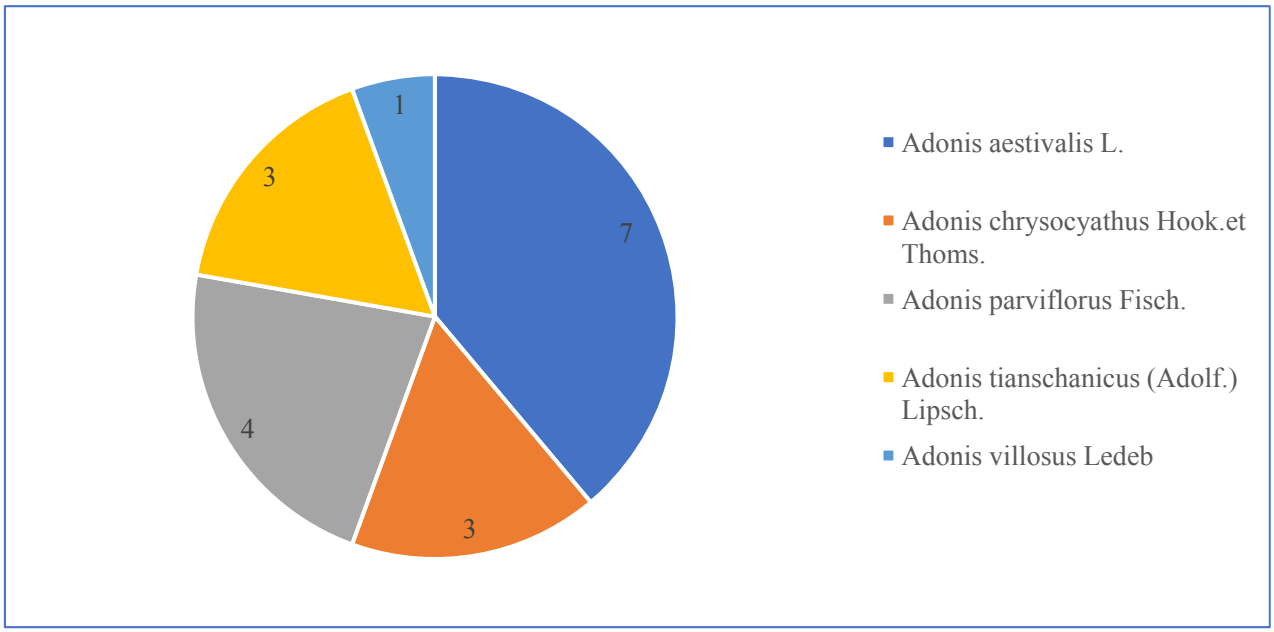

Figure 2. Herbarium collections of *Adonis* L. species, Al-Farabi Kazakh National University

The following herbarium sheets are represented in the DAPO and KIR herbarium collections of 4 species of the genus *Adonis* L. in the study area (Fig. 3): 2 herbarium storage sheets of *A. parviflora* species were found: Alma-Ata region, Turgenskoye gorge, slope, 05.05.1981, Kazenas; Djambul region, Talas district, Intermountain valley, on meadow gray loamy soils, 06.06.1986, Dementeva I. V., Romanova T. G.;

2 herbarium sheets of storage, species *A. aestivalis* were revealed: Chimkent oblast, Aksu-Dzhabagly reserve, middle mountain h~1900 m, lower part on dark brown soils, 10.06.1970, Usenoko, Kazenas; Djambul oblast, Merken district, rural orkug Pobeda, complicated sands, 27.04.19, Strelnikov;

2 herbarium storage sheets of *A. wolgensis* species were found: Dzhezkazgan region, Ulutau district lands, 28.04.1979, Kazenas O. D.; Semipalatinsk region, Ayaguzovsky district, Akchatau farm, 16.05.1981, Yakovlev;

1 herbarium storage leaf of the species A. vernalis was found: Semipalatinsk region, Ayaguz district, interspot depression, on meadow-chestnut soils, 24.04.1983, Victorov E. E., Kazenas O. D.;

Herbarium materials of species of the genus *Adonis* L. collected from the territory of Kazakhstan, in herbarium funds of MSU, Faculty of Biology, Department of Geobotany, Laboratory Herbarium revealed the following herbarium storage sheets:

Only 3 herbarium sheets of the species *A.apennina (A.sibirica*) are represented in the herbarium collection of MSU (Fig. 4): Southern Altai, Sarymsakty Mountains, vicinity of Katon-Karagai, forest meadow, 10.05.1962, Seregin A. P.; Western (Kazakhstan) Altai, Katon-Karagai district, East Kazakhstan region, 13.08.1972, Pimenov M.; Western (Kazakhstan Altai), East Kazakhstan region, Auezov street, Katon-Karagai district, 15.08.1972, Voronov A. G.;

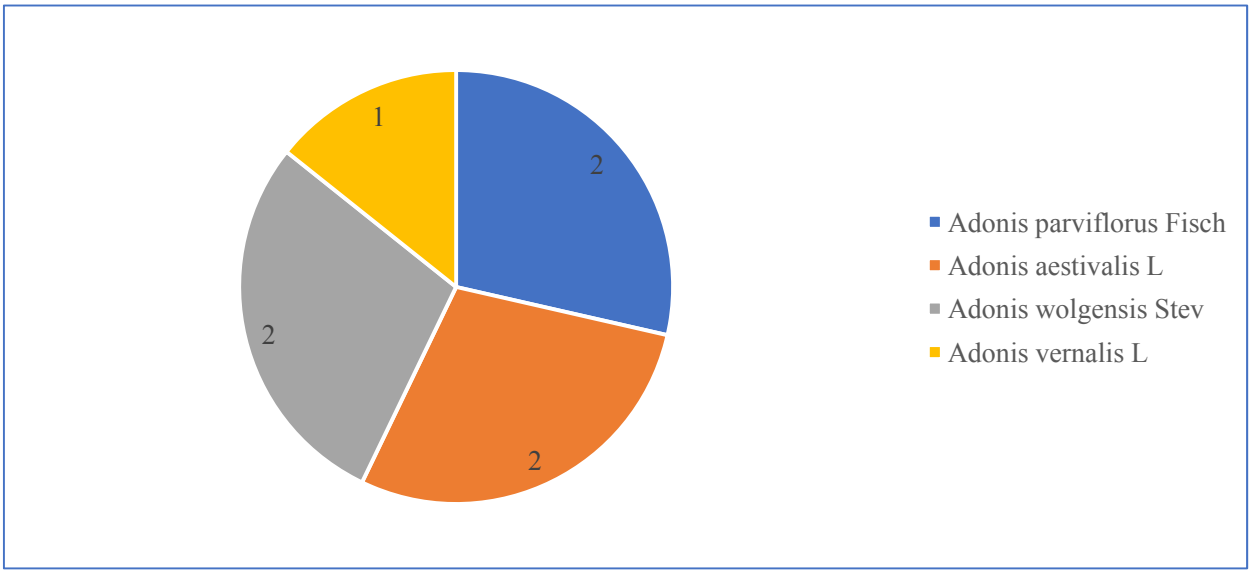

Figure 3. Herbarium collections of species of *Adonis* L., DAPO and KIR

Herbarium fund of MSU is presented only 2 herbarium sheets of *A. villosa* species: East Kazakhstan region, vicinity of Skalistoe village, 40 km south of Ust-Kamenogorsk city, Valley of steppe brook, on a slope, 27.04.1987, Smirin V.M.; East Kazakhstan, vicinity of Leninogorsk, steppe slopes of mountains, 05.1969, A.P. Poshkurlat.

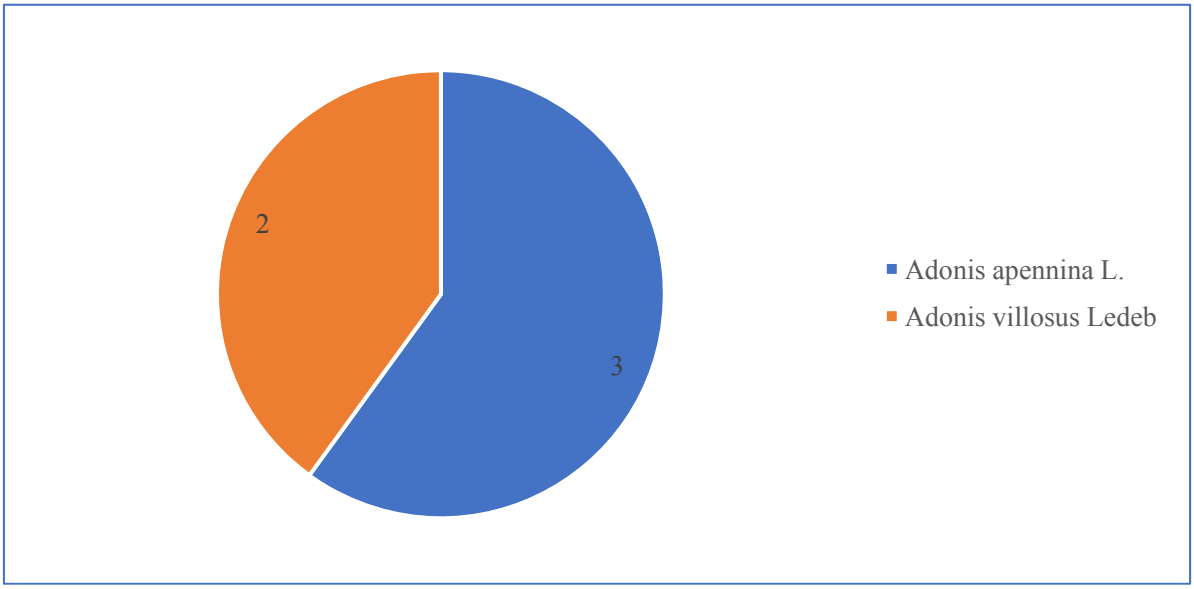

Figure 4. Herbarium collections of *Adonis* L. species, Herbarium Fund of MSU

Conclusions

The largest number of specimens of *A. aestivalis* (50) is represented in the herbarium collection of the Institute of Botany, while other collections reviewed contain a minimum number of specimens of this species. The analysis of the species' places of occurrence indicates its greatest representation in the Kungai Alatau. However, individual specimens were recorded in the territory of Almaty and Jambul regions along the Chu River, as well as in general in the territory of the Zailiyskiy Alatau. The species is confined to the heights of mountains, to rocky and wet habitats, as well as to sandy soils. Of the analyzed specimens of Adonis apennina L., 15 are represented in the collection of the Institute of Botany and Phytointroduction (AA) and *A. chrysocyathus* 7 specimens, *A. parviflora* 13 specimens, *A. tianschanica* 9 specimens, *A. vernalis* 2 specimens, *A. villosa* 3 specimens and *A. volgensis* 19 specimens, growing in Dzungarian Alatau, along the Talgara and Malaya Almatinka rivers and in Central Kazakhstan. The species grows on moist soils along coniferous trees, along river banks, on mountains, on stony slopes. The studied genus in the collection of DEPO is represented in small herbarium sheets, in collections of MSU and KazNU practical not collected and not studied, thus these species of the genus is endangered.

All specimens viewed date mainly from 1932–1972, modern collections are extremely scarce. Thus, research is needed to identify the current state of biodiversity of species and their natural growing points of these species.

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Adonis L. туысы түрлерінің таралу аймағын зерттеу

Мақалада *Adonis* L. туыс түрлерінің Қазақстанда таралуы туралы мәліметтер келтірілген. *Adonis* туыс түрлерінің заманауи таралу орындарын әрі қарай нақтылау және түгендеу мақсатында ботаникалық ұйымдардың негізгі гербарий қоры зерттелді. Жүргізілген талдаулар түрлердің ең көп кездесетіні Алматы облысына тиесілі екенін көрсетті. Қазақстанда таралуын нақтылау және *Adonis* L. туысы түрлерінің өсу нүктелерін құру үшін әл-Фараби атындағы ҚазҰУ, Ботаника және фитоинтродукция институты, Алматы қаласының АТЗ және КІЖД, Мәскеу мемлекеттік университетінің цифрлық гербарийы бойынша жалпы 148 гербарий парағы (1843-2021 жж.) қаралып, өңделді. Негізінен олар 1843 жылдан басталса, ең көп саны 1940-1972 жылдарға тиесілі, ал негізгі коллекторлар С.А. Арыстанғалиев, Б.Быков, Н.В. Павлов, А.А. Иващенко. Қазақстан флорасында *Adonis* L. туысының 8 түрінің 148 нақты өсу нүктесі анықталды, олар: *Adonis aestivalis* L., *Adonis apennina* L. (*Adonis sibirica* Patr.ex Ledeb.), *Adonis chrysocyathus* Hook.f. & Thomson*., Adonis parviflora* Fisch*., Adonis tianschanica (*Adolf*.)* Lipsch., *Adonis vernalis* L., *Adonis villosa* Ledeb., *Adonis volgensis* Steven ex DC. *Adonis* L. туысы түрлерінің көбісі Жоңғар Алатауында, Батыс Алтайда, Тарбағатай және Іле-Күнгей-Алатауында анықталды, олар сирек кездеседі және саны азаюда. Географиялық тұрғыдан ең көп тарағандары *A. aestivalis, A. parviflora* және *A. tianschanica*. Жүргізілген зерттеу *Adonis* L. туысының Қазақстан флорасындағы түрлері мен таралуы туралы ақпаратты жүйелеуге, нақтылауға және толықтыруға мүмкіндік берді.

Кілт сөздер: таралу, гербарий, флористикалық аймақтар, есепке алу, Қазақстан.

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Изучение ареала распространения видов рода *Adonis* L.

В статье представлены данные о распространении видов рода *Adonis* L. в Казахстане. С целью дальнейшего уточнения мест распространения и инвентаризации современного произрастания видов рода *Adonis* был изучен основной Гербарный фонд ботанических организаций. Проведенные анализы показывают, что наибольшая встречаемость видов отмечена в Алматинской области. Для уточнения распространения и составления точек встречаемости видов рода *Adonis* в Казахстане было просмотрено и обработано 148 гербарных листов (1843–2021) из Казахского национального университета имени Аль-Фараби, Института ботаники, ДАПО и КИР и цифрового гербария Московского государственного университета. Представлены сборы с 1843 г., наибольшее количество сборов приходится на 1940–1972 гг., и основными коллекторами являются С.А. Арыстангалиев, Б. Быков, Н.В. Павлов, А.А. Иващенко. Было выявлено 148 фактических мест произрастания для 8 видов *Adonis* из флоры Казахстана: *Adonis aestivalis* L., *Adonis apennina* L. (*Adonis sibirica* Patr.ex Ledeb.), *Adonis chrysocyathus* Hook.f. & Thomson*., Adonis parviflora* Fisch*., Adonis tianschanica (*Adolf*.)* Lipsch., *Adonis vernalis* L., *Adonis villosa* Ledeb., *Adonis volgensis* Steven ex DC. Видовое разнообразие *Adonis* L. установлено в Джунгарском Алатау, Западном Алтае, Тарбагатайском и Иле-Кунгей-Алатау, которые классифицируются как редкие и их численность сокращается. Географически наиболее распространенными являются *A. aestivalis*, *A. parviflora* и *A. tianschanica*. Проведенное исследование позволило систематизировать, уточнить и дополнить информацию о видовом разнообразии и распространении рода *Adonis* L. во флоре Казахстана.

Ключевые слова: распространение, гербарий, флористические регионы, инвентаризация, Казахстан.

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Application and research progress of acupuncture and moxibustion therapy in sports medicine: a short review

The theoretical basis of acupuncture and moxibustion in traditional Chinese medicine is recognized as "dredging meridians, promoting blood circulation, and removing blood stasis". In modern medical theories, the mechanism of acupuncture and moxibustion is discussed as "analgesia, improving the microenvironment, influencing hormone release and inflammatory mechanism". Many studies have confirmed its healing effects and established it as an effective method for treating sports medicine conditions. The application of acupuncture and moxibustion in the treatment of sports medicine conditions, such as tendinopathy, myofasciitis, ligament injury, peripheral nerve injury, tendon and bone healing, has been analyzed to understand its clinical efficacy and mechanism. Although acupuncture and moxibustion are widely used in sports medicine conditions, most of the current studies are retrospective and lack randomized double-blind controlled trials. Future research should include more randomized double-blind trials, using multi-center and large sample clinical observation, to further confirm the efficacy of acupuncture and moxibustion in the treatment of sports medicine disorders and improve its clinical application.

Keywords: acupuncture therapy, moxibustion therapy, sports medicine, curative effect, traditional Chinese medicine, tendinopathy, myofasciitis, ligament injury.

Introduction

Acupuncture, which includes both "needle" and "moxibustion", is an important part of traditional Chinese medicine. Throughout its origin, practice and historical development, acupuncture has preserved distinct Chinese cultural and regional characteristics. It has also spread throughout the world as a valuable heritage of Chinese national culture and scientific tradition. The clinical application acupuncture and moxibustion therapy is characterized by its simplicity, cost-effectiveness, safety and reliability, and remarkable efficacy. This therapy is widely used in various medicinal fields, including internal medicine, surgery, gynecology, pediatrics, and more (Fig.). With the continuous progress of the aging society, the incidence of various sports medicine diseases such as tendinopathy, myofascitis, ligament injury, peripheral nerve injury, and tendon-bone injury is increasing. These conditions now account for 60 % to 70 % of orthopaedic outpatient visits. The high prevalence of sports medicine conditions imposes a significant economic burden on individuals and society, highlighting the need for cost-effective treatments with excellent curative effects. Acupuncture is recognized as a leading traditional medical treatment in 113 countries worldwide.

Acupuncture was first legalized in Nevada and California in 1972, and has since been approved in 44 states and Washington, D.C. In Canada, for example, comprehensive acupuncture coverage is as high as

88 %, demonstrating its therapeutic efficacy. However, the increased popularity of acupuncture and moxibustion has also led to complications, including infection, central nervous system damage, and even death. This paper reviews the research progress of acupuncture in the treatment of various sports medicine conditions by reviewing the relevant literature.

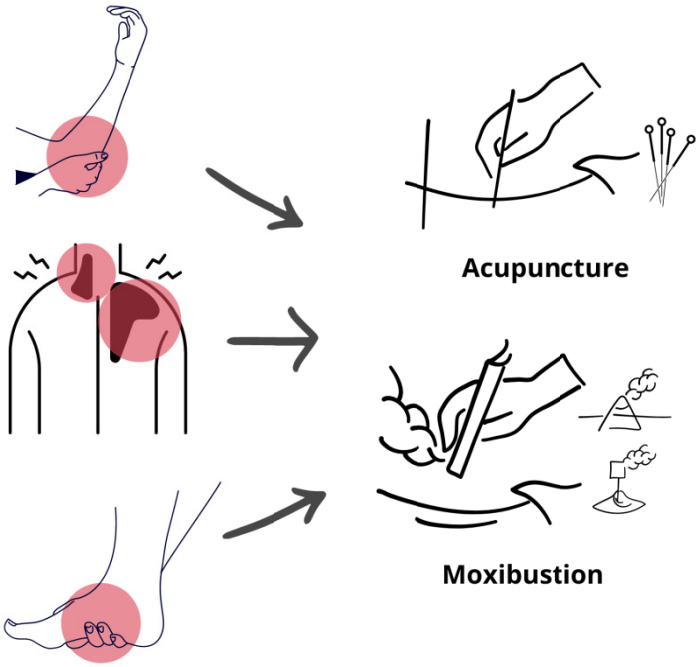

Figure. Acupuncture (practice puncturing the skin with needles) and moxibustion therapy (practice that entails burning dried mugwort) application

1 Tendinopathy

Tendinopathy refers to degenerative changes in tendon tissue caused by overexertion, minor trauma, or exposure to cold. It is characterized by aseptic inflammation, with clinical manifestations primarily including pain and dysfunction. This condition has a significant impact on the patient's daily life and work, resulting in significant disability. Among the various types, supraspinatus tendinitis is a common shoulder disorder, with epidemiologic studies indicating a high prevalence in young and middle-aged individuals, with an incidence rate of approximately 20 %. Achilles tendinopathy occurs in approximately 11 % of track and field athletes, 9 % of dancers, and 7 % to 9 % of elite distance runners. The unique lifestyle demands of athletes often result in recurrent tendinopathy, severely limiting their athletic careers. Currently, the clinical management of tendinopathy consists mainly of symptomatic supportive care, which is often not very effective [1].

In Traditional Chinese Medicine (TCM), tendinopathy is classified under the category of “myobi”. The theoretical mechanism of TCM attributes tendinopathy to the invasion of external pathogens, blocked qi and blood flow, blood stasis and meridian obstruction. Acupuncture and moxibustion can dilate local blood vessels, accelerate blood flow, promote inflammatory absorption, and facilitate tissue repair. These therapies also warm the meridians, promote qi and blood circulation, disperse blood stasis, and eliminate pathogenic factors, achieving good therapeutic effects in the clinical treatment of tendinopathy. For example, Huang treated patients with quadriceps tendon terminal disease with warm acupuncture and moxibustion, achieving cure in 9 cases, effectiveness in 6 cases, and ineffectiveness in 1 case, with a total effectiveness rate of 93.8 %. In clinical practice, acupuncture and moxibustion are often combined with other treatments. A study of 50 cases of supraspinatus tendinitis treated with acupuncture and massage reported an overall efficacy rate of 96.0 % [2]. Zhao et al. treated 30 cases of biceps brachialis tendinitis with acupuncture and acupoint injection; 12 cases were cured after one course of treatment (acupuncture once a day, five sessions per course), 15 cases after two courses, and one case after three courses. In another study of 41 patients with supraspinatus tendinitis, 21 were randomly assigned to a treatment group (acupuncture combined with shoulder joint loosening training) and 20 to a control group (injection of 2 % lidocaine hydrochloride with triamcinolone ace-

tate). The overall efficacy rate was 100 % in the treatment group compared to 65 % in the control group. Papa, a Canadian scientist, reported a successful case of Achilles tendinopathy treatment with acupuncture and moxibustion, noting significant pain relief and restoration of lower limb function after nine weeks of treatment. No recurrence was observed after 12 months of follow-up, demonstrating the efficacy of acupuncture and moxibustion in the treatment of Achilles tendinopathy [3, 4]. In addition, British researchers have suggested that acupuncture may relieve pain and stimulate the release of growth factors in the treatment of tendinopathy, although the specific mechanisms require further experimental confirmation.

2 Myofasciitis

Myofasciitis is a pain syndrome characterized by tension in muscle cords, highly localized and irritating trigger points, referred pain to other areas of the body, and referred depression. It commonly affects the neck, back, and buttocks. Clinically, myofasciitis is often accompanied by anxiety, depression, sleep disturbances, and other mental health issues that can exacerbate pain and dysfunction, creating a vicious cycle. Myofasciitis itself is not a self-limiting disease; it can also cause referred pain or inhibition in muscles other than the one where the pain is located, leading to persistent dysfunction. Foreign epidemiologic studies have shown that the incidence of low back pain in the population is about 62 % to 86 %, and 85 % of these patients suffer from myofascial pain. The most common age range for this condition is 30 to 50 years, but it is increasingly affecting younger people. It affects approximately 44 million people in the United States and has an annual economic impact of $47 billion. The most common treatment for myofasciitis is conservative oral drug therapy, primarily non-steroidal anti-inflammatory drugs (NSAIDs). However, these drugs have significant side effects and are relatively expensive, making patients reluctant to use them. Acupuncture and moxibustion have been widely used in clinics for the treatment of myofasciitis and have shown obvious curative effects [5].

In TCM, myofasciitis is considered a form of “myobi” and myocoagulation syndrome. The etiology and mechanism are primarily explained by the sluggish operation of local Qi and blood, often due to liver and kidney deficiency or tendon injuries caused by labor. This, combined with external factors such as wind, cold and dampness, can lead to tendon and vein damage and, in severe cases, muscle obstruction and Qi and blood stasis [6]. Acupuncture and moxibustion play a role in dredging meridians and collaterals, regulating Qi and blood, and can achieve the effects of fuzhen (strengthening the body's resistance) and dispelling evil spirits after treatment. In a study, Ding Xiyan and Liu Shunyi treated 30 patients with back muscle myositis using acupuncture once a day for three days as a single treatment. The results showed that 19 cases were cured, 11 cases were effective, and none were ineffective, with a 100 % effectiveness rate. Another clinical trial of 78 patients with myofascial pain syndrome compared acupuncture and shock wave therapy. After 20 days, the significant efficacy of the acupuncture group was 84.6 %, compared with 61.5 % in the shockwave group, indicating that acupuncture had a better effect on myofascial pain syndrome [7]. In addition, combining acupuncture and moxibustion with other treatments has been shown to be more effective. In one study, patients were treated with a combination of scraping and warm acupuncture and moxibustion, while the control group received acupuncture and moxibustion alone [8]. The results showed that the significant efficacy of the control group was 84.0 %, while all patients in the treatment group showed significant improvement. Another study by Wu et al. randomly divided 120 patients with lumbar and back myofasciitis into two groups: the treatment group received acupuncture and moxibustion combined with acupuncture and bloodletting, while the control group received acupuncture alone. The results showed that the efficacy rate was significantly higher in the treatment group (91.67 %) than in the control group (71.67 %), suggesting that combining acupuncture and moxibustion with other methods can achieve better efficacy in the treatment of myofasciitis [9].

3 Ligament injuries

When a ligament is subjected to external direct or indirect forces, it can experience abnormal physiological stress, resulting in excessive stretching. If the force exceeds the ligament's tolerance, an injury can result. In Finland, with a population of only 5 million, more than 200,000 cases of acute tendon injuries occur each year. In the United States, approximately 30 % to 50 % of sports injuries are tendon strains. Approximately 100,000 to 200,000 patients suffer ACL injuries each year, or about 1 in 3,000 people. In addition, more than 51 % of people over the age of 80 experience a rotator cuff injury each year. The high prevalence of tendon injuries places a significant financial burden on healthcare systems worldwide. For example, direct medical expenditures for rotator cuff repair in Australia exceed $250 million per year, while the U.S. government spends more than $7 billion annually on rotator cuff injuries [9].

In TCM, ligament injuries are often classified as “Bi Syndrome”. The acupuncture and moxibustion treatment approach combines the principles of “pain as transfusion” and meridian-based acupuncture point selection, which not only provides effective analgesia, but also promotes circulation, reduces swelling and increases blood flow. This approach helps restore normal muscle and joint function. Acupuncture and moxibustion have been widely used in the clinical treatment of ligament injuries, with numerous studies confirming its therapeutic benefits. For example, studies have shown that acupuncture can significantly improve the recovery of proprioception in patients with lateral ankle ligament injuries, often surpassing the results of conventional physical therapy [10]. Kasuya conducted a study in which 60 patients with old lateral collateral ligament injuries of the interphalangeal joints were randomly divided into an acupuncture group and a physiotherapy group. The acupuncture group received mild moxibustion, while the physiotherapy group was treated with TDP irradiation. After 20 days of treatment, the overall excellent, good, and optimal rates were significantly higher in the acupuncture group (83.3 % and 56.7 %, respectively) than in the physiotherapy group (76.7 % and 36.7 %, respectively). These results suggest that acupuncture and moxibustion are particularly effective in the treatment of old interphalangeal joint collateral ligament injuries [11]. In another study, Zhang et al. treated 40 patients with ankle ligament injuries with acupuncture. The duration of treatment ranged from 5 days to 20 days, with an average of 10 days. The final results showed a 98 % cure rate with acupuncture therapy [12]. These results suggest that acupuncture is effective in treating various ligament injuries, providing benefits such as pain relief, improved circulation, and faster recovery of joint function.

4 Peripheral nerve injuries

Peripheral nerve injury is one of the most common conditions in sports medicine with a high incidence rate. An epidemiologic survey indicates that there are approximately 170,579 cases of upper extremity nerve injury annually in the United States. In addition, peripheral nerve injuries often result in a high rate of disability, causing limb dysfunction in patients and significantly impacting their quality of life. The treatment and rehabilitation process for these injuries can be lengthy and costly, with an annual growth rate of 9.59 %. This places a significant financial burden on families and society. Despite advances in surgical techniques and pharmacological treatments, recovery of nerve regeneration is typically slow, overall outcomes are not always satisfactory, and treatment costs remain high. There is an urgent need for comprehensive therapies to improve the rehabilitation of peripheral nerve injuries [13].

In TCM, peripheral nerve injuries are categorized under terms such as “tendon injury”, “Bi syndrome” and “impotence syndrome”. Lu et al. reported successful treatment of ulnar nerve injury with acupuncture. In their study, a patient with a completely severed ulnar nerve and partial muscle damage due to a sharp instrument cut on the forearm received acupuncture treatment after surgical suture and conventional rehabilitation therapy. Acupuncture was applied to the ulnar nerve sulcus and innervated dorsal hand area, and low-frequency electrical stimulation (2 Hz, 6 mA) was applied once a week for six months. The patient reported pain relief within the first month, gradual recovery of motor function by the third month, and was able to return to work. By the sixth month, the patient's motor and sensory functions had almost returned to normal [14]. Another study by Chang et al. examined the effectiveness of acupuncture in the treatment of peripheral nerve injury. Patients were randomly assigned to one of three groups: electroacupuncture alone, warm acupuncture alone, or a combination of electroacupuncture and warm acupuncture. Treatment was administered daily for 45 days. The study found that the combination of warm acupuncture and electroacupuncture was significantly more effective than the other two treatment modalities, as evidenced by improvements in knee osteoarthritis [15]. Anandkumar and Manivasagam also investigated the efficacy of acupuncture in the treatment of cubital tunnel syndrome. They evaluated functional outcomes after ulnar nerve repair using the Lascar grading method. The results showed that patients in the acupuncture group had significantly better improvements in the Visual Analog Scale score and motor sensory function of the hand compared to the control group [16].

5 Tendon-bone healing

The effectiveness of tendon-bone healing is a critical determinant of the success of postoperative ligament repair and reconstruction procedures. This is especially true for patients undergoing procedures such as knee cruciate ligament, lateral collateral ligament, posterolateral stress reconstruction, shoulder rotator cuff repair, or ankle ligament reconstruction. The extent of tendon-bone healing has a direct impact on the postoperative rehabilitation process and overall surgical outcome. Although there are relatively few direct studies on the effects of acupuncture on tendon-bone healing, some research indirectly supports the beneficial role of acupuncture in this area. Rha et al. conducted a study in which 39 patients with supraspinatus tendon injuries were divided into two groups: one treated with acupuncture and moxibustion, and the other treated with ul-

trasound-guided platelet-rich plasma injections. After six months of follow-up, shoulder pain and disability scores were significantly lower in the acupuncture group (17.7±3.7) than in the platelet-rich plasma group (29.5±3.8). This finding suggests that acupuncture is superior to platelet-rich plasma in the treatment of supraspinatus tendon injuries, and numerous studies have confirmed that platelet-rich plasma significantly aids in promoting tendon and bone healing [17]. Yu et al. conducted another study in which 60 patients who had undergone rotator cuff repair were randomized into two groups. The control group received standard postoperative rehabilitation training, while the observation group received the same treatment combined with warm shoulder acupuncture three times for 12 weeks. The results showed that the observation group had significantly better results in VAS and Constant-Murley scores ($P<0.05$) compared to the control group. This indicates that warm acupuncture can enhance the recovery of shoulder joint function, reduce pain, and promote tendon and bone healing in patients after rotator cuff repair [18].

Conclusion

Acupuncture and moxibustion have been used extensively in the treatment of sports-related disorders, with promising results. However, most studies to date are retrospective and lack the rigor of randomized, double-blind, controlled trials. Future research should focus on conducting more randomized, double-blind trials to validate the efficacy of acupuncture in the treatment of sports medicine conditions. In addition, these studies should aim to explore the mechanisms of action through multicenter and large-sample clinical observations. In conclusion, acupuncture and moxibustion offer definitive therapeutic benefits for sports medicine disorders, with the advantages of being cost-effective and having minimal adverse effects, making them worthy of wider clinical adoption and application.

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Спорттық медицинадағы инемен емдеу мен күйдіру терапиясының қолданылуы мен ғылыми-зерттеу жетістіктері: қысқаша шолу

Дәстүрлі қытай медицинасының теориялық шеңберіндегі инемен емдеу мен күйдіру терапиясының теориялық негізі «меридиандарды тереңдету, қан айналымын ынталандыру және тоқырауын жою» әдісі деп танылады. Қазіргі медициналық теорияларда инемен емдеу мен күйдіру механизмдері «анальгезия, гормондардың бөлінуіне және қабыну механизміне әсер ететін микроортаның жақсаруы» ретінде талқыланады. Көптеген зерттеулер оның емдік әсерін растады және ол спорттық медицинада тиімді емге айналды. Спорттық медицина ауруларын емдеуде инемен емдеу мен күйдіру терапиясының мүмкіндіктері талданды, сонымен қатар тендинопатияны, миофасцитті, байламдардың зақымдануын, перифериялық нервтерді, сіңірлер мен сүйектерді емдеуді және басқа ауруларды емдеуде инемен емдеу мен күйдіруді қолданудың клиникалық тиімділігі мен механизмі зерделенген. Инемен емдеу мен күйдіру спорттық медицина ауруларында кеңінен қолданылғанымен, қазіргі зерттеулердің көпшілігі ретроспективті және қос соқыр рандомизацияланған бақыланатын сынақтарсыз жасалған. Сондықтан, болашақ зерттеулерде инемен емдеу мен күйдіру спорттық медицина ауруларын емдеудегі тиімділігін одан әрі растау және клиникада жақсырақ қолдану үшін қос соқыр рандомизацияланған бақыланатын сынақтарды үлкен іріктеумен көп орталықты клиникалық бақылаулар жүргізу керек.

Кілт сөздер: ине рефлексті терапия, күйдіру терапиясы, спорттық медицина, емдік әсері, дәстүрлі қытай медицинасы, тендинопатия, миофасцит, сіңір байламдарының зақымдануы.

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Применение и научно-исследовательский прогресс иглоукалывания и прижигательной терапии в спортивной медицине: краткий обзор

Теоретической основой иглоукалывания и прижигания в теоретическом кругу традиционной китайской медицины признается «углубление меридианов, стимулирование кровообращения и устранение застоя крови». В современных медицинских теориях механизм иглоукалывания и прижигания обсуждается как «обезболивание, улучшение микроокружения, влияющее на высвобождение гормонов и воспалительный механизм». Большое количество исследований подтвердило его лечебный эффект, и он стал эффективным методом лечения в спортивной медицине. Проанализированы возможности иглоукалывания и прижигания при лечении заболеваний в спортивной медицине, а также обсуждены клиническая эффективность и механизм применения иглоукалывания и прижигания при лечении тендинопатии, миофасцита, повреждениях связок, периферических нервов, заживления сухожилий и костей и других заболеваний. Хотя иглоукалывание и прижигание широко используются в спортивной медицине, большинство текущих исследований являются ретроспективными и не содержат рандомизированных двойных слепых контролируемых исследований. Следовательно, в будущих исследованиях следует использовать больше рандомизированных двойных слепых исследований для дальнейшего подтверждения эффективности иглоукалывания и прижигания при лечении заболеваний в спортивной медицине посредством многоцентрового клинического наблюдения с большой выборкой, чтобы лучше применять их в клинике.

Ключевые слова: иглорефлексотерапия, термопунктура, спортивная медицина, лечебный эффект, традиционная китайская медицина, тендинопатия, миофасцит, травма связок.

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Rosmarinic acid inhibits biofilm formation of *Streptococcus mutans*

Emerging antimicrobial resistance and adverse effects associated with antimicrobial over use necessitate new antimicrobial therapeutics with natural compounds considered as attractive alternatives to synthetic drugs. Rosmarinic acid is abundant in medicinal plants. The aim of this study was to elucidate its possible role as an inhibitor of *Streptococcus mutans* biofilm growth. The amount of biofilm formed by *S. mutans* bacteria was estimated using colorimetric method and optical profilometry. In this study, rosmarinic acid showed significant inhibitory activity at 5 mg/mL concentration on *S. mutans* biofilm formationin 1 % sucrose containing medium. Considering the broad antimicrobial and antibiofilm spectrum of activity, rosmarinic acid can be used as an antimicrobial agent along with a number of medicinal plants containing rosmarinic acid as a dominant compound. However, rosmarinic acid can serve as a basis for the development of antimicrobial and therapeutic and prophylactic drugs used in dental practice.

Keywords: colorimetric method, optical profilometry, biofilms, *Streptococcus mutans*.

Introduction

Rosmarinic acid (RA) is an organic compound belonging to the group of phenolic acids. RA is probably one of the most well-known secondary metabolites of plants. It is most often and in large quantities found in plants of the *Lamiaceae* family: rosemary (*Rosmarinus officinalis*), sage (*Salvia officinalis*), basil (*Ocimum basilicum*), lemon balm (*Melissa officinalis*) [1]. RA has a wide range of beneficial properties and is currently being actively studied in scientific and medical research. The chemical structure of RA is shown in Figure 1.

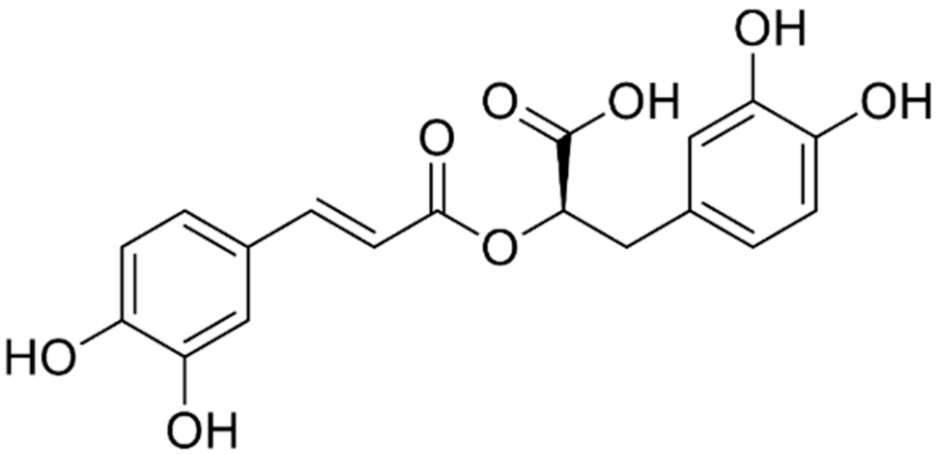

Figure 1. Chemical structure of rosmarinic acid

RA ($C_{18}H_{16}O_8$) contains several key chemical groups that determine its properties and functions. Phenolic groups in plants play an important role in their biological activity and have a variety of properties, thus the two phenolic rings present in RA give it antimicrobial and antioxidant properties [2]. In addition to phenolic groups, RK contains carboxyl, hydroxyl and ether groups that affect solubility and participate in the formation of hydrogen bonds [3]. RA is used for application in various industries such as cosmetology, medicine, food industry, pharmaceutical, and agricultural industry [4].

Dental caries is currently one of the most common dental problems worldwide and is a serious problem for the population, especially for children. *Streptococcus mutans* is a facultative aerobic gram-positive bacterium and an important cariogenic pathogen. This bacterium inhabits the human oral cavity, causing dental plaque and dental caries [5]. The main virulence factors of *S. mutans* are the ability to form biofilms attached to the tooth surface, the ability to produce organic acids (acidity), and viability under low pH conditions (acidity) [6]. *S. mutans* has the ability to adhere to tooth enamel, forming the initial layers of biofilm (plaque). These bacteria use specific adhesive molecules such as adhesins and exopolysaccharides to attach to the tooth surface [7].

RA exhibits antimicrobial properties against gram-positive strains: *Staphylococcus aureus*, methicillin-resistant *Staphylococcus aureus*, *Bacillus cereus*, *Enterococcus faecalis*, *Listeria monocytogenes*; gram-negative strains: *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella* spp*., Klebsiela pneumoniae* [8, 9]. However, the literature does not contain studies on the effect of RA on the formation of biofilm caused by the growth of *S. mutans* bacteria. In this regard, it is relevant to study the effect of RA on the formation of *S. mutans* biofilms. Given the high antimicrobial activity, RA has the potential for use in the development of new dental and prophylactic agents.

Experimental

Plant material. Wild plant of the flora of Kazakhstan *Salvia stepposa* Des. -Schost (synonym *Salvia dumetorum*) was collected during expeditions in the Karaganda region, Republic of Kazakhstan, collection coordinates (N 49°88898’; E 73°15569’) in the budding and flowering phase in July-August 2023.

Isolation of RA. Rosmarinic acid was isolated from *Salvia stepposa* according to the methods described in the literature [10, 11].

Biofilm formation, processing and analysis by colorimetric analysis. Experimental data were obtained using the method described in the literature [12]. *Streptococcus mutans* strain UA159 (ATCC 700610) was cultured in Todd-Hewitt (TH) broth under anaerobic conditions (95 % N_2 and 5 % CO_2) at 37 °C for 18 h before the experiments. 1000 mg of rosmarinic acid was dissolved in 10 mL of pure dimethyl sulfoxide (DMSO) to obtain stock solutions with a concentration of 100 mg/mL. The prepared stock solution of RA was stored at –35 °C until use.

At the beginning of the experiments, 24-well flat-bottomed polystyrene cell culture plates were filled with TH containing 1 % sucrose, and then RA solution was added to the corresponding wells at final concentrations of 1 mg/mL, 2.5 mg/mL, 5 mg/mL, 7.5 mg/mL, and 10 mg/mL. Three RA concentrations were selected from this range for the treatment of *S. mutans* bacteria. DMSO solvent was added to the corresponding wells at final concentrations of 1 %, 2.5 %, 5 %, 7.5 %, and 10 % (v/v).

Before each experiment, the optical density (OD) of the bacterial culture was adjusted to 0.2 at 595 nm using a BioTek Synergy HTX microplate reader. *S. mutans* bacteria were then added to the wells of the plate containing RA at a final dilution of 1:100, and all plates were incubated anaerobically (95 % N_2 and 5 % CO_2) at 37 °C for 24 h. In the experiments, wells of the plate without bacterial cells were used as blank controls, while untreated bacteria without sucrose served only as an internal control for the experiments and were not included in the calculations.

After 24 h of incubation, TH was removed from the plates, the wells were washed with distilled water to remove loosely adherent cells, and then the adherent bacteria were fixed with 95 % ethanol. The fixed and air-dried *S. mutans* biofilm in the wells of the plate was stained with 0.01 % crystal violet for 15 min.

The bound dye was extracted with 33 % acetic acid for 30 min. Afterwards, 200 µl of the extracted dye solution from each well was transferred to the corresponding wells of an optically clear flat-bottomed 96-well microplate. The OD of the samples was measured at 595 nm using a BioTek Synergy HTX microplate spectrophotometer. Background staining was corrected by subtracting the amount of staining in the empty wells (Fig. 2).

The percentage inhibition of biofilm formation was calculated using the OD values (%) according to the equation:

$$\%\ \text{of inhibition} = \frac{x(\text{control}) - x(\text{treatment})}{x(\text{control})} \cdot 100\%$$

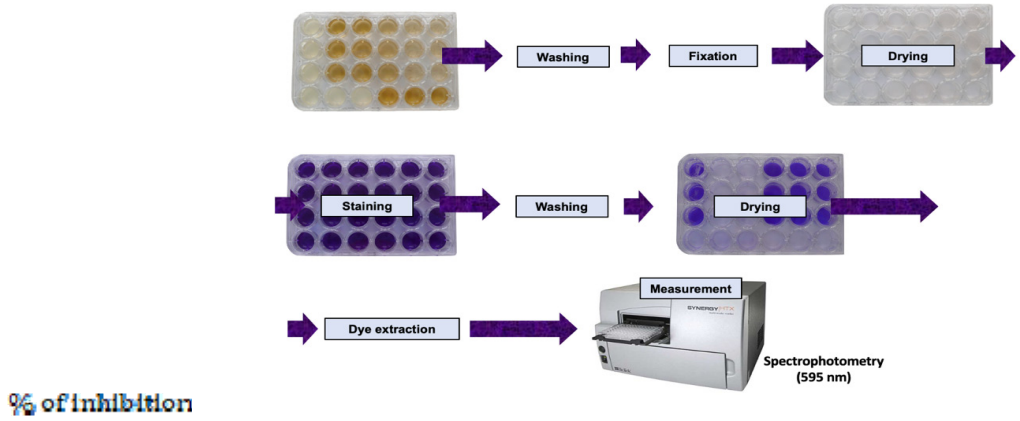

Figure 2. Colorimetric assay [13]

Statistical analysis. Data were analyzed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Differences between the control (untreated) and treatment groups were assessed using one-way analysis of variance followed by the least significant difference post hoc test for multiple comparisons. Data are presented as mean ± standard error. $P< 0.05$ was considered to indicate a statistically significant difference.

Results and Discussion

Despite the widely studied antimicrobial activity of RA, no data on its effectiveness against *S. mutans* have been found. However, other phenolic acids or their derivatives showed antimicrobial activity against biofilm formation of *S. mutans*. Scientists have found that rosemary extract (*Rosmarinus officinalis*) has an antimicrobial effect on *S. mutans*. Studies show that rosemary extract can effectively reduce the total protein level in *S. mutans* biofilms, achieving a reduction of approximately 32 % [14]. Studies have been published on carnosic acid and carnosol, which as RA, belong to the class of phenolic plant metabolites, confirming the activity of these compounds against *S. mutans* at concentrations of 40 μg/mL and 75 μg/mL, respectively [15]. Other authors have found that the flavonoids quercetin and kaempferol also reduce *S. mutans* biofilm formation compared to the control [16]. Caffeic acid derivate such as caffeic acid phenethyl ester (CAPE) showed a good inhibitory effect on the biofilm-forming and cariogenic abilities of *S. mutans*. CAPE (0.04 mg/mL) inhibited biofilm formation by at least 50 %, and at 0.08 mg/mLCAPE inhibited biofilm formation by more than 90 %. Additionally, CAPE can inhibit crucial virulence factors of *S. mutans* related to its cariogenic potential, such as acid production, acid tolerance, and the synthesis of extracellular polysaccharides, without compromising bacterial viability at lower concentrations [17].

Evaluation of the efficacy of RA in inhibiting *S. mutans* biofilm formation using a colorimetric assay showed the ability to significantly inhibit *S. mutans* biofilm formation in a dose-dependent manner on the polystyrene surface of 24-well cell culture plates. Treatment with RA at a concentration of 2.5 mg/mL resulted in only a slight reduction in biofilm formation at the bottom of wells in 24-well cell culture plates (Fig. 3).

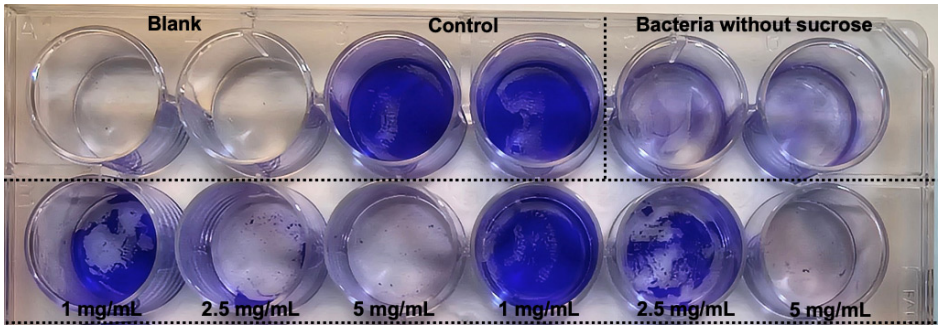

Figure 3. *S. mutans* biofilm stained with 0.01 % crystal violet solution after 24 h of incubation in the presence of RA

DMSO significantly reduced the biofilm formation of *S. mutans*, except for the DMSO concentration of 1 % (Fig. 4). However, the inhibitory activity of RA at a concentration of 5 mg/mL significantly exceeded the experimental results compared to the corresponding DMSO concentrations.

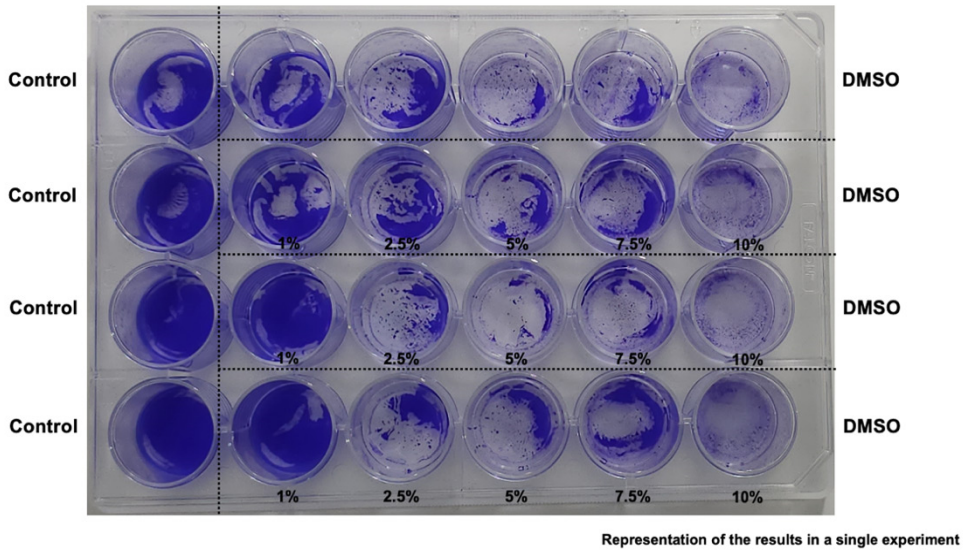

Figure 4. *S. mutans* biofilm stained with 0.01 % crystal violet solution after 24 h of incubation in the presence of dimethyl sulfoxide (DMSO)

As shown in Figure 5, RA at a concentration of 1 mg/mL does not reduce the formation of *S. mutans* biofilm. However, with an increase in the concentration from 2.5 mg/mL to 5 mg/mL RA, positive dynamics are observed in reducing the formation of *S. mutans* biofilm by 54 % (*p < 0.05 compared to the control) and 90 % (**p < 0.05 compared to DMSO), respectively.

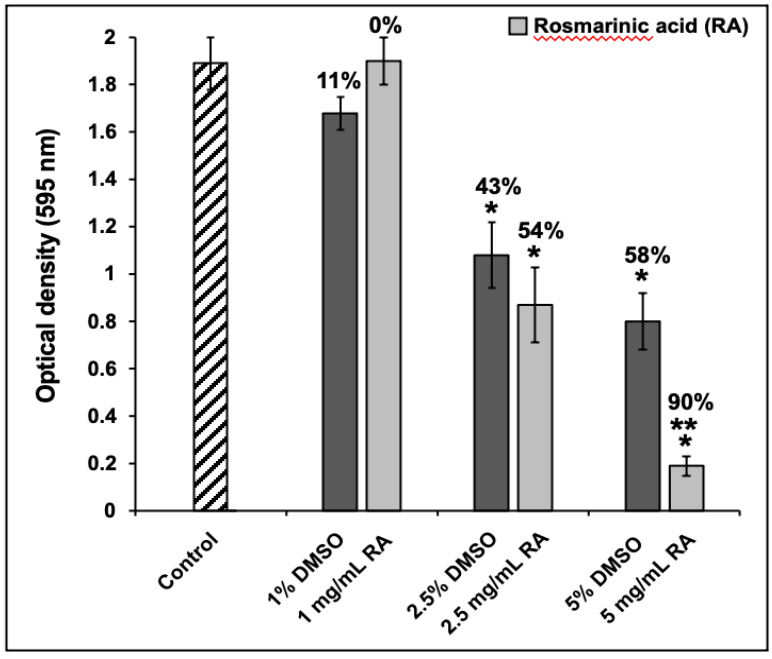

Figure 5. Optical density of *S. mutans* biofilm after 24 h of incubation in the presence of RA (*p < 0.05 compared to control; **p < 0.05 compared to DMSO). Values are mean ± standard error of four independent experiments (n=4–18); One-way ANOVA, LSD Post Hoc test (SPSS software, version 23.0); Percentages indicate the inhibitory effect of extracts compared to the control (untreated bacteria).

Thus, RA exhibits inhibitory activity against *S. mutans* biofilm formation in a medium containing 1 % sucrose (which is the main inducer of biofilm formation for *S. mutans* bacteria). The solvent DMSO also reduces *S. mutans* biofilm formation in a concentration-dependent manner in a medium containing 1 % sucrose, but the inhibitory activity of RA against *S. mutans* biofilm formation is slightly higher compared to DMSO.

Conclusion

RA is an important secondary metabolite of plants, which finds its wide application due to its diverse spectrum of biological activity. *S. mutans* is a major cariogenic pathogen that contributes to the occurrence of many oral diseases. The best treatment option is the selective exclusion of dental caries. Anti-biofilm agents can inhibit the growth of *S. mutans* in the microareas of teeth, dental restorations or implant-supported prostheses. However, currently oral antimicrobial agents are mainly used as broad-spectrum bactericides, and they poorly regulate the production of both biofilms and virulence factors. In this regard, in this study, the potential of RA, which is an easily renewable metabolite obtained from plants, in inhibiting the biofilm formation of *S. mutans* was investigated.

As a result of the experiment, it was revealed for the first time that RA has a significant biological effect and can protect teeth from damage caused by *S. mutans*. It was found that RA exhibits the greatest suppressive effect on the formation of *S.mutans* biofilm in a medium containing 1 % sucrose at a concentration of 5 mg/mL. The results of the study can be used to develop new therapeutic and prophylactic dental products.

Acknowledgements

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Streptococcus mutans биоқабықшасының түзілуін тежеуші Розмарин қышқылы

Антибиотиктерді шамадан тыс қолданумен байланысты дамып келе жатқан микробқақарсы төзімділік пен жанама әсерлер, тартымды балама ретінде қарастырылатын табиғи қосылыстары бар жаңа микробқақарсы терапияның қажеттілігін туғызды. Розмарин қышқылы дәрілік өсімдіктерде көп кездеседі. Зерттеудің мақсаты розмарин қышқылының *S. mutans* биоқабықшасының түзілуін тежеуші ретіндегі ықтимал рөлін анықтау. *S. mutans* бактериялары түзетін биоқабықша мөлшері, колориметриялық әдіс пен оптикалық профилометрия көмегімен бағаланды. Бұл зерттеуде розмарин қышқылы 5 мг/мл концентрацияда, құрамында 1 % сахароза бар ортада *S. mutans* биоқабықшасының түзілуін айтарлықтай тежеу белсенділігін көрсетті. Микробқақарсы және биоқабықшаның түзілуіне қарсы белсенділіктің кең спектрін ескере отырып, розмарин қышқылын басым қосылыс ретінде және құрамында розмарин қышқылы бар бірқатар дәрілік өсімдіктермен бірге микробқақарсы агент ретінде пайдалануға болады. Розмарин қышқылы стоматологиялық тәжірибеде қолданылатын микробқақарсы және емдік-профилактикалық препараттарды әзірлеу үшін негіз бола алады.

Кілт сөздер: розмарин қышқылы, колориметриялық әдіс, профилометрия, биоқабықшалар, *Streptococcus mutans*.

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Розмариновая кислота, ингибирующая образование биопленки *Streptococcus mutans*

Возникающая устойчивость к противомикробным препаратам и побочные эффекты, связанные с чрезмерным использованием антибиотиков, обусловливают необходимость в новых противомикробных терапевтических средствах с природными соединениями, рассматриваемыми в качестве привлекательной альтернативы. Розмариновая кислота в изобилии присутствует в лекарственных растениях. Целью данного исследования было выяснить ее возможную роль в качестве ингибитора роста биопленки *S.mutans*. Количество биопленки, образованной бактериями *S. mutans*, оценивали с помощью колориметрического метода и оптической профилометрии. В данном исследовании розмариновая кислота продемонстрировала значительную ингибирующую активность в концентрации 5 мг/мл на образование биопленки *S. mutans* в среде, содержащей 1 % сахарозы. Учитывая широкий антимикробный и антибиопленочный спектры активности, розмариновая кислота может быть использована как антимикробный агент вместе с рядом лекарственных растений, содержащих розмариновую кислоту, в качестве доминирующего соединения. Тем не менее розмариновая кислота может служить основой для разработки антимикробных и лечебно-профилактических препаратов, использующихся в стоматологической практике.

Ключевые слова: розмариновая кислота, колориметрический метод, профилометрия, биопленки, *Streptococcus mutans.*

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Antimicrobial activity of the dense extracts of *Dracocephalum nutans* L. and *Dracocephalum ruyschiana* L.

In the article the results of ultrasonic extraction of *Dracocephalum nutans* L. and *Dracocephalum ruyschiana* L. from Central Kazakhstan were presented. The effectiveness of the process was evaluated based on the quantitative yield of total extractive substances, the content of total polyphenolic compounds, flavonoids, phenolic acids, and the antimicrobial activity of the obtained extracts. It was experimentally established that the solvent ensuring the quantitative extraction of total extractive substances is 70 % ethanol. The obtained extracts of *Dracocephalum nutans* L. and *Dracocephalum ruyschiana* L. can be considered as substances for the development of antimicrobial pharmaceuticals.

Keywords: Dracocephalum, antimicrobial activity, ultrasonic extraction, HPLC, pathogenic bacteria.

Introduction

In modern conditions, there is a development of microorganism strains with multiple drug resistance and their active spread, which highlights the need for new antimicrobial and antifungal agents. In this context, plant-based medicines are becoming increasingly important alongside synthetic drugs. The biologically active compounds in these substances are similar in structure and action to the natural components of the human body, which leads to a significant reduction in side effects from their use [1–5]. Bacteria resistant to synthetic antibiotics threaten their effectiveness and limit treatment options even for common infections. Therefore, significant attention should be given to plant-based agents that can be used as highly effective antimicrobial medications.

Currently, plant-based medicines are successfully used for the treatment of most diseases, despite the fact that synthetic drugs, which emerged about a century and a half ago, have significantly advanced medicine [6].

In the flora of Kazakhstan, there are more than 1,000 essential oil plants. Of particular interest are some species from the families *Lamiaceae, Apiaceae*, and *Asteraceae*, which have either not been studied at all or have only brief information available on their chemical composition and biological properties. In this regard, the family *Lamiaceae*, which is one of the leading families in the flora of Kazakhstan, is especially noteworthy. For instance, within this family, the republic has 233 species classified into 45 genera [7].

Among them, plants of the genus *Dracocephalum* L. are the most well-known, serving as a rich and widespread source of essential oils. According to the database The Plant List (as of August 2016), the genus includes 74 species, with 20 species found in Kazakhstan [8].

Studies have shown that some species of *Dracocephalum* possess antibacterial, antitussive, antidiarrheal, antioxidant, anticancer, anti-inflammatory, antidiabetic, and soothing properties [9–12].

Experimental

The research objects are the above-ground parts of *Dracocephalum nutans* L. and *Dracocephalum ruyschiana* L., collected during the flowering phase from the Karkaraly Mountains (Karaganda Region, N $49^0$43'23", E $75^0$48'38"), in May 2022.

For obtaining dense extracts, the method of ultrasonic extraction was used for the above-ground parts of *Dracocephalum nutans* L. (nodding dragonhead) and *Dracocephalum ruyschiana* L. (Ruysch's dragonhead). The choice of the ultrasonic method is due to its ability to extract biologically active substances from plant material within a short time (15–30 minutes), whereas classical methods typically require 8–24 hours [13–15].

For the analysis, an ultrasonic bath Stegler 3DT (3 L, 20-80 °C, 120W, frequency 40 kHz) was used. The raw material was extracted using a mixture of water and ethanol (1:1) and ethanol alone, with a ratio of

raw material to extractant of 1:20. Ultrasonic extraction was performed with a water: ethanol ratio of 1:1. The raw material was initially soaked for 20 minutes and then subjected to ultrasonic treatment for 30 minutes at room temperature. The extraction process was repeated three times under the same conditions, and the filtrates were combined, cooled to room temperature, and evaporated using a rotary evaporator.

For the analysis of phenolic compounds in the extracts, high-performance liquid chromatography coupled with ultraviolet (UV) detection and real-time tandem mass spectrometry (ESI-MS/MS) was used.

The content of phenolic compounds in the extracts was calculated using the external standard method according to the formula (1):

$$X=\frac{S_1 \text{ x } m_0 \text{ x25 x P x100}}{S_0 \text{ x m x25 x100}}, \quad (1)$$

where S_1 is the peak area value of the compound in the chromatogram of the test solution;

S_0 is the peak area value of the compound in the chromatogram of the standard;

m_0 is the mass of the standard compound, in grams; m_1 is the mass of the extract, in grams;

P is the content of the compound in the standard compound, in %; and 25, 25 are the dilution factors.

The antimicrobial activity of the samples was studied using the disk diffusion method.

The antimicrobial activity of the aforementioned samples was studied against Gram-positive bacteria Staphylococcus aureus and Bacillus subtilis, Gram-negative bacteria Escherichia coli and Pseudomonas aeruginosa, and the yeast fungus Candida albicans using the disk diffusion method. The reference substances used were benzylpenicillin for bacteria and nystatin for the yeast fungus Candida albicans.

For the study, a suspension containing a standard number of viable bacterial cells was prepared and seeded as a lawn on the surface of the nutrient medium in Petri dishes. 0.01 mL of each sample was applied to sterile filter paper disks. The disks with the samples were placed on the seeded surface in a circular arrangement, 2.5 cm from the center of the dish (4 disks per dish). The inoculated plates were incubated at 36 °C for 24 hours. After incubation, zones of complete and partial bacterial growth inhibition appeared around the disks against the uniform bacterial lawn. The results were recorded by measuring the diameters of the inhibition zones. Each sample was tested in triplicate. For comparative assessment of antimicrobial activity, antibiotic solutions were used: sodium benzylpenicillin, sodium ceftriaxone, nystatin, with 70 % ethanol and DMSO in equivalent volumes used as controls.

The antimicrobial activity of the samples was assessed by measuring the diameter of the inhibition zones around the test strains (mm). An inhibition zone diameter of less than 10 mm and continuous growth in the dish were considered as indicating no antibacterial activity, 10–15 mm indicated weak activity, 15–20 mm indicated moderate activity, and over 20 mm indicated strong activity.

Statistical analysis of the data was performed using parametric statistical methods, including the calculation of the arithmetic mean and standard error.

Results and Discussion

The HPLC analysis of the chemical composition of phenolic compounds in the dense extracts of *Dracocephalum nutans* and *Dracocephalum ruyschiana* was conducted at the Research Center of the Medical University of Karaganda (Karaganda, Kazakhstan). The composition of phenolic compounds in dense extracts of *D.nutans* and *D.ruyschiana*, obtained by ultrasonic extraction, and the mass spectra for the identified compounds in negative ionization mode are presented in Table 1 and Figures 1 and 2.

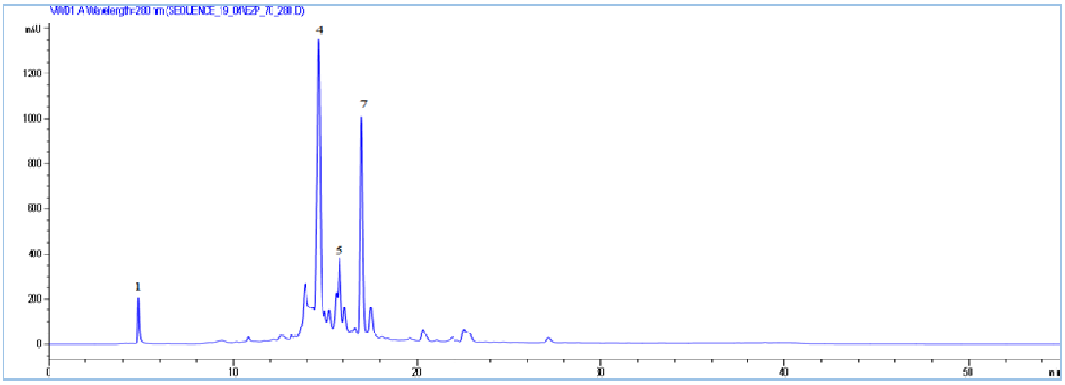

Figure 1. Chromatogram of *Dracocephalum nutans* extract at a wavelength of 280 nm

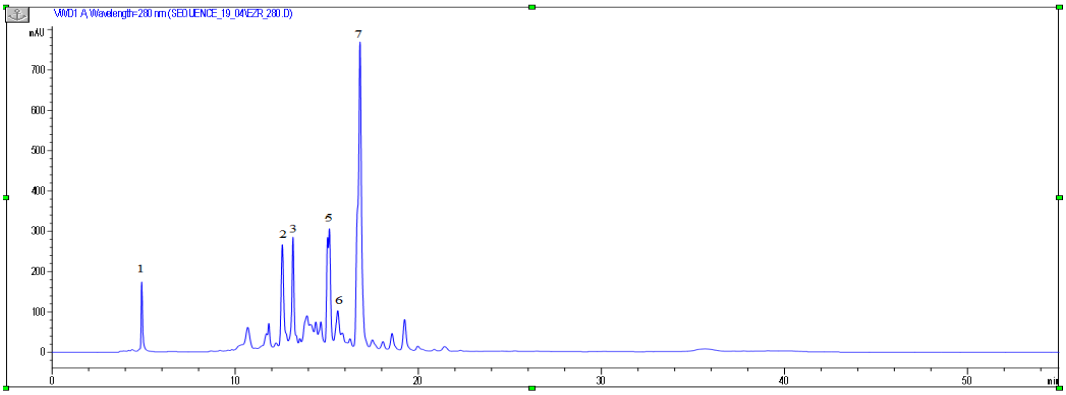

Figure 2. Chromatogram of *Dracocephalum ruyschiana* extract at a wavelength of 280 nm

Table 1

Identification and Content of Phenolic Compounds in Dense Extracts of *Dracocephalum nutans* and *Dracocephalum ruyschiana*

№ Peak	Retention Time, min	M-H − (m/z)	Identified Components	Content (mg/g of extract)	
				D. ruyschiana	*D. nutans*
1	4.985	179	caffeic acid	1.33±0.08	1.37±0.11
2	12.568	353	chlorogenic acid	12.33±0.15	-
3	13.907	163	p — couric acid	12.37±0.05	-
4	14.717	463	quercetin-3'-glucoside	-	47.95±0.19
5	15.136	574	ferulic acid	7.29±0.10	3.43±0.13
6	15.593	163	o — couric acid	3.1±0.10	-
7	16.995	359	rosmarinic acid	44.76±0.15	19.54±0.28

As shown in Table 1, a total of 7 phenolic compounds were identified and quantified in the dense extracts of *D.nutans* and *D.ruyschiana*, including 6 phenolic acids and 1 flavonoid.

The dominant phenolic compounds in the extracts are rosmarinic acid, with contents of 19.54 and 44.76 mg/g, and quercetin-3'-glucoside in *D.nutans*, with a content of 47.95 mg/g (Table 2).

Table 2

Results of the Antimicrobial Activity Study of *Dracocephalum nutans* and *Dracocephalum ruyschiana* Extracts

mm / name	Staphylococcus aureus ATCC 6538	Bacillus subtilis ATCC 6633	Escherichia coli ATCC 25922	Pseudomonas aeruginosa **ATCC 27853**	Candida albicans A TCC 10231
D.ruyschiana	15 ± 0.5	15 ± 1	10 ± 0.5	9 ± 1	12 ± 0.6
D.nutans	14 ± 1.2	12 ± 0.1	14 ± 0.3	9 ± 0.3	12 ± 0.1
Sodium benzylpenicillin	16 ± 0.1	14 ± 0.1	15 ± 0.1	12 ± 1	-
Sodium ceftriaxone	20 ± 0.3	19 ± 0.17	19 ± 0.5	19 ± 1	-
DMSO	-	-	-	-	-
(70 %) Ethanol	10 ± 0.1	10 ± 0.1	9 ± 0.1	9 ± 0.1	8 ± 0.1
Nystatin	-	-	-	-	21 ± 0.2

The extract of *D.ruyschiana* exhibits moderate antimicrobial activity against Gram-positive bacteria *Staphylococcus aureus* and *Bacillus subtilis*, and weak antimicrobial activity against Gram-negative bacteria *Escherichia coli* and *Pseudomonas aeruginosa*, as well as against the yeast fungus *Candida albicans*.

The extract of *D.nutans* demonstrates weak antimicrobial activity against the Gram-positive bacteria *Staphylococcus aureus* and *Bacillus subtilis*, as well as weak activity against the Gram-negative bacteria *Escherichia coli* and *Pseudomonas aeruginosa*, and weak activity against the yeast fungus *Candida albicans*.

Conclusion

1. For the first time, ultrasonic extraction of *Dracocephalum nutans* and *Dracocephalum ruyschiana* from the Central Kazakhstan region was successfully performed.

2. The chemical composition of the extracts of *Dracocephalum nutans* and *Dracocephalum ruyschiana* was determined using high-performance liquid chromatography (HPLC).

3. The extract of *Dracocephalum ruyschiana* can be considered as a potential substance for the development of antimicrobial agents.

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А. Рамазанова, Г.А. Атажанова, Г.К. Курмантаева, Б.Б. Аширбекова

Dracocephalum nutans L. және *Dracocephalum ruyschiana* L. қою экстрактарының микробқақарсы белсенділігі

Мақалада Орталық Қазақстанда өсетін *Dracocephalum nutans* L. және *Dracocephalum ruyschiana* L. өсімдік шикізаттарының ультрадыбыстық экстракциялау нәтижелері келтірілген. Процестің тиімділігі экстрактивті заттардың жалпы шығымы, полифенолды қосылыстардың, флавоноидтардың, фенолқышқылдарының жалпы мөлшері және алынған экстрактардың микробқақарсы белсенділігі бойынша бағаланды. Эксперименталды түрде экстрактивті заттардың жалпы мөлшерін тиімді алу үшін 70 % этил спирті экстрагент ретінде қолданылды. Алынған микробқақарсы белсенділігі бар *Dracocephalum nutans* L. және *Dracocephalum ruyschiana* L. экстрактылары дәрілік заттарды әзірлеу үшін субстанция ретінде қарастырылды.

Кілт сөздер: Dracocephalum, микробқақарсы белсенділік, ультрадыбыстық экстракция, ЖТСХ, патогенді бактериялар.

А. Рамазанова, Г.А. Атажанова, Г.К. Курмантаева, Б.Б. Аширбекова

Антимикробная активность густых экстрактов *Dracocephalum nutans* L. и *Dracocephalum ruyschiana* L.

В статье представлены результаты ультразвуковой экстракции *Dracocephalum nutans* L. и *Dracocephalum ruyschiana* L., произрастающих на территории Центрального Казахстана. Эффективность процесса оценивали по количественному выходу суммы экстрактивных веществ, содержанию общего количества полифенольных соединений, флавоноидов, фенольных кислот и антимикробной активности полученных экстрактов. Экспериментально установлено, что экстрагентом, обеспечивающим количественное извлечение суммы экстрактивных веществ, является 70 %-ный спирт этиловый. Полученные экстракты *Dracocephalum nutans* L. и *Dracocephalum ruyschiana* L. можно рассматривать в качестве субстанций для разработки лекарственных средств противомикробного действия.

Ключевые слова: Dracocephalum, антимикробная активность, ультразвуковая экстракция, ВЭЖХ, патогенные бактерии.

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Система мониторинга и обеспеченность данными прогноза наводнений Восточно-Казахстанской области

Статья посвящена сбору доступной информации о водных объектах Восточно-Казахстанской области, полученной из открытых источников Национальной гидрометеорологической службы Республики Казахстан и Министерства по чрезвычайным ситуациям Республики Казахстан с целью формирования базы атрибутивных данных с пространственной привязкой в ГИС и формированию основы последующих исследований, направленных на разработку и внедрение моделей прогнозирования наводнений. Проведен обзор исследований, посвященных прогнозу наводнений в разных регионах Казахстана и в других странах, в результате чего сформированы критерии оценки данных и системы гидрологического мониторинга. Приведена характеристика гидрологического режима основных репрезентативных водных объектов Восточного Казахстана. На основе пространственного анализа сети гидрологических постов и известных зон затопления дана оценка пространственному охвату государственной системы наблюдений и определены рекомендации по ее расширению. Сделаны выводы о возможности применения собранных данных при создании прогнозных моделей.

Ключевые слова: наводнения, мониторинг, ГИС, атрибутивные данные, Восточно-Казахстанская область, водные объекты, гидрологический пост, зоны затопления, гидрология, прогноз.

Введение

Наводнения относятся к одним из наиболее разрушительных стихийных бедствий, которые оказывают не только негативное влияние на различные отрасли экономики, но и являются реальной угрозой для жизни населения. Восточно-Казахстанская область одна из наиболее многоводных среди других областей Республики Казахстан, что увеличивает вероятность затоплений и связанные с этим риски. Особенность наводнений здесь всегда связывалась с их генезисом, который обусловливался характером местности, гидрологическим режимом водных объектов и климатическими особенностями. Прогнозирование наводнений с целью разработки эффективных противопаводковых мероприятий и минимизации рисков для региона остается приоритетной и актуальной задачей.

Целью настоящего исследования является формирование базы данных о водных объектах Восточно-Казахстанской области в программной среде ГИС с учетом особенностей и требований различных моделей прогнозирования наводнений для предварительной оценки паводковой ситуации. Объектом исследования выступает бассейн реки Ертис (Иртыш) в пределах Восточно-Казахстанской области.

В рамках исследования были поставлены следующие задачи:

- дать краткую характеристику водным объектам на территории Восточно-Казахстанской области, провести их типизацию в контексте существующей системы мониторинга;

- провести сбор, обработку и систематизацию имеющихся атрибутивных данных, сформировать единую базу гидрологических данных;

- визуализировать данные с помощью ГИС для получения интерактивных электронных карт с привязкой к атрибутивным данным.

Обзор международного опыта современных гидрологических исследований показывает повсеместное использование различных типов моделей для прогноза наводнений. Среди работ по мета-анализу [1–3] выделяются различные типы моделей, в том числе основанные на гидрологических, гидравлических данных, статистике, дистанционном зондировании и ГИС, искусственном интеллекте и машинном обучении, а также анализе комплексных решений. В цитируемых работах оцениваются преимущества и недостатки моделей, приводятся сведения о входных данных. В зависимости от типа данных различаются источники и подходы к их сбору. В ряду гидрологических данных выделяют два основных показателя — многолетние расходы и уровни воды в реках и водоемах. Кроме того, к важнейшим для моделирования данным относят метеоданные, величину снегозапасов, информацию о строении русла и дна, особенностях водосборных бассейнов, уровне и режиме грунтовых вод, состоянии регулирующих сток гидротехнических сооружений и др.

Современные системы, применяемые для составления долгосрочных и краткосрочных прогнозов, зачастую основаны на использовании одной или нескольких математических моделей, призванных облегчить анализ множества данных различного характера и дать своевременное экспертное заключение. При этом возможность и целесообразность применения тех или иных моделей обусловлены полнотой и доступностью входных данных о водных объектах и прилегающей к ним территории в границах водосборных бассейнов. Среди важнейших характеристик этой информации следует отметить ее географическую привязанность и корректное пространственное распространение. Исходя из объема информации, процессы ее сбора, хранения, систематизации и анализа наиболее удобно проводить в программной среде какой-либо ГИС, где хранение данных осуществляется посредством атрибутивных таблиц, связанных с представленными географическими объектами на электронных картах.

В последние годы для территории Республики Казахстан появляется все больше исследований, посвященных проблеме наводнений. В первую очередь, это труды специалистов, работающих в Институте географии и водной безопасности (г. Алматы). Из последних работ можно выделить [4, 5], где даётся описание режимов рек и особенностей наводнений для всей территории Казахстана, приводится сравнение специфики прохождения экстремальных периодов водного режима у разных групп рек.

Также среди работ, посвященных оценке рисков, связанных с наводнениями, можно выделить региональные исследования, проведенные в Акмолинской области, в результате которых получены данные о степени вероятности возникновения различных видов экологических рисков, выявлены закономерности развития их негативных последствий [6]. В работах [7, 8] представлены оценки изменения качественных и количественных характеристик рек Центрального Казахстана во время половодья и выявлены основные причины наводнений для рек бассейнов Нуры и Есиля в условиях современных климатических изменений. В статье [9] рассматриваются причины и оцениваются факторы, влияющие на частоту и интенсивность наводнений на реке Есиль у города Петропавловска, а также предложены меры по их предотвращению и минимизировании последствий. Работа [10] посвящена ретроспективной оценке катастрофических наводнений весны 2024 г. в Западном регионе Казахстана. Проведены гидрологические расчеты, исследованы характерные уровни воды в реке Жайык, а также площади затопления прибрежных территорий.

С учетом специфики текущего исследования, одной из наиболее важных работ является статья [11], в которой рассматриваются последствия паводковых явлений, характерных для территории Восточно-Казахстанской области, приводится краткий обзор наводнений в исследуемом районе, произошедших за последние 10 лет. В работе также проведен первичный анализ зон затопления отдельных рек на основе спутниковых изображений и предложен ряд мер по снижению рисков.

Немало работ посвящено применению методов дистанционного зондирования для оценки масштабов затопления и прогнозирования наводнений на территории Казахстана. К наиболее свежим работам по данной тематике можно отнести [12], где приведены результаты пространственного анализа наводнений, смоделированы зоны затопления отдельных территорий республики. В работе [13] рассматривается опыт применения модели FLOMIS для оперативного картирования зон подтопления в Западном Казахстане. Статья [14] посвящена применению ГИС-технологий и данных дистанцион-

ного зондирования для космического мониторинга наводнений. В исследовании [15] описываются концепция и основы разработки методических принципов мониторинга и прогнозирования наводнений на территории Восточно-Казахстанской области с последующей целью создания собственной системы прогнозирования паводков и затоплений. С 2001 г. в Республике Казахстан на базе Национального центра космических исследований и технологий обеспечен прием спутниковых данных Terra MODIS, которые позволяют вести оперативное наблюдение за потенциальными очагами опасных явлений природного характера. В работе [16] представлены результаты и краткая характеристика этой технологии.

Материалы и методы

Данные, собранные о водных объектах Восточно-Казахстанской области, доступные к использованию для прогнозирования наводнений, на текущий момент достаточно обширны, однако нуждаются в определенной обработке и оценке их применимости. Основным источником информации выступают государственные организации, осуществляющие сбор первичных данных путем проведения режимных наблюдений. Несмотря на практическую ценность, структура подачи информации имеет ряд неудобств и ограничений, что влияет не только на качество, но и на саму возможность применения отдельных наиболее эффективных моделей прогноза. Существующая сеть наблюдательных пунктов имеет ряд недостатков, связанных с полнотой охвата территории. Многие материалы, в частности архивные исторические, не оцифрованы, что осложняет работу с ними. Практически отсутствуют элементы визуализации и удобной для пользователя подачи информации. Почти не используются возможности, предоставляемые современными географическими информационными технологиями. Все эти проблемы отнимают у конечных пользователей большое количество времени на самостоятельные попытки структурировать данные удобным для них способом.

Единственным источником достоверной гидрометеорологической информации на территории Республики Казахстан является Национальная гидрометеорологическая служба Республики Казахстан — РГП «Казгидромет», занимающаяся в рамках программ гидрологического и метеорологического мониторинга сбором данных на пунктах государственной наблюдательной сети, их обработкой и прогнозированием опасных природных явлений. Не менее важными материалами о наиболее подверженных затоплениям территориях и принимаемых мерах для обеспечения безопасности населения обладают структурные подразделения Министерства по чрезвычайным ситуациям Республики Казахстан. Материалы, используемые в настоящем исследовании, получены из открытых источников указанных организаций. Гидрологические данные приведены из гидрологических ежегодников РГП «Казгидромет» с 1960 по 2021 гг. В качестве инструментов для создания картографической базы данных использовалась программная среда ArcGISDesktop версии 10.4.1. Пространственная привязка атрибутивных данных осуществлялась в системе координат СК–42 (зона 14), наиболее удобной для отображения территории Восточно-Казахстанской области.

Результаты и их обсуждение

Территория Восточно-Казахстанской области полностью расположена в пределах Ертисского водохозяйственного бассейна (ВХБ). Общая площадь Ертисского ВХБ в пределах Республики Казахстан составляет около 545 тыс. км^2. Главной водной артерией, протекающей с юго-востока на северо-запад, является река Ертис. В пределах Республики Казахстан ее протяженность составляет около 1835 км. Ертис является транзитной рекой, берущей начало в Китайской Народной Республике, под названием Кара-Ертис (Черный Иртыш), протекающей по территории Восточно-Казахстанской области, области Абай и Павлодарской области и далее впадающей на территории Российской Федерации в реку Обь, глобально являясь частью бассейна Северного Ледовитого океана [17].

Практически все водные объекты на территории Восточно-Казахстанской области являются либо составной частью реки Ертис, либо ее притоками. Пересекая китайскую границу, река Кара-Ертис впадает в озеро Жайсан, после чего вытекает из него уже под названием Ертис, образуя Буктырминское водохранилище, переходящее ниже по течению в Усть-Каменогорское, а на границе с областью Абай — Шульбинское водохранилище. Гидрологически все они составляют единый водный объект. Питание реки смешанное, в пределах области, преимущественно, снегово-ледниковое. Сток реки Ертис в пределах ВКО полностью зарегулирован плотинами трех крупнейших в РК ГЭС, образующих одноименные водохранилища, что минимизирует риски, связанные с затоплением территорий, при-

легающих к основному руслу реки. Исключение составляют участки, где река приобретает более равнинный характер, и ее русло становится многорукавным.

Для больших по площади озерных участков реки существует вероятность образования ветровых нагонных явлений [17]. Река Ертис никогда полностью не замерзает. Начало половодья приходится на март–апрель, а конец — на май–июнь. Среднемноголетний расход воды реки Ертис в районе г. Усть-Каменогорска за весь период наблюдений с 1961 по 2021 гг. составляет 559 м^3/с при среднемноголетнем уровне воды 287,25 мБС. Максимальный уровень воды на посту наблюдался 26.04.88 г. и составлял 292,84 мБС. При этом критический уровень начала выхода воды на пойму для данного участка составлял 287,88 мБС [18].

Таблица 1

Многолетние данные по уровням воды за весь период наблюдений на гидрологических постах с наиболее полным непрерывным рядом не менее 10 лет, по состоянию на 2021 г.

№	Гидрологический пост	Критический уровень, см	Среднемноголетний уровень, см	Высший уровень, см
1	р. Кара Ертис — с. Боран	525	255	555
3	р. УлкенБокен — с. Джумба	380	176	406
4	р. Куршим — с. Вознесенка	310	135	418
5	р. Нарын — с. Улькен Нарын	160	132	290
6	р. Буктырма — с. Печи	250	106	447
7	р. Буктырма — с. Лесная Пристань	530	324	750
8	р. Левая Березовка — с. Средигорное	200	79	252
10	р. Ульби — с. Ульби-Перевалочная	380	125	438
11	р. Оба — г. Шемонаиха	430	113	504
12	р. Глубочанка — с. Белокаменка	334	204	344
16	р. Буктырма — с. Берель	290	140	322
17	р. Белая — с. Белое	140	91	295
19	р. Красноярка — с. Предгорное	350	180	320
20	р. Абылайкит — с. Самсоновка	420	254	457
21	р. Улан — с. Герасимовка	440	294	524
23	р. Кандысу — с. Сарыолен	-	55	131

Таблица 2

Многолетние данные по расходам воды за весь период наблюдений на гидрологических постах с наиболее полным непрерывным рядом не менее 10 лет, по состоянию на 2021 г.

№	Станция	Среднемноголетний расход, м^3/с	Наибольший расход, м^3/с
1	р. Кара Ертис — с. Боран	290	2330
3	р. Улкен Бокен — с. Джумба	8	428
4	р. Куршим — с. Вознесенка	61	1050
5	р. Нарын — с. Улькен Нарын	10,8	166
6	р. Буктырма — с. Печи	109	1340
7	р. Буктырма — с. Лесная Пристань	216	2740
8	р. Левая Березовка — с. Средигорное	1,09	27,1
10	р. Ульби — с. Ульби-Перевалочная	64,7	2220
11	р. Оба — г. Шемонаиха	172	3050
12	р. Глубочанка — с. Белокаменка	0,65	8,37
16	р. Буктырма — с. Берель	37,3	444
17	р. Белая — с. Белое	17,1	305
19	р. Красноярка — с. Предгорное	3,28	58,4
20	р. Абылайкит — с. Самсоновка	5,54	72,2
21	р. Улан — с. Герасимовка	0,97	29
23	р. Кандысу — с. Сарыолен	4,83	21,1

По характеру стока и водному режиму все притоки реки Ертис в пределах ВКО целесообразно разделить на 3 группы. К группе I относятся правобережные притоки, берущие начало на хребтах и в предгорьях Юго-Западного Алтая. Они характеризуются постоянным стоком, многоводностью и обеспечивают большую часть питания реки Ертис. К ним, в первую очередь, относятся реки Буктырма, Оба, Ульби и в меньшей степени Куршим, Кальжир, Нарын и другие. Среди других крупных водных объектов необходимо отметить Маркаколь, проточное озеро, соединенное с рекой Кара-Ертис через ее приток Кальжир. Анализ водного режима рек I группы приведен на примере реки Буктырма [17].

Река Буктырма относится к горным рекам со смешанным типом питания. Начало половодья приходится на последнюю декаду апреля, а конец — на первую декаду июня. В отдельные годы с августа по ноябрь на реке наблюдаются паводковые явления, поднимающие уровень воды до значений половодья того же года. Нередко паводковые явления сопровождают и период половодья, еще сильнее поднимая уровень в реке. Четко выраженной остается лишь зимняя межень с декабря по март. Устойчивый ледяной покров формируется во второй декаде декабря и держится до середины апреля. Периоды осеннего и весеннего ледохода могут сопровождаться образованием зажоров и заторов. Среднемноголетний расход воды реки Буктырма в районе с. Лесная Пристань за весь период наблюдений с 1954 по 2021 гг. составляет 216 м^3/с при среднемноголетнем уровне воды 430,91 мБС (табл. 1 и 2). Максимальный уровень воды на посту наблюдался 31.03.18 г. и составлял 435,17 мБС. При этом критический уровень начала выхода воды на пойму для данного участка составляет 432,97 мБС. Для реки и ее притоков характерны наводнения в период половодья, кратковременных паводковых явлений и зажорно-заторного типа [18].

II группа притоков реки Ертис значительно менее многоводна, но в большинстве имеет постоянный сток. Все они берут начало на Калбинском хребте и впадают в Буктырминское, Усть-Каменогорское и Шульбинское водохранилища или на участке р. Ертис между последними. К наиболее крупным из них относят реки Улкен-Бокен, Кайынды, Аблакетка, Уланка, Дресвянка и Кызылсу. Наиболее многоводным притоком левобережья является река Улкен Бокен (Большая Буконь), впадающая в Буктырминское водохранилище с юго-востока и образующая достаточно широкие разливы в устье, что послужило аргументами для выбора ее в качестве примера при анализе рек II группы [17].

Улкен Бокен относится к равнинным рекам со смешанным типом питания, с преобладанием дождевого. Половодье наступает в середине апреля и заканчивается в конце мая. Нередкими являются паводковые явления в период летне-осенней межени. Зимняя межень длится с декабря по март. Устойчивый ледяной покров на реке Улкен Бокен формируется во второй декаде ноября и держится до второй декады апреля. Для реки также характерны зажорно-заторные явления. Среднемноголетний расход реки за период с 1953 по 2021 гг. составляет 8 м^3/с, при среднемноголетнем уровне 691,81 мБС (табл. 1 и 2). Река характеризуется достаточно неустойчивым уровнем стока за разные годы с максимальными уровнями расходов, колеблющимися от 14 до 70 м^3/с, что еще раз доказывает зависимость ее питания от дождевых осадков. Наивысший уровень в реке наблюдался 25.04.15 г. у с. Джумба, достигнув отметки 694,11 мБС и, превысив критический уровень (693,85 мБС) на 26 см. Для реки характерны паводковый тип и наводнения в период половодья, возможны образования заторов и зажоров [18].

В III группу попадают реки, берущие начало на хребтах Саур и Тарбагатай и стекающие к озеру Жайсан. Большинство этих рек теряется в песках или пересыхает. Они характеризуются резкими подъемами уровня и широким разливом в силу преобладания равнинного рельефа в их устье. Это обусловлено климатическими особенностями и строением Зайсанской впадины, в которой расположено озеро. На питание реки Ертис и озера Жайсан значительного влияния они не оказывают.Среди подобных рек с более устойчивым стоком можно выделить Кандысу, Уйдене, и Кендерлык. Ниже приведен анализ рек III группы на примере Кандысу [17].

Река Кандысу является ярким примером рек III типа со смешанным питанием, с преобладанием дождевого, впадает в озеро Жайсан с юга. Верховья реки имеют постоянный круглогодичный сток, тогда как низовье часто пересыхает. Воды из реки Кандысу доходят до озера Жайсан только в периоды половодья и наиболее сильных паводков. В среднем течении река перестает быть горной и достаточно сильно разливается. Для регулирования воды на реке Кандысу и сохранения стоков построено Кандысуское водохранилище и канально-арычная сеть, используемая для полива. Русло реки неустойчивое и разделяется на множество рукавов. Начало половодья на реке Кандысу приходится на ко-

нец марта, а конец — на начало мая. Паводковые явления наблюдаются достаточно часто в течение всего теплого периода года и напрямую зависят от количества осадков, нет четкой выраженности даже зимнего периода межени. Ледостав на реке неустойчив, начало ледовых явлений приходится на середину ноября, а конец — на третью декаду марта. Зажорно-заторные явления не наблюдались. Среднемноголетний расход воды реки Кандысу в районе с. Сарыолен за весь период наблюдений с 2012 по 2021 гг. составлял 4,83 м^3/с при среднемноголетнем уровне воды 996,55 м усл. (табл. 1 и 2). Максимальный уровень воды на посту наблюдался 29.03.12 г. и составлял 997,31 м усл. При этом критический уровень начала выхода воды на пойму для данного участка не установлен. Для реки и ее притоков характерны наводнения в период половодья и кратковременных паводковых явлений [18].

В рамках исследования был проведен сбор и структуризация данных гидрологических наблюдений. Результаты были оформлены в виде электронной карты с привязанной информацией в виде реляционных таблиц (рис. 1). Собранные данные позволяют дать оценку состоянию гидрологической наблюдательной сети в целом, предложить рекомендации по ее усовершенствованию и могут быть использованы в дальнейшем для разработки и наполнения моделей прогнозирования наводнений. Основным критерием пригодности данных гидрологических постов для построения прогнозных моделей является период непрерывных наблюдений не менее 10 лет. Анализ распределения гидрологических постов по территории позволил дать оценку охвата водных объектов государственной сетью мониторинга.

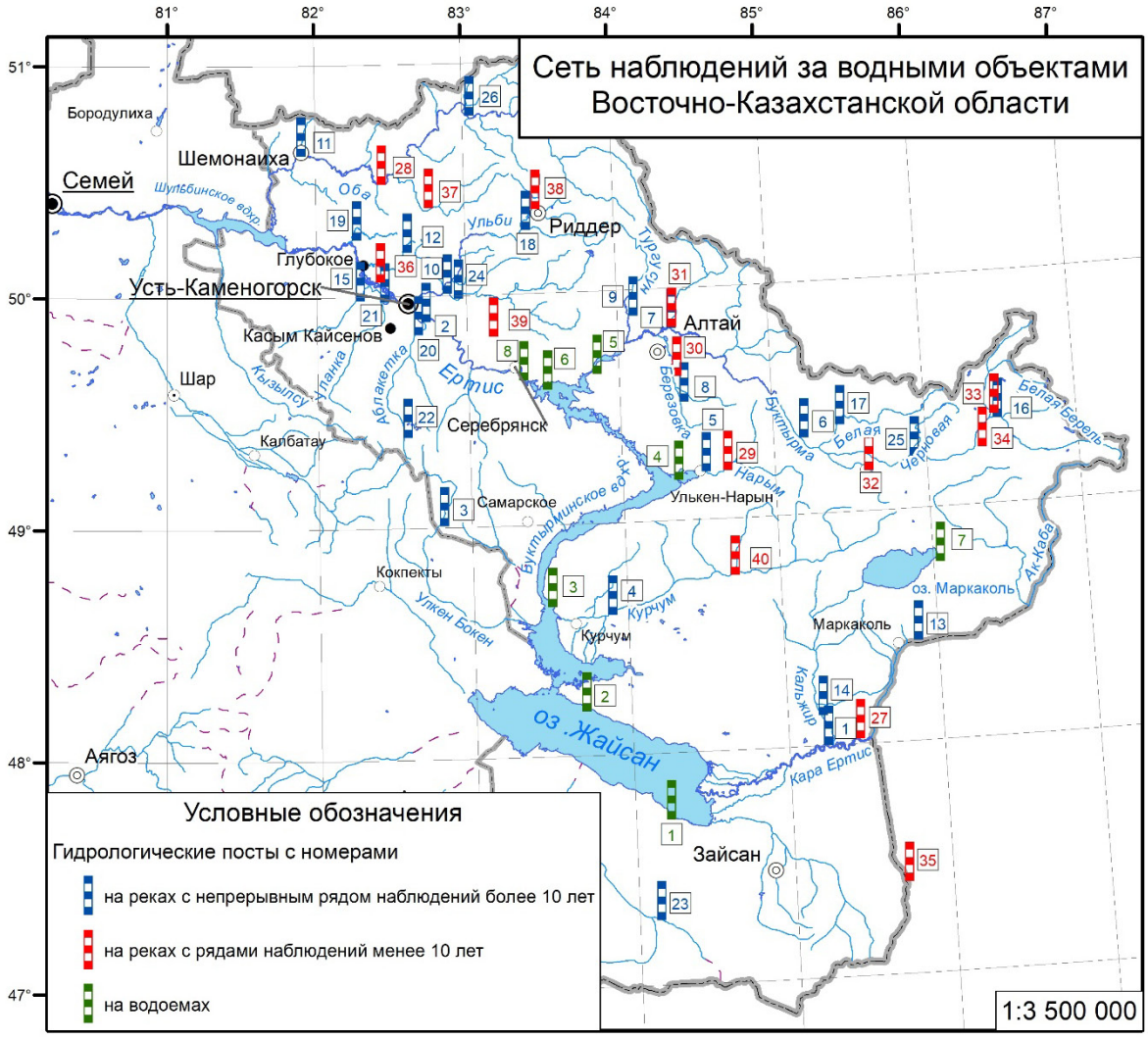

Рисунок 1. Карта распределения гидрологических постов государственной наблюдательной сети в границах Восточно-Казахстанской области

Государственная наблюдательная сеть в пределах Восточно-Казахстанской области представлена 48 гидрологическими постами. Из них 8 размещены на 3 водоемах и 40 — на 31 реке. Из 40 речных постов только 26 обладают достаточным для большинства гидрологических исследований непрерывным десятилетним рядом наблюдений, 5 из оставшихся 14 были созданы только в 2021 г. [18].

Наилучший охват наблюдениями осуществлен на реке Ертис совместно с озером Жайсан, водохранилищами и рекой Кара-Ертис. В целом на водном объекте размещены 7 озерных (2 на озере Жайсан и 5 на Буктырминском водохранилище) и 4 речных постов (по 2 на реке Кара-Ертис и на участке реки Ертис ниже Усть-Каменогорского водохранилища). Посты на водоемах существуют достаточно давно. Наиболее старые из них расположены у п. Тугыл (№ 1), который действует с 1931 г. (реорганизован в 1961 г.), и у с. Заводинка (№ 5), запущенный в работу с 1937 г. (реорганизован в 1963 г.). Реорганизация постов с перемещением оборудования связаны с запуском Буктырминского водохранилища в 1960 г. Остальные озерные посты также были построены в 60-е годы XX века в разное время с перерывом в пару лет. Следовательно, все действующие посты на Буктырминском водохранилище и озере Жайсан имеют ряды наблюдений не менее 60 лет, что является хорошим показателем и снижает вероятность ошибки при использовании моделей для прогнозирования наводнений на указанных водоемах. Кроме стандартного набора наблюдений за водным режимом и ледовыми явлениями, на данных постах ведутся наблюдения за температурой воды и повторяемостью ветра, что является важным для прогнозирования затоплений прибрежных территорий, связанных с ветровыми нагонами. Среди постов на реке Ертис, гидропост у п. Аблакетка (№ 2), расположенный ниже Усть-Каменогорского водохранилища, также действует с 1960 г., а речной пост у с. Уварово (№ 36) был запущен только в 2021 г. и достаточным рядом наблюдений обладать не может. Похожая ситуация существует и на реке Кара-Ертис, где речной пост № 1 у с. Боран (№ 1) ведет наблюдения с 2003 г., а гидропост на границе с КНР (№ 27) работает с 2016 г. Таким образом, среди из 11 постов на реке Ертис с водоемами, обладают достаточными рядами данных для построения актуальных моделей гидропрогноза только 9.

Крупнейший приток Ертиса — река Буктырма также достаточно хорошо охвачена системой гидрологических наблюдений. Общее число речных постов на ней и ее притоках составляет 12. Среди них 3 достаточно равномерно распределены по руслу самой Буктырмы (№ 6, 7 и 16), охватывая как верховья, так и низовья, 2 — на реке Березовка (№ 30) с притоком Левая Березовка (№ 8) и по 1-му на реках Хамир (№ 31), Тургысын (№ 9), Белая (№ 17), Сарымсакты (№ 32), Черновая (№ 25), Орел (№ 34) и Белая Берель (№ 33). На 2024 г. только 7 постов проходят критерий отбора 10 и более лет наблюдений, среди них посты на реках Буктырма, Левая Березовка, Тургысын, Белая, Черновая.

В пределах бассейна реки Ульби размещены 4 гидропоста. Из них 2 на реке Ульби (№ 10 и 18) в верхнем и нижнем течении, 1 — р. Киши Ульби (№ 24) и 1 — на реке Шаравка (№ 38). Все посты, кроме № 38 на Шаравке, имеют ряды наблюдений более 10 лет. Стоит отметить, что охват наблюдательной сетью на притоках реки Ульби гораздо ниже с учетом достаточно большой густоты речной сети. Нет стационарных постов наблюдений на реках Тихая и Громотуха, образующих при слиянии р. Ульби. Несмотря на то, что в рамках мониторинга качества поверхностных вод, ведутся наблюдения и отборы проб на химический состав в реках Филипповка и Брекса (притоки Тихой), расположенных в старейшем районе горнодобывающей промышленности, гидропосты здесь также отсутствуют. Слабо охвачена р. Киши Ульби, в верховьях которой расположено Малоульбинское водохранилище.

На реке Оба расположены 3 наблюдательных гидропоста (№ 11, 26 и 28) и 1 расположен на ее притоке Малой Убинке (№ 37). Рядами наблюдений более 10 лет обладают только посты № 11 и 26, расположенные в г. Шемонаиха и у с. Каракожа. Малое количество гидрологических постов объясняется низкой заселенностью северо-восточных и северных горных районов, где расположены верховья реки Оба и множество ее притоков, то есть отсутствует безотлагательная необходимость постоянного контроля режима реки ввиду отсутствия или низкой плотности объектов подверженных риску затопления. Среди потенциальных точек размещения новых постов можно выделить устье реки Оба, где она впадает в Шульбинское водохранилище и существуют риски затопления прибрежных территорий.

Река Куршим берет начало в горных хребтах Юго-Западного Алтая, но в нижнем течении становится равнинной, в устье образуя дельту при впадении в Буктырминское водохранилище. Притоки реки достаточно маловодны и незначительны. На реке Куршим расположены 2 гидрологических поста: у с. Вознесенка (№ 4) и у с. Маралды (№ 40), в нижнем и среднем течении, соответственно. Пост № 40 запущен только в 2020 г., из чего следует, что ряд наблюдений более 10 лет присутствует толь-

ко на гидропосте № 4. По охвату 2-х гидрологических постов для низовий бассейна реки вполне достаточно. Установка дополнительных постов в верховьях реки может сопровождаться сложностями, сопряженными с селевой опасностью района.

Бассейн реки Кальжир, включает в себя озеро Маркаколь и, соответственно, по 1 озерному и речному постам. Гидропост на озере Маркаколь (№ 8) — один из старейших, работает с 1942 г., что полностью соответствует критерию непрерывности и длине ряда наблюдений. Пост на реке Кальжир (№ 14) также имеет ряд наблюдений более 10 лет. Охват сетью постов в данном бассейне минимален, отсутствуют наблюдения на реках, впадающих в озеро Маркаколь, кроме реки Урунхайка, где расположен озерный пост. Дополнительный речной пост может быть установлен в верховьях реки Кальжир.

На реке Нарын имеются 2 гидрологических поста (№ 5 и 29), что вполне достаточно для ее низовий, учитывая небольшие размеры бассейна. В верховьях размещение гидропоста может быть сопряжено с селевой опасностью района. Недалеко в Буктырминском водохранилище расположен озерный пост № 4, в районе бывшего устья реки Нарын. Только пост № 5 непрерывно работает более 10 лет, пост № 29 был создан в 2020 г.

Среди более мелких рек, впадающих непосредственно в реку Ертис на разных участках, необходимо отметить, что по 1 посту расположено на реках Смолянка (№ 39), Глубочанка (№ 12) и Красноярка (№ 19). Учитывая малозначимость их бассейнов, этого вполне достаточно. Критерию непрерывности ряда наблюдений более 10 лет соответствуют только посты № 12 и 9. Гидропост на реке Смолянка был создан только в 2021 г.

Отдельно также стоит упомянуть пограничную с КНР реку бассейна Кара-Ертиса — Бас-Теректы, где также расположен 1 пост под номером 13. Он обладает достаточным рядом непрерывных наблюдений, несмотря на то, что сама река большого значения в стоке Кара Ертиса не имеет.

Среди водотоков II группы, являющихся левобережными притоками Ертиса гидропосты расположены на реках Улкен Бокен (№ 3), Аблакетка (№ 20), Сибе (№ 22), Уланка (№ 21) и Дресвянка (№ 15). Все указанные гидропосты имеют ряд непрерывных наблюдений более 10 лет. Учитывая маловодность данных рек, малый охват их наблюдательной сетью гидрологических постов вполне объясним. Перспективными местами размещения новых постов здесь являются реки левобережья Буктырминского водохранилища в Самарском районе области, которое в последние годы активно застраивается и начинает вовлекаться в сферу туризма. Примерами таких мест могут быть устья рек Улкен Бокен, Кайынды и Лайлинка.

Реки III группы получили наименьший охват гидрологической сетью. Практически единственным гидрологическим постом здесь является пост у с. Сарыолен на р. Кандысу (№ 23). Он запущен с 2012 г. и уже имеет достаточный для анализа ряд наблюдений, чего, однако, недостаточно для оценки ситуации по всей протяженности реки. Второй пост расположен на Улкен Уласты (№ 35), пограничной с КНР реке, сток которой номинально относится к бассейну Кара-Ертиса, но фактически теряется в песках на территории Китая. На определнных равнинных участках реки указанной группы достаточно широко разливаются ввиду малых перепадов высот, что приводит к затоплению больших участков земли. Перспективные гидрологические посты здесь можно разместить, в первую очередь, на реках Кендерлык и Уйдене, играющих важную роль в орошении.

В целом можно сделать вывод, что государственной сетью мониторинга режима поверхностных вод в наилучшей степени охвачено правобережье реки Ертис, за исключением труднодоступных горных территорий на границах с Россией и Китаем. Левобережная часть охвачена значительно меньше, здесь все еще имеется достаточное количество водоемов и рек, нуждающихся в режимных наблюдениях. В рамках настоящего предварительного исследования приведены только наиболее перспективные участки расширения гидрологической сети. Для более детального анализа необходимо провести моделирование территории и экспертную оценку полученных результатов, что и планируется осуществить в дальнейшем.

Созданная в рамках настоящего исследования база гидрологических данных была дополнена информацией о расположении населенных пунктов с наиболее частыми случаями регулярных затоплений в результате разлива рек. Источником данных послужили обработанные сводки, обзоры МЧС РК и публикации в средствах массовой информации за период с 2010 по 2021 гг. Результаты исследования оформлены в виде электронной карты с привязкой атрибутивных данных (рис. 2).

По пространственному распределению наибольшее количество затапливаемых участков сконцентрировано в районе г. Усть-Каменогорска на участке реки Ертис и его притоках от нижнего бьефа

Усть-Каменогорской ГЭС до пос. Предгорное (Глубоковский район), в том числе на реке Ульби до г. Риддер, реках Красноярка, Глубочанка и других. Необходимо отметить, что большинство этих водных объектов охвачены сетью наблюдений гидрологических постов, за исключением наиболее мелких ручьев и проток.

Другой участок с наибольшей концентрацией населенных пунктов, подверженных затоплению, располагается на реке Буктырма от города Алтай до ее впадения в Буктырминское водохранилище. Отдельные очаги встречаются и выше по течению, а также на всех основных притоках. Бассейн реки Буктырма достаточно хорошо охвачен гидропостами, что позволяет достаточно точно прогнозировать затопления. Единственным неохваченным уязвимым населенным пунктом здесь является с. Чапаево на реке Крестовка.

Среди других крупных рек стоит выделить бассейн р. Оба, где затапливаемые населенные пункты достаточно сильно рассеяны и не везде имеются гидрологические посты. К таким участкам можно отнести пос. Усть-Таловку на р. Таловка (Шемонаихинский район) и с. Убинка в устье р. Оба.

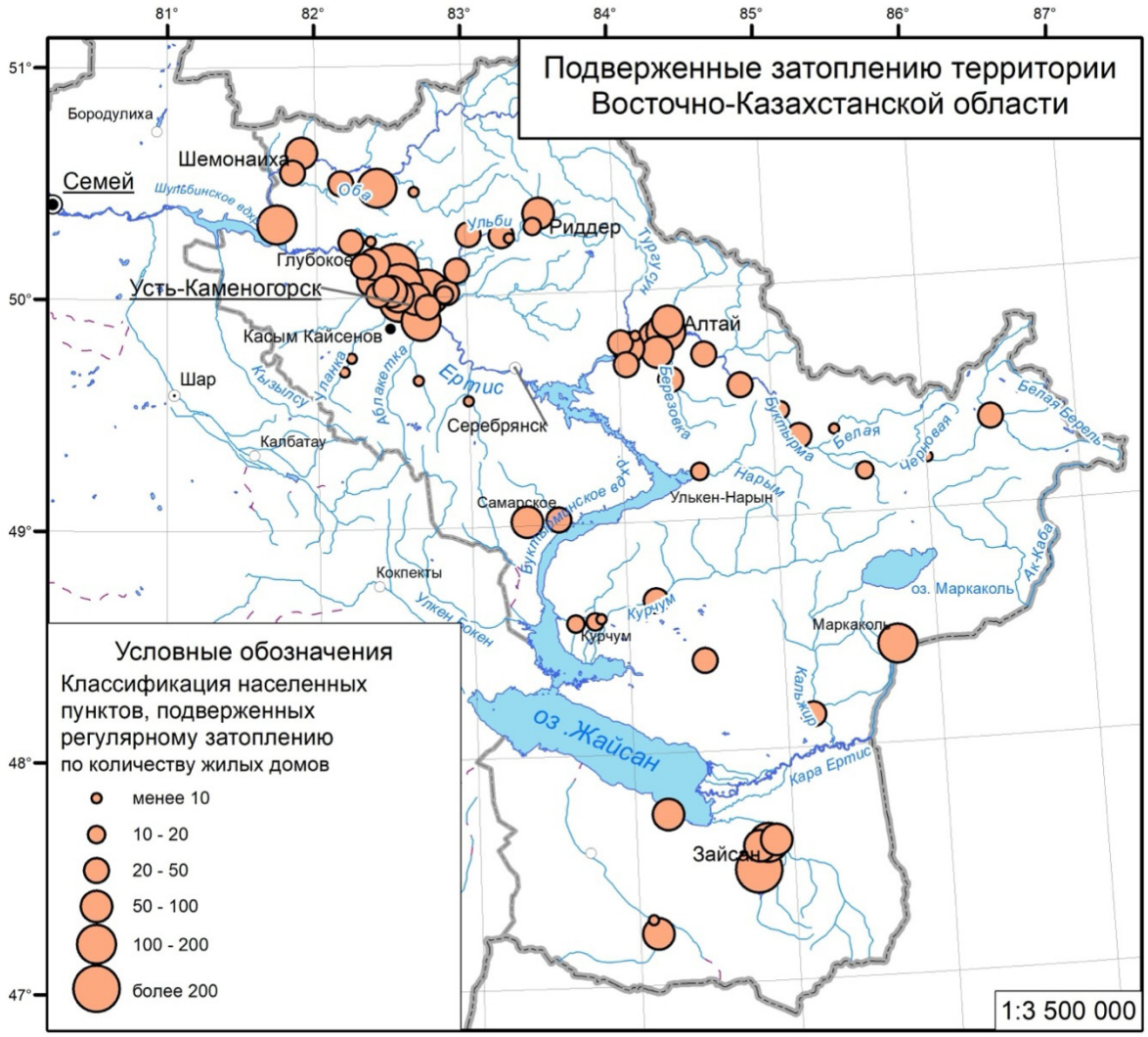

Рисунок 2. Карта подверженных затоплению участков Восточно-Казахстанской области по состоянию на 2021 г.

Затапливаемые участки бассейнов рек Кальжир, Куршим и Нарын в основном сосредоточены в низовьях и при впадении в реку Кара Ертис и Буктырминское водохранилище. Все они охвачены гидрологическими постами, как и р. Бас-Теректы. Единственным неохваченным населенным пунктом в Куршимском районе остается с. Каратогай на р. Калгутты, в полноводные периоды впадающей в Буктырминское водохранилище.

Левобережные реки II группы наблюдательной сетью охвачены достаточно слабо, в результате чего здесь местами встречаются подверженные затоплениям небольшие населенные пункты. Среди них административный центр с. Самарское на реке Лайлинка, с. Миролюбовка на р. Кайынды, с. Уланское и Жанузак в верховьях реки Уланка, с. Асубулак на реке Унгырды и с. Бестерек на ручье Колбала.

Среди рек III группы, как отмечалось выше, единственный гидрологический пост расположен на р. Кандысу, здесь же находятся подверженные затоплению населенные пункты, с. Сарыолен и Жанаул. На реке Уйдене гидрологических постов нет и при этом расположены 4 подверженных затоплениям населенных пункта (с. Кенсай, Жарсу, Бакасу и Сарыжыра).

В районе пос. Тугыл также имеется затапливаемый участок на реке Кабыргатал. Речных постов здесь нет, однако имеется пост на озере Жайсан.

Необходимо отметить, что не все зоны затопления охвачены в рамках настоящего исследования, в том числе остались без внимания населенные пункты и базы отдыха, размещенные на побережье Буктырминского водохранилища. Это объясняется тем, что информация по многим из них достаточно разрознена и сложна для качественной обработки, а данное исследование посвящено предварительному сбору информации о водных объектах с последующей целью подбора подходящей модели для прогнозирования наводнений. В дальнейшем база данных будет уточнена и дополнена.

Заключение

Анализ зарубежного и отечественного опыта в области исследования наводнений показал важность использования длительных рядов данных непрерывных наблюдений с четкой пространственной привязкой для получения возможности применения наиболее точных и комплексных моделей прогнозирования.

Анализ основных притоков р. Ертис в пределах Восточно-Казахстанской области позволил выделить 3 группы рек по водному режиму и территориальным особенностям.

К группе I отнесены правобережные притоки, берущие начало на хребтах и предгорьях Юго-Западного Алтая. Они характеризуются постоянным стоком, многоводностью и обеспечивают большую часть питания р. Ертис. К ним в первую очередь относятся р. Буктырма, Оба, Ульби и в меньшей степени Куршим, Кальжир, Нарын и другие. Среди других крупных водных объектов необходимо отметить Маркаколь, проточное озеро, соединенное с рекой Кара-Ертис через ее приток Кальжир. Начало половодья на этих реках приходится на последнюю декаду апреля, а конец — на первую декаду июня. В отдельные годы с августа по ноябрь могут наблюдаться опасные паводковые явления, поднимающие уровень воды до значений половодья того же года. Зимняя межень длится с декабря по март. Устойчивый ледяной покров формируется во второй декаде декабря и держится до середины апреля. Периоды осеннего и весеннего ледохода могут сопровождаться образованием зажоров и заторов.

II группа притоков р. Ертис значительно менее многоводна, но в большинстве имеет постоянный сток. Все они берут начало на Калбинском хребте и впадают в Буктырминское, Усть-Каменогорское и Шульбинское водохранилища или на участке р. Ертис между ними. К наиболее крупным из них относят р. Улкен-Бокен, Кайынды, Аблакетка, Уланка, Дресвянка и Кызылсу. Реки II группы отнесены к равнинным рекам со смешанным типом питания, с преобладанием дождевого. Половодье наступает в середине апреля и заканчивается в конце мая. Нередкими являются паводковые явления в период летне-осенней межени. Зимняя межень длится с декабря по март. Для рек II группы характерны паводковый тип и наводнения в период половодья, возможны образования заторов и зажоров.

В III группу попадают реки, берущие начало на хребтах Саур и Тарбагатай и стекающие к озеру Жайсан. Большинство этих рек теряется в песках или пересыхает. Они характеризуются резкими подъемами уровня и широким разливом в силу преобладания равнинного рельефа в их устье. Это обусловлено климатическими особенностями и строением Зайсанской впадины, в которой расположено озеро. На питание реки Ертис и озера Жайсан значительного влияния они не оказывают. Среди подобных рек с более устойчивым стоком можно выделить Кандысу, Уйдене, и Кендерлык. Реки III типа имеют смешанное питание с преобладанием дождевого. Верховья рек имеют постоянный круглогодичный сток, тогда как низовье часто пересыхает, их воды доходят до озера Жайсан только в периоды половодья и наиболее сильных паводков. Русло неустойчивое и может разделяться на множество рукавов. Начало половодья приходится на конец марта, а конец — на начало мая. Паводковые явления наблюдаются достаточно часто в течение всего теплого периода года и напрямую зависят от

количества осадков, нет четкой выраженности даже зимнего периода межени. Ледостав неустойчив, начало ледовых явлений приходится на середину ноября, а конец — на третью декаду марта. Зажорно-заторные явления никогда не наблюдались. Для реки и ее притоков характерны наводнения в период половодья и кратковременных паводковых явлений.

Проведенный анализ гидрологических данных позволил установить, что из 48 гидрологических постов государственной наблюдательной сети в пределах Восточно-Казахстанской области только 26 работают продолжительное время, достаточное для того, чтобы накопить ряд непрерывных наблюдений более 10 лет. По пространственному размещению гидропостов определено, что в наибольшей степени ими охвачены бассейны рек I группы и в наименьшей — III группы. К перспективным районам размещения дополнительных гидропостов отнесены бассейны р. Ульби, Оба, верховья р. Куршим, Нарын и Кальжир, реки левобережья Буктырминского водохранилища (Улкен-Бокен, Кайынды и Лайлинка) и реки бассейна озера Жайсан (Кандысу, Кендерлык и Уйдене). Приведены только наиболее перспективные участки расширения гидрологической сети. Для более детального анализа необходимо провести моделирование территории и экспертную оценку полученных результатов, что и планируется осуществить в дальнейшем.

Анализ данных МЧС РК позволил выделить наиболее проблемные участки рек затапливаемых территорий и сравнить эти участки с охватом гидрологических постов. К проблемным участкам, нуждающимся в расширении государственной сети наблюдений, отнесены следующие населенные пункты: с. Чапаево на р. Крестовка (район Алтай), пос. Усть-Таловка на р. Таловка и с. Убинка в устье р. Оба (Шемонаихинский район), с. Каратогай на р. Калгутты (Куршимский район), с. Самарское на р. Лайлинка и с. Миролюбовка на р. Кайынды (Самарский район), с. Уланское и Жанузак в верховьях р. Уланка, с. Асубулак на р. Унгырды и с. Бестерек на ручье Колбала (Уланский район), с. Кенсай, Жарсу, Бакасу и Сарыжыра на р. Уйдене и пос. Тугыл на р. Кабыргатал (Зайсанский район). Уязвимые участки выделены предварительно, в том числе остались без внимания населенные пункты и базы отдыха, размещенные на побережье Буктырминского водохранилища.

Созданная картографическая база данных с применением ГИС-технологий послужит отправной точкой для более детальных исследований на основе моделирования и экспертных оценок. Анализ собранных материалов свидетельствует о том, что существующий объем гидрологических данных недостаточен для глобального моделирования всей территории ВКО целиком в крупном масштабе, и для прогнозирования наводнений потребуется применение подходов, направленных на использование косвенных данных о климате, особенностях рельефа и др. На текущем этапе целесообразнее сфокусировать усилия на отдельных локальных участках, в особенности на уязвимых населенных пунктах.

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А.В. Павленко, А.Қ. Мансурова, А. Қызырқанов, Д.В. Черных

Шығыс Қазақстан облысындағы су тасқынының болжау деректерімен қамтамасыз етілуі және бақылау жүйесі

Мақала Шығыс Қазақстан облысындағы су объектілері туралы қолжетімді ақпаратты жинақтауға арналған. Бұл мәліметтер Қазақстан Республикасының Ұлттық гидрометеорологиялық қызметі мен Қазақстан Республикасының Төтенше жағдайлар министрлігінің ашық дерек көздерінен алынған. Жинақталған мәліметтер негізінде географиялық ақпараттық жүйеде (ГАЖ) кеңістіктік байланыстыру арқылы атрибутивтік мәліметтер базасын құру және су тасқынын болжау модельдерін әзірлеу мен енгізуге бағытталған кейінгі зерттеулер негізін қалыптастыру көзделген. Қазақстанның әртүрлі аймақтарындағы және шетелдердегі су тасқынын болжау бойынша зерттеулерге шолу жүргізіліп, нәтижесінде мәліметтерді бағалау критерийлері мен гидрологиялық мониторинг жүйесі жасалды. Шығыс Қазақстанның негізгі су объектілерінің гидрологиялық режиміне сипаттама берілді. Гидрологиялық бекеттер желісі мен белгілі су басу аймақтарының кеңістіктік талдауы негізінде мемлекеттік бақылау жүйесінің кеңістіктік қамтуына баға беріліп, оны кеңейту бойынша ұсыныстар айқындалды. Жиналған мәліметтерді болжамдық модельдер жасау барысында қолдану мүмкіндігі туралы қорытындылар жасалды.

Кілт сөздер: су тасқыны, бақылау, ГАЖ, атрибутивтік мәліметтер, Шығыс Қазақстан облысы, су объектілері, гидрологиялық бекет, су басу аймақтары, гидрология, болжам.

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Monitoring System and Data Availability for Flood Forecast in the East Kazakhstan Region

This article focuses on collecting available information about water bodies in the East Kazakhstan Region, sourced from open data provided by the National Hydrometeorological Service of the Republic of Kazakhstan and the Ministry of Emergency Situations of the Republic of Kazakhstan. The goal is to create a spatially referenced attribute data base in a GIS framework and to lay the foundation for subsequent research aimed at developing and implementing flood forecasting models. A review of studies on flood forecasting in various regions of Kazakhstan and other countries was conducted, resulting in the formation of criteria for evaluating data and hydrological monitoring systems. The article also provides a characterization of the hydrological regime of key representative water bodies in East Kazakhstan. Based on spatial analysis of the hydrological station network and known flood zones, an assessment of the spatial coverage of the state observation system was made, and recommendations for its expansion were developed. Conclusions were drawn regarding the applicability of the collected data in creating predictive models.

Keywords: floods, monitoring, GIS, attribute data, East Kazakhstan Region, water bodies, hydrological station, flood zones, hydrology, forecasting.

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Assessment of the impact of the life quality on human health (on the example of the greater Caucasus province of the Republic of Azerbaijan)

Health occupies an important place among the system of indicators determining the life quality. The issues of ameliorating health indicators, which are the basis of the quality of life of the population, are especially actual for the Greater Caucasus province, which plays an important role in the socio-economic development of the Republic of Azerbaijan, and has a high demographic and labour potential. The primary aim of the research work with practical importance is to study the territorial organisation of healthcare in the Greater Caucasus province, the quality of the environment and their impact on the quality of life. Dissemination indicators of the disease among the population settling in the province were scrutinised based on the statistical materials, and the current state of the contemporary healthcare facilities and how they affect the quality of life were investigated. According to the results of the research, the role of environmental factors in the health of the population populating in the province has been significant in recent years. It was revealed that during the investigated period, the amount of waste from stationary and automobile transport has decreased in the province, and the number of diseases has increased. In addition to this, the relationship of the Human Development Index with the environment and its impact ways on the quality of life were investigated. Analyses indicate that along with other factors, the quality of the environment affects the quality of life of the population. Nominately, the Human Development Index has increased as the amount of waste discharged into the atmosphere has decreased. More precisely, the correlation between them is negative and the coefficient of determination is 0,857 in other words, dependence was determined to be 85 %.

Keywords: life quality, human health, healthcare, environment, Human Development Index.

Introduction

Protecting the health of the population, which is the main indicator of socio-economic development, is one of the most urgent problems of the modern era. The primary aim of this development consists of creating a favourable environment for living long and healthy of the people. Diseases and their regional distribution depend on natural geographic conditions, environmental quality, and other factors [1]. Mankind has always depended on the natural environment throughout his life. Nature is one of the essential factors that constantly ensure human survival and development. Protection of the environment and conducting a policy aimed at improving the quality of life in these conditions is one of the important factors affecting the sustainability of socio-economic development and the improvement of the quality of life [2]. Human welfare and quality of life depend pretty much on the quality and quantity of water, food, energy, and biological resources getting today and in the coming days. In the research area, environmental degradation influences society in various ways. It has brought about the spread of various diseases by depriving people of the means necessary for living, having a negative effect on their health. Thus, the role of environmental pollution and environmental stress in the emergence of diseases is undeniable [3]. As a result of anthropogenic activity, changes in the thermal balance as a consequence of deforestation, destruction of greenery, accumulation of dust particles and volatile gases creating a greenhouse effect in the atmosphere, the exacerbation of global warming, and other processes have led to the increase of diseases in modern times. In addition to these processes, the low quality of food products is also one of the important factors affecting the health of the population. All these mentioned factors, in turn, influence the quality of life of the population.

Experimental

The Greater Caucasus province has a favourable economic and geographical position encapsulating the north, north-west and north-east parts of the Republic of Azerbaijan. Thus, the region has a complex hypsometric relief from the coastal plains of the Caspian Sea to the highest peak of the republic (Mount Bazarduzu, 4466 metres). Having 27,8 thousand km^2 area, the province covers 32,1 % of the country's territory (Fig. 1).

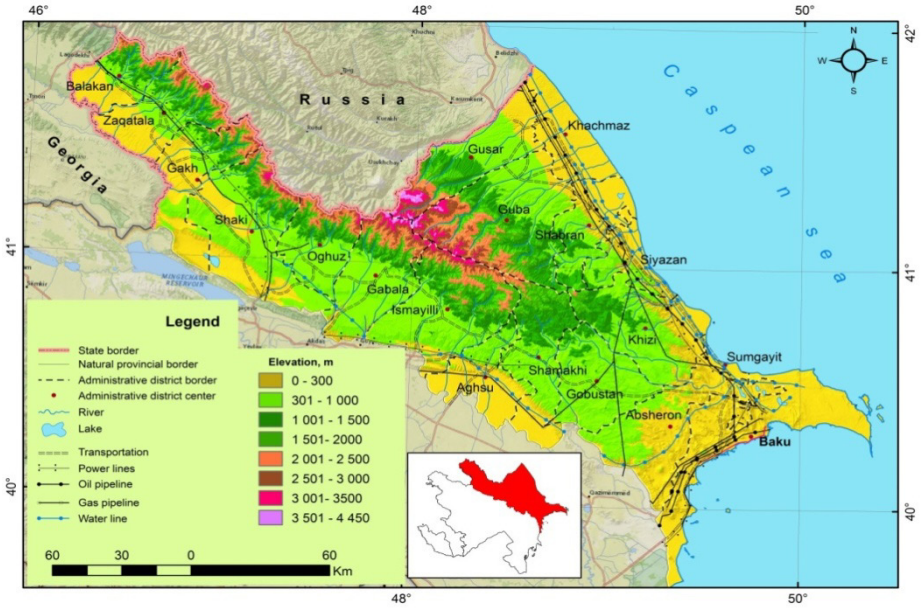

Figure 1. Natural and geographical conditions of the Greater Caucasus Province

Conceptual framework and method. In order to apply the information to the region, the works of scientists who conducted research in this field were referred to in the research work. S.A. Vasnev [4] used socio-economic indicators such as human health and average life expectancy in evaluating the concept of quality of life. M.Sh. Salimov [5] investigated the characteristics of the quality of life, such as the development of human potential, medical and environmental characteristics, material welfare and employment characteristics, and parameters of the security field.

Among Azerbaijani scientists Sh.M. Muradov [6], J.B. Guliyev and R.S. Abdullayeva [7], Z.N. Eminov [8], S.I. Rzayeva [1] and othershave studied more widely changes occuring indicators of the life quality of population, the quality of the environment, medical-geographical problems, and their causes and consequences as a result of socio-political and economic processes taking place in the country, as well as in various economic regions. Although studies have been conducted in the field of the quality of life of the population in various regions, the problems of the influence of the geographical distribution of diseases on the quality of life have not been researched. Thereby, this research can be considered the first study of the impact of the geographical distribution of diseases on the quality of life of the population in the Greater Caucasus province of Azerbaijan.

All data utilised in the research work is procured from official sources published in recent years. The statistical, comparative analysis, system-structural, cartographic, SPSS statistics and other methods were used in the article.

The application of Geographical Information Systems (GIS) tools plays a key role in the large-scale assessment of the quality of life as well [9]. In the contemporary epoch, the leap in graphic capabilities of computer technology has led to the expansion of its use fields. GIS is a computer-aided technology that collects, stores, updates, analyses, models, and forecasts spatial and attributive data related to geographic objects and events and is used in finding solutions to problems [10]. Corresponding information was carried out using the integrated tools of GIS.

Results and Discussion

The Greater Caucasus province includes Baku, Absheron-Khizi, Shaki-Zagatala, Guba-Khachmaz and Daghlig (Mountainous) Shirvan economic regions [11]. According to the statistical data of 2022, constituting 46,5 % of the country's population, the population of the Greater Caucasus province is 4676,1 thousand people. There are 20 cities and 1312 rural settlements in this province. The urban population of the Greater Caucasus province is 3550, 1 thousand people, and the rural population is 1126,0 thousand people [12]. In the Greater Caucasus province, 65,7 % of the urban population is concentrated in Baku city, 21,1 % in the Absheron-Khizi economic region. 3–5 % of the urban population of the province falls to other economic regions' share. There were sharp differences between the city of Baku and other economic regions of the

republic in the level of socio-economic development and the formation of demographic potential. The concentration of the majority of the industry and service areas in this province has led to the migration of the population from rural areas to the city. The concentration of most of the socio-cultural and demographic potential in Baku has led to the concentration of medical facilities in this area. Therefore, most of the healthcare facilities, doctors and paramedics are located in this place. In this regard, the essential medical-geographical processes such as the geographical distribution of diseases, their socio-economic problems and expected results were investigated as one of the indicators affecting the life quality of the population in the Greater Caucasus province of the Republic of Azerbaijan.

In the year 2021, 158 hospitals operated in Baku city, and they had 20,1 thousand hospital beds (pads). The number of doctors was 21,1 thousand, and the number of secondary medical workers was 22,7 thousand. It was observed that the healthcare indicators per 10,000 people of the population decreased during the 21-year period (Table).

T a b l e

Healthcare indicators per 10,000 of the population

Economic regions	The number of doctors			The number of paramedics			The number of hospital beds (pads)			The power of ambulator care and polyclinic facilities		
	2000	**2010**	**2021**	**2000**	**2010**	**2021**	**2000**	**2010**	**2021**	**2000**	**2010**	**2021**
Baku city	84,4	89,7	91,7	108,1	106,0	98,4	115,0	91,2	87,3	182,4	146,1	165,1
Absheron-Khizi	33,9	38,2	30,1	82,4	67,8	47,9	79,3	53,4	37,3	94,2	70,6	63,6
Shaki-Zagatala	19,9	22,2	15,8	68,8	65,0	52,9	83,4	28,5	22,6	140,8	127,7	102,0
Guba-Khachmaz	14,1	16,6	13,7	47,0	43,3	34,8	58,3	29,2	19,0	99,5	98,8	100,3
Daghlig (Mountainous) Shirvan	13,1	15,0	9,9	50,1	43,4	29,0	57,5	25,1	27,1	106,7	87,4	73,4
Province	33,1	36,3	32,2	71,3	65,1	52,6	78,7	45,5	38,7	124,7	106,1	100,9

Note – Source: Regions of Azerbaijan, 2005, 2022 [13, 14]

During the research period, a significant decrease (50–60 %) was observed in both the number of hospitals and the number of hospital beds in the economic regions. In addition, the number of qualified doctors in the regions is inadequate, there is a shortage of doctors in different specialties. Therefore, patients from the regions come to Baku. Healthcare indicators per 10,000 people in Baku are 2-3 times higher than the average provincial indicators. The relative indicators of other economic regions are in most cases close to the average indicators of the province.

Research indicates that in 2021, 1303,9 thousand patients (2,664 per 10,000 people) were registered in the Greater Caucasus province, which is 1,5 times more than in 2000. One of the most widespread diseases among the population is respiratory diseases. The relative rate of people suffering from this disease in the province is 1045,1 per 10,000 people. The highest indicator for economic regions was observed in Daghlig (Mountainous) Shirvan (1386,2) and Baku (1205,8). The second widespread disease is infectious and parasitic diseases. 303,9 patients per 10,000 people were registered in the province. Absheron-Khizi has the highest rate with 570,6 people, in other economic regions, it varies between 150–300 people per 10,000 people. Diseases of the nervous system, digestive system and circulatory system are the third on the list. In 2021, 290,3, 191,6, and 170,7 patients per 10,000 people were registered in the province, respectively. Neurological diseases were mostly observed in Baku (539,2), Shaki-Zagatala (306,3) and Absheron-Khizi (301,7). Digestive system diseases were recorded in Baku (273,7) and Shaki-Zagatala (260,5), and circulatory diseases were recorded more in Shaki-Zagatala (291,7). Compared to 2015, there was a 25,3 % increase in the total number of patients in the Greater Caucasus province in 2022. However, a sharp increase in the development of diseases related to infectious and parasitic, neoplasms, neuropathy, and circulatory diseases was observed. The occurrence of such cases in the last 3 years was directly related to the negative effects of the “isolation” brought by the coronavirus pandemic on the population (Fig. 2).

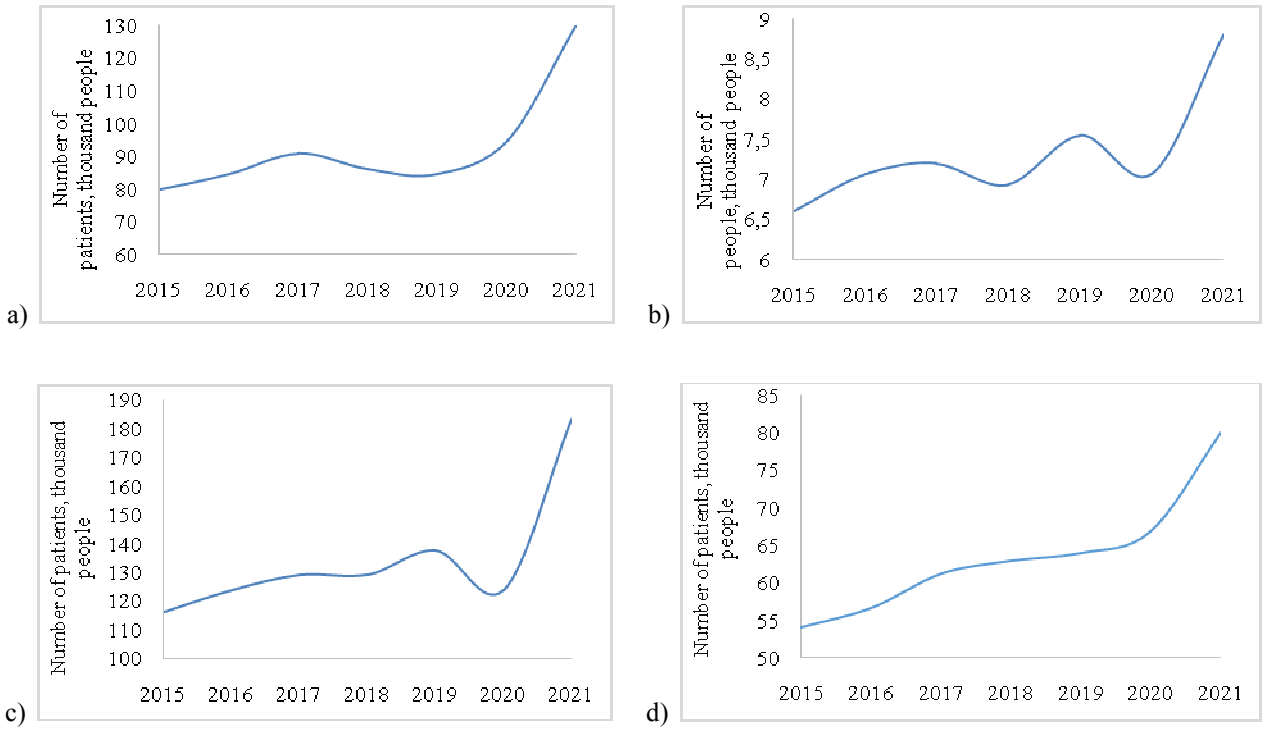

Figure 2. Infectious and parasitic (a), neoplasms (b), neuropathy (c), circulatory disease's (d) perennial dynamics

Thus, there are serious differences in the regional organisation of healthcare services, the number of healthcare facilities, and the coverage of the population with these facilities. The sparseness of hospitals in the regions, low salaries, and poor organisation of the social protection system have led to the lack of personnel and the inability of services to meet modern requirements. It is fairly important to solve these problems and improve the medical services provided to the population.

The quality of the environment for a person is determined by his health. The environment is a set of components that affect the quality of life, living conditions and human health [15]. Extreme heat, sudden changes in temperature, poor air quality, and extreme weather conditions adversely affect health. The increased risk of heart attack and stroke, suicide, mental problems, asthma, allergies, and some infectious diseases is especially noticeable. Atmospheric pollution is one of the necessary factors that cause climate changes, which are considered environmental problems in the Greater Caucasus province, and indirectly affect the quality of life and human health. Air pollution and violation of its transparency and gas concentration pose not only climate changes but also a threat to the health of the population in the area [3]. As can be seen from the analysis, the majority of polluting substances released into the atmosphere in 2021 fall on the share of Baku city (94.2 %). The Greater Caucasus region also plays an important (88,3 %) role in air pollution across the republic. This is also related to the location of Baku city in the province. In other economic regions, the amount of pollutants released into the atmosphere was 0,1–3,7 thousand tons. Compared to 2005, a sharp decrease in these indicators was witnessed in the Absheron-Khizi economic region, as well as Baku city. Accordingly, there was a decrease of 3,6 times compared to 2005 in the province. During the years 2000–2021, a total of 2,880,000 tons of pollutants were released into the atmosphere from stationary sources in various economic regions located in the Greater Caucasus province. The primary part of this falls to Baku city's share (2726 thousand tons) [13, 14]. Although the share of pollutants emitted into the atmosphere increased slightly in the Daghlig (Mountainous) Shirvan, Guba-Khachmaz and Shaki-Zagatala economic regions in the years 2000 and 2021, a decrease was observed in the Baku and Absheron-Khizi economic regions. The amount of waste thrown into the environment is one of the most important factors affecting human health. In order to visually observe the geographical distribution of the amount of waste and diseases, the relevant data were visualised using the ArcGIS software (Fig. 3). Based on the analysis, it can be enunciated that the number of patients is also high in the areas where the amount of waste is high. These indicators depend on each other.

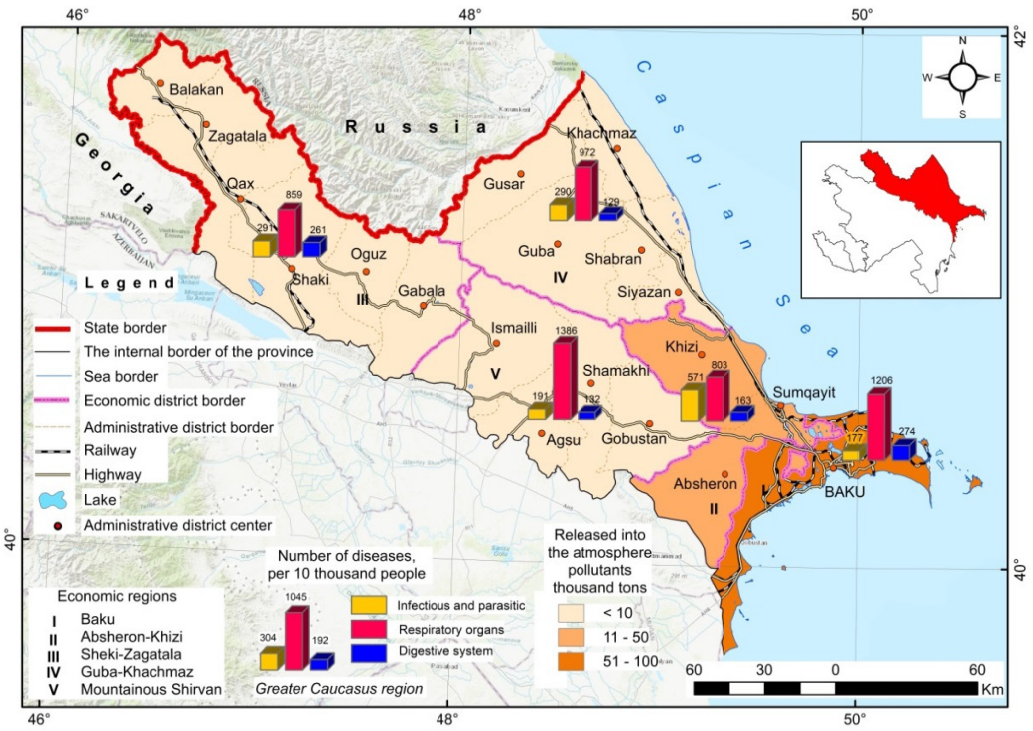

Figure 3. The number of air pollutants emitted into the atmosphere and the geographical distribution of diseases in the Greater Caucasus province

The reduction of pollutants released into the atmosphere is the result of the closure of some enterprises and the recent reforms in the field of environmental protection. After the waste is collected, it is neutralised by the state institutions by means of disposal, selection, decomposition, recycling and other methods. The average annual amount of household waste in economic regions such as Guba-Khachmaz, Shaki-Zagatala, and Daghlig (Mountainous) Shirvan was 364 thousand m^3 compared to 5354 thousand m^3 in Absheron and Baku. It is 1000 m^3 daily in mountainous regions, and close to 15 thousand m^3 in Absheron and Baku [13, 14]. Observations indicate that the uncontrolled and untimely collection of household waste in residential areas has caused the spread of harmful waste to the surrounding areas through air and rainwater, causing the emergence and spread of several diseases. Based on the analysis, it can be enunciated that as the amount of household waste increases, so does the number of infectious patients. These indicators depend on each other. The result of the linear correlation coefficient is 0,863. The relationship between indicators is intense. Assuming that the coefficient of determination ($R2$) is 0,617, it can be concluded that the obtained regression model is significant and useful for forecasting based on the data of the database. The increase in the amount of waste affects the health of the population by 61 % (Fig. 4).

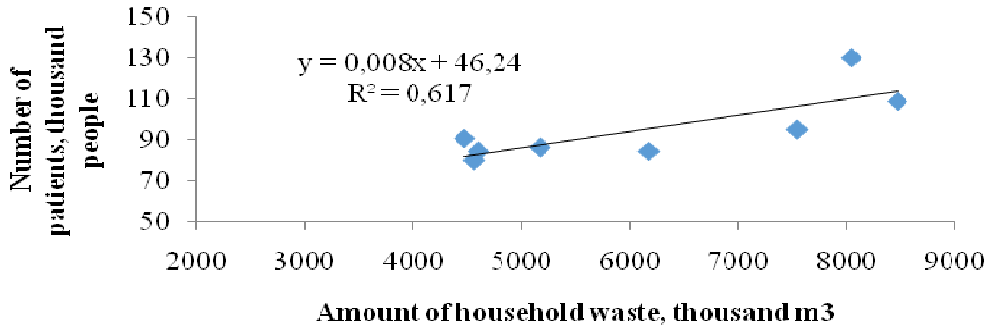

Figure 4. Regression relationship between household waste and infectious diseases

Natural and environmental factors have a serious impact on the human health. Several natural-geographical, socio-economic and anthropogenic factors directly or indirectly affect the health status of people. Economic, social, natural, biological and demographic factors of the environment are considered the most important among them. Along with being closely related to each other, these factors' influence is complex. In this case, certain diseases appear in the human body, and natural-ecological factors play an important role in the occurrence of these diseases [1].

It is important to evaluate the Human Development Index (HDI) in the region since the indicators that shape the quality of life and the problems that arise are ultimately directed to the development of the human factor [16]. It is known that the health of the population is one of the indicators of the HDI. Health is the greatest blessing for mankind, and its indicators are one of the urgent factors characterizing human development. Depending on the goals of calculating the coefficients characterizing sustainable human development and the calculated coefficient, different health indicators are used. Using of various indicators characterising health depends, first of all, on determining the level of development of the countries, on the health problems faced by the country in question, formed in a certain period and how to overcome them [17]. As the health index increases, so does the Human Development Index. The interdependence of these indicators was analysed. The result of the linear correlation coefficient is 0,967. The coefficient of determination ($R2$) 0.935 indicates that 94 % of the random variables lie on the trend line. The relationship between the indicators is intense (Fig. 5).

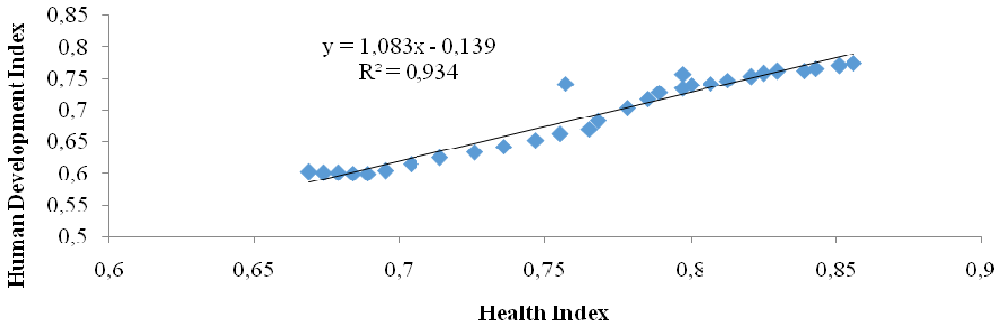

Figure 5. Relationship between the Health Index and Human Development Index

Another most important factor affecting human health is the environmental factor. Inadequate waste disposal methods can lead to pollution, contamination of soil and water sources, spread of diseases, and ultimately adversely affect the quality of life. In order to clearly observe this, the relationship between emissions from road transport and HDI was studied and presented in the form of a linear regression equation (Fig. 6). The result of the correlation coefficient is -0,939. This indicates that there is a negative correlation between the amount of waste and HDI. The coefficient of determination is 0,857. That is, the dependence is 85 %. Analysis of the linear equation indicates that as the amount of pollutants released into the atmosphere from stationary sources decreases, the HDI increases. Subsequently, there is a relationship between the environmental factor and HDI. Therefore, it is important to consider environmental factors when measuring the level of development of countries.

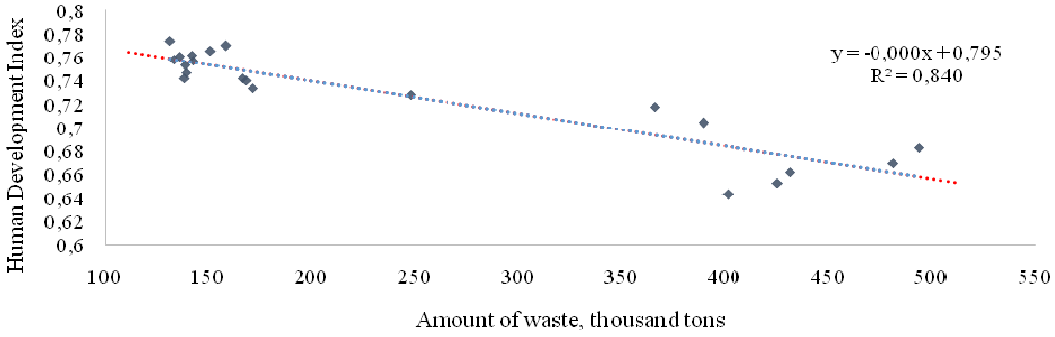

Figure 6. Dependence between the amount of waste and the Human Development Index

Hereby, improving the environment is considered a very important factor for human health. Thus, while ensuring the development of individual industrial and agricultural sectors in the country, it is very important to take environmental factors into account. Regional and international cooperation is always necessary for the successful solution of extremely important ecological problems, such as the reduction of harmful substances released into the atmosphere and prevention of river water pollution.

Conclusion

The impact of health problems on the quality of life of the population in the Greater Caucasus province can be seen primarily in the regional differences in the territorial organization of healthcare facilities. Most of the healthcare facilities and most of the medical services are located in Baku city. The distribution of diseases by region is also different according to urban and rural areas within the province. Thus, the prevalence of diseases in cities is 1,5 times higher than in villages. The primary reasons for this are air and water quality, low physical activity, high population density, and other factors. Medical care in rural areas is inadequate. Villagers have to come to the city centre for routine medical care. Because there are only paramedics in the villages. These stations are also very poorly provided with material and technical base.

The quality of the environment has a significant impact on the human health. The increase in the amount of waste affects the health of the population by 74 %. On average, 192,000 tons of pollutants are released into the atmosphere every year and 526 tons per day in the territory of the province. The relationship between the amount of household waste and the spread of infectious diseases is 61 %. The relationship between vehicular emissions and the Human Development Index (HDI) was researched and the result of the correlation coefficient was -0,939, and the dependence coefficient was 85 %.

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Т.М. Хусейнова

Өмір сапасының адам денсаулығына әсерін бағалау (Әзірбайжан Республикасының Үлкен Кавказ аймағының мысалында)

Денсаулық өмір сапасын анықтайтын көрсеткіштер жүйесінде маңызды орын алады. Халықтың өмір сүру сапасының негізін құрайтын денсаулық көрсеткіштерін жақсарту мәселелері, әсіресе, Әзірбайжан Республикасының әлеуметтік-экономикалық дамуында маңызды рөл атқаратын, жоғары демографиялық және еңбек әлеуеті бар Үлкен Кавказ аймағы үшін өзекті. Практикалық маңызы бар зерттеу жұмысының негізгі мақсаты — Үлкен Кавказ аймағындағы денсаулық сақтаудың аумақтық ұйымын, қоршаған ортаның сапасын және олардың халықтың өмір сүру сапасына әсерін зерделеу. Статистикалық материалдар негізінде провинцияда тұратын халық арасында аурудың таралу көрсеткіштері, сонымен қатар қазіргі заманғы денсаулық сақтау нысандарының жағдайы және олардың өмір сапасына әсері зерттелді. Зерттеу нәтижелеріне сәйкес, соңғы жылдары провинцияда тұратын халықтың денсаулығындағы экологиялық факторлардың рөлі айтарлықтай болды. Зерттелген кезеңде провинцияда стационарлық және автомобиль көлігінен шығатын қалдықтар азайып, аурулар саны көбейгені анықталды. Сонымен қатар, адам потенциалының даму индексінің қоршаған орта жағдайымен байланысы және оның өмір сапасына әсер ету жолдары қарастырылды. Талдау көрсеткендей, басқа факторлармен қатар қоршаған орта сапасы халықтың өмір сүру сапасына әсер етеді. Атмосфераға шығарылатын қалдықтардың мөлшері азайған сайын адам әлеуетінің даму индексі номиналды түрде артады. Дәлірек айтқанда, олардың арасындағы корреляция теріс, ал анықтау коэффициенті 0,857, басқаша айтқанда, тәуелділік 85 % деңгейінде анықталды.

Кілт сөздер: өмір сапасы, адам денсаулығы, денсаулық сақтау, қоршаған орта, адам дамуының индексі.

Т.М. Хусейнова

Оценка влияния качества жизни на здоровье человека (на примере Большого Кавказского региона Республики Азербайджан)

Здоровье занимает важное место в системе показателей, определяющих качество жизни. Вопросы улучшения показателей здоровья, составляющих основу качества жизни населения, особенно актуальны для Большого Кавказского Велаята, играющего важную роль в социально-экономическом развитии Азербайджанской Республики, обладающего высоким демографическим и трудовым потенциалом. Основной целью исследовательской работы, имеющей практическую значимость, является изучение территориальной организации здравоохранения в Большом Кавказском крае, качества окружающей среды и их влияния на качество жизни населения. На основе статистических материалов были изучены показатели распространения заболевания среди населения, проживающего в провинции, а также исследовано состояние современных объектов здравоохранения и их влияние на качество жизни. Согласно результатам исследования, в последние годы роль экологических факторов в состоянии здоровья населения, проживающего в провинции, была значительной. Выявлено, что за исследуемый период в провинции уменьшилось количество отходов от стационарного и автомобильного транспорта, а количество заболеваний увеличилось. Кроме того, была исследована связь индекса развития человеческого потенциала с состоянием окружающей среды и способами ее воздействия на качество жизни. Анализ показал, что, наряду с другими факторами, качество окружающей среды влияет на качество жизни населения. Номинально индекс развития человеческого потенциала увеличивается по мере уменьшения количества отходов, выбрасываемых в атмосферу. Точнее, корреляция между ними отрицательная, а коэффициент детерминации составляет 0,857, другими словами, зависимость была определена на уровне 85 %.

Ключевые слова: качество жизни, здоровье человека, здравоохранение, окружающая среда, индекс человеческого развития.

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Features of the distribution of vegetation cover depending on the physical and geographical location of the northern part of the Kazakh Uplands

In the article the peculiarity of the distribution of vegetation cover, due to the natural landscape specifics of the lands of Kazakhstan was noted. In this regard, the object under study — the northern part of Saryarka, is characterized by physical and geographical features: landscape structure, soil cover, climatic indicators. In accordance with these data, the soil cover is characteristic, where the distribution of the plant world is characteristic. This connection is based on the regularity of the unity of the natural complex. This object is a fundamental factor in the relief of the country due to its geological specificity. Accordingly, it includes several natural zones, parts of zones that differ from its constituent parts. Because of this, the composition of the vegetation cover has a great difference in distribution from north to south. The above ground part of the region is rich in water sources and a variety of vegetation. In the south, this diversity is scantier and on the desolate steppes passes into the Tipchakovo-kovylny district. This is due to the fact that the chernozem of the North reduces fertility and in places becomes saline litter. Also, such variability is strongly influenced by climate change from west to east. The amount of precipitation decreases, and the temperature index increases. Depending on this factor, the region is divided into 3 parts: hilly steppes, dry steppes and desert steppes. The landscape structure consists mainly of: clay-loamy shale, effusions. The paper analyzes the main zonal species and edaphic orders of the steppe part of the Kazakh Uplands. It presents the main representatives of lowland communities: calcifite, petrophyte types. Although the year of publication of the maps used in the work, the relevance took place.

Keywords: Saryarka, melkosopochnik, physico-geographical, zone, relief, landscape, climate, soil, plants.

The largest physical-geographical object on the territory of Kazakhstan — Kazakh Uplands (Saryarka) occupies a huge area. Its width in the west and east makes a big difference, in the west — 950 km, in the east — 350–400 km. This region consists mainly of deformed and leveled ridges, low mountains with hummocks. Due to the peculiarities of the tectonic structure, the northern slopes of the mountain massifs are steeper than the southern ones. There are large and small hollows and holes between each mountainous region. Due to the favorable climatic conditions, the northern slope of the low-mountain region is richer in springs and plants than the southern one. Meanwhile, drier southern region is gravel. From this mountainous region, rivers such as Nura, Sherubai-Nura, Zharly, Karkaraly, Taldy, Tundik, Tokirauyn, etc., originate. They are located in the intertidal plains at an altitude of 850–1000 m above sea level and lie in the watersheds that separate them at this height. The small hummock is surrounded by plains on all sides [1].

The largest physical-geographic object on the territory of Kazakhstan — Kazakh uplands (Saryarka) occupy a huge area. Its width in the west and east makes a big difference, in the west — 950 km, in the east — 350–400 km.

In the north-west of the mountainous region, near Karaganda and to the north, i.e. towards the direction where there is more moisture, mountain massifs are well covered, deeply cut by ravines. The described unique mountain system consists of elevated hilly plains — hills flattened or divided by wider channels, rocky chains and groups of slopes. But ravines and valleys are rare in moisture-poor regions.

In the areas where small hummocks are spread, the main element of the topography is undulating plains and wide valleys that served as river channels in the past. In addition to rivers channel of which dries up in many seasons of the year, this region is also characterized by lakes with no flow or temporary flow. Most of them are located below the mentioned valleys. In the territory of Karaganda with these characteristics, these lakes are shallow (0.5–3 m), flat and muddy, most of them dry up by the end of summer. After some lakes dry up, salt accumulates in place, others form only a thin layer of salt, the third lakes are fresh water, the fourth ones are overgrown with grass, and the fifth ones are grassy lakes, which become watery only in spring and play an important role in mowing grass [2]. The history of geological development, climatic con-

ditions, landforms, landscape structure, etc. Due to its physical and geographical features, soil cover of the territory is also diverse.

Depending on its geographical location, territory passes through several natural zones: the far northwest enters the forest steppe, the main part lies in the steppe zone, and the southern part is in the desert nature zone. Since its largest area is in the steppe zone, it can be divided into several parts from a biological point of view:

1) dry steppe part — fescue-gray steppe with dark brown soil;

2) a part of the temperate dry steppe zone — meadow with various grasses — gray fescue on black soil with lowfertility (southern);

3) part of medium wet steppe zone — field with various grasses and crops on “average” and “ordinary” fertility black soil.

These parts of the steppe, change from south to north, make great deviations from the latitudinal distribution due to the difference in absolute altitude, strong salinity in some areas and the change of climate from west to east. The distribution of vegetation cover according to the above-mentioned soil types can be seen on the geobotanical zoning map in Figure 1.

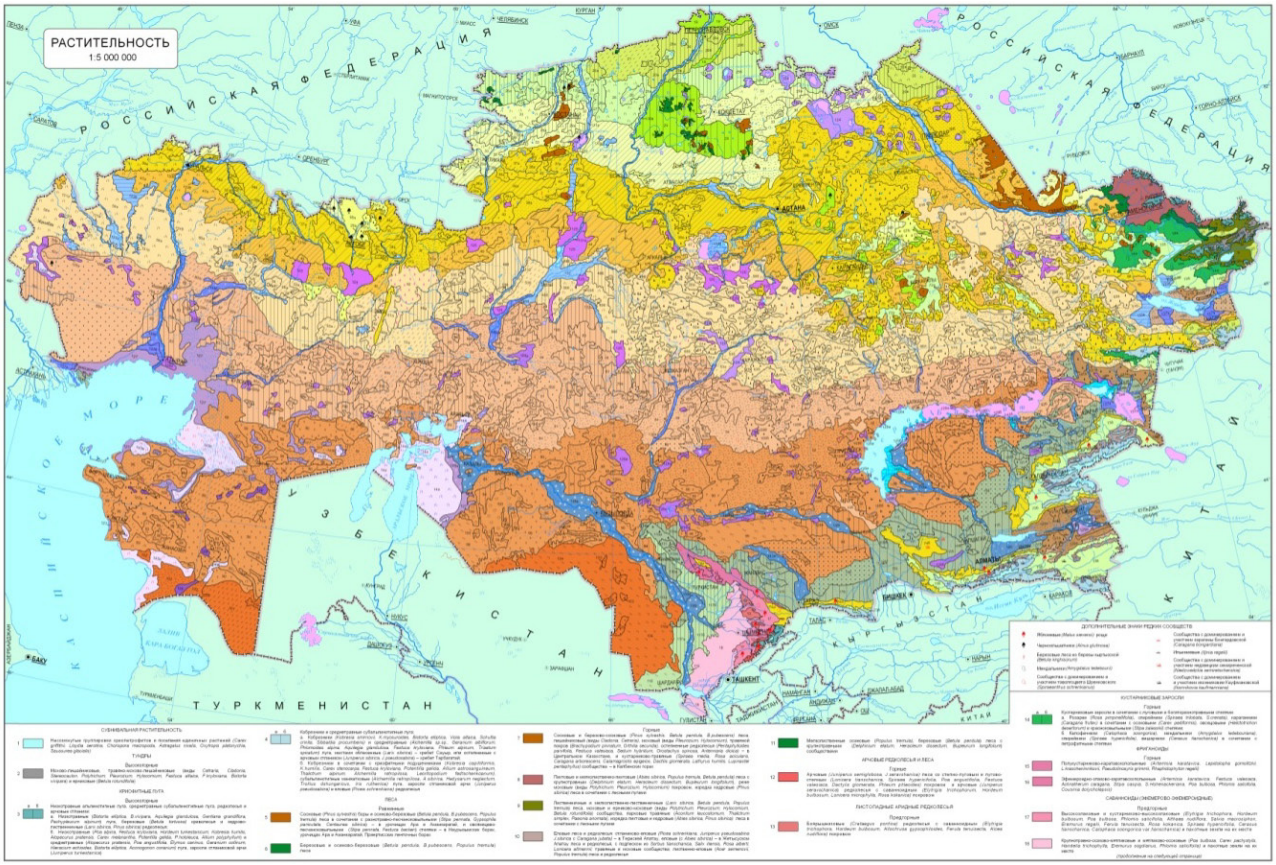

Figure 1. Geobotanical zoning of Kazakhstan

According to the given geobotanical map, the main vegetation cover distributed in the northern part of the Saryarka research object can be seen in the image of the section presented below in an enlarged version (Fig. 2).

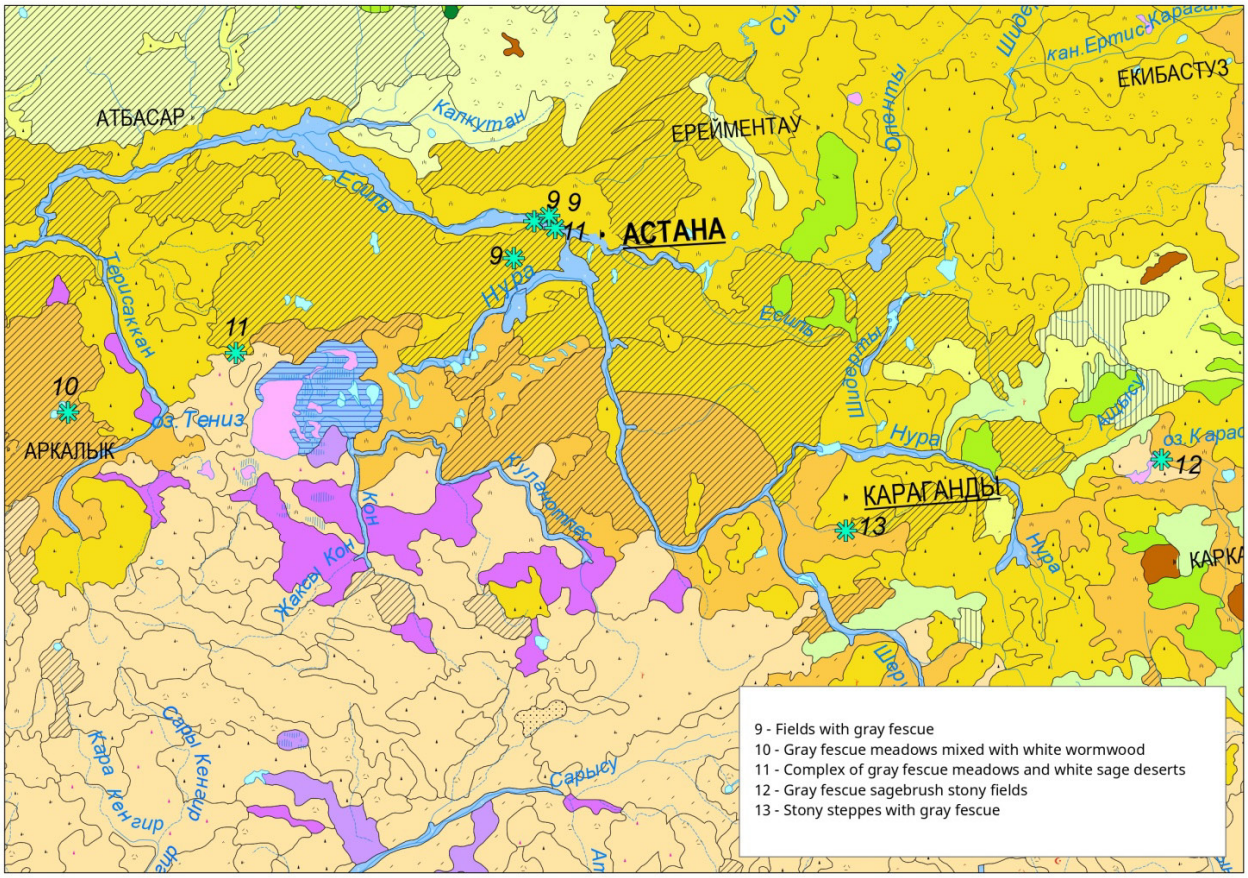

Figure 2. Vegetation cover characteristic of gray-fescue steppe zone with dark soil

9-Gray-fescue steppes; 10-Steppes of gray fescue mixed with white wormwood; 11-Complex of gray fescue steppes and white sage deserts; 12-Gray fescue-wort stony steppes; 13-Gray fescue stony steppes.

According to the geobotanical zoning map of Kazakhstan [3], the region is divided into several zone parts specific to its physical and geographical conditions. The region alternated from north to south with gray fescue steppes, white sagebrush steppes, desert and stony steppes. It is formed on the basis of structure based on the landscape of the region based on its topography (Landscape map of Kazakhstan). This feature can be seen in Table 1 below [4].

Table 1

Landform structure of the northern region of Kazakh Uplands

Parts of the landform depending on the topography	Landform structure	Vegetation cover	Soil type
Uplands	Small hilly plains composed of granular clayey shale	Shrub-gray-fescue plants	Normal, poorly developed black soil of the south
	Small hilly plains near the river composed of quartzite, shale, and effusives.	Various herbaceous plants with red fescue and in some places Korzhin fescue	Black soil of the south is not properly matured
	Small hills composed by granite	Petrophyte-various grass-oat-fescue plants	Less mature black soil of the south
	Quartzite, shale, and effusives are small hills with slopes.	Rich variety of herbaceous red fescue plants	Normal black soil, sometimes less mature

The immediate continental climate of Kazakhstan is typical of the studied area. According to B.P. Alisov, the small hill of Central Kazakhstan belongs to the territory of continental West Siberia (steppe). Extending over a large area from north to south, it leads to zonal differences in the climate in terms of heat and moisture. The feature of the latter is defined by the radiation index of dryness. The climate of the Kokshetau plateau and the plains surrounding it (various grass-fescue steppes and forest steppe belt) belong to the area with the lowest dryness. The radiation index of aridity in this region is 1, and in dry steppes this index is close to 2, that is, temperate-insufficient moisture here. Climatic indicators of the entire region by zone parts are presented in Table 2 [5].

Table 2

Climatic indicators of the northern regions of Saryarka

№	Region (part of zone)	Amount of precipitation, mm	Average temperature of January, t^0C	The average temperature of July, t^0C
1	The steppes near Kokshetau, various grass-fescue fields	300–350, in some places 390	-17-19	+18+20
2	Dry steppes	200–250, in some places 300	-18-21 (minimum — 39,5)	+19+22 (maximum + 38+39)
3	Deserte fields	200, in many places 175	-15-16 (minimum — 40)	+22+25 (maximum +40+45)

During the vegetation period, the total average temperature of the steppe zone from 3211^0 to 2108^0 (in the desert-steppe from 3574^0 to 2566^0).

The primary distinction between the steppe zone and the desert zone lies in the varied distribution of precipitation throughout the year. Despite an annual rainfall total of 260 mm, each area exhibits a different pattern. Precipitation in spring and early summer surpasses that in winter. In the southern part of this zone, snow cover recedes in the latter half of March, while in the north, it persists until the second decade of April.

The air's relative dryness gradually increases, and the development of overall vegetation is contingent on the weather during this period. The physical and geographical conditions of the research object serve as the primary factors influencing the distribution of soil and plant cover characteristic of the region.

Fertilization is primarily concentrated in saline clay rocks. Due to the wetter climate and lower soil salinity, the role of xerophytic wormwood in the natural landscape is diminishing. Sorghum, on the other hand, is found predominantly in highly saline habitats. Grassland crops constitute the primary source of ground fuel in the steppe.

Some species from other plant families are also categorized as temperate xerophytes. Alongside them, there are plants of Class V moisture, which are highly sensitive to insufficient moisture in the soil and air— these include soft, broad-leaved mesophytes. In the southern part of the zone, sorrel is less abundant in open ground fuel. As one moves northward, it replaces xerophytes, occupying more space due to increased moisture. Their maximum growth occurs in the III-IV class of moisture, in the summer they stop for a short time and partially. Some species of other families also belong to temperate xerophytes, along with them there are plants of class V moisture, which are very sensitive to insufficient moisture in the soil and air — soft, broad-leaved mesophytes. In the southern part of the zone, sorrel is less abundant in open ground fuel, but to the north it replaces xerophytes, taking up more space due to increased moisture. Due to soil erosion, the share of ephemerals in wildfire is small.

In the second half of summer, especially in dry year, there are wildfires. During this period, the vegetation cycle of steppe plants is interrupted because, despite the summer rainfall, as a result of strong transpiration of the thick upper layer of the soil, sufficient moisture reserves for the plant in the soil are exhausted. In September, when the temperature decreases and the air becomes dry, the second growing season begins and lasts until the stabilization of the snow cover in October [6].

In a non-salinized steppe, the dark brown soil typical of the dry steppe may be completely free of salinization. This condition, as well as the presence of large amount of humus (0–10 cm deep, 3–5 %) determines its specificity. As a rule, the surface layer of the soil does not exist, humus layer has a grayish-brown (dark) color. Layering is observed only in its surface layer, and below it is loose, less granular, and the roots have penetrated into the soil. As it goes deeper, it becomes whiter and denser. The lower layer of humus boils with acid, and a lot of carbonate and gypsum deposits accumulate there. The chemical analysis

of such soil shows that humus is completely absent in the leaching layer due to leaching, it is rich in calcium and magnesium, and there is a small amount of soda. Such, in well-drained conditions, looks like a loose yellow soil, matured in rocks, a normal dark-brown steppe soil.

In the normal dark-brown soil and covering 45–55 % of the dry steppe, the vegetation cover is usually dominated by sedge-fescue, and in the lower layer there is a mixed desert oat. In more arid areas, the importance of the trailing gray increases.

Temperate dry steppes develop in southern black soil with little humus, typical of Kazakhstan. The dark-brown grayish surface layer, with a humus content of 4–6 %, is characterized by fragmented or fine granularity, although the grain is irregular rather than layered. The alternating layer begins at 20–35 cm and becomes lighter as it descends. Along the cracks, there are humus flows and pale, carbonate-enriched rocks in the lower part of the crust. Further descent reveals the parent rock, which is compacted and concentrated with limestone and sometimes gypsum [7].

Temperate dry steppes on low-humus (southern) black soil are characterized by the increasing importance of red fescue, and in some cases, oat dominates the vegetation in this region.

Table 3

The main zonal types and edaphic variations in the steppe part of the Central-Kazakhstan hummocks

1nd stripes	2nd stripes	Association of Plakorly residents	Calcifite type	Petrophyte type
Dry gray-fescue steppes	Dry gray fescue steppes on dark brown soil	Gray fescue (Stipa Lessingiana, Festuca sulcata, Plomis agrarian, Dianthus leptopetalus) steppes	Stipa Korshinskyi bed-gray-fescue (Stipa Lessingiana, Festuca sulcata, Galatella divaricala) steppes	Petrophytic gray-brush sedge with Spiraea hypericifolia (Stipa Capillataa, Festuca sulcata, Onosma simplcissimum, Berteroa spathulata, Allium globosum) steppes
	Dry xerophyte-various herbaceous gray-fescue steppes on brown soil	-	Dry xerophyte-various herbaceous gray-fescue (Stipa Lessingiana, Festuca sulcata, Galatella tatarica, Tanacetum achilleifolium) speppes	
Deserted sage brush and fescue steppes	Deserted sagebrush-fescue steppes on light-brown soil (northern strip).	Thinning sagebrush-thinning sagebrush-gray (Stipa Lessingiana, Festuca sulcata, Artemisia gracilescens) communities in the complex of thin sagebrush-fescue steppes	Calcephytic variegated grass-sage-fescue (Stipa lessingiana, Artemisia terrae-albae ssp.semiarida, Agropyron pectiniforme, Serratula cardunculus, S.dissecta, Galatella divaricata) steppes	Sublessingian sagebrush steppes with (Stipa capillata, Festuca sulcata, Artemisia sublessingiana) Stipa hypericifolia
	Deserted sagebrush steppes on light-brown soil (southern strip)	Complex steppes with thinning sage-brush sedges; (Stipa sereptana, Artemisia gracilescens); thinning sagebrush steppes containing Ferula ferulaeoides; (Artemisia gracilescens, Artemisia terraealbae ssp.semiarida); contains Eurotia ceratoides steppes with thickets	Gray sagebrush steppes (Stipa lessingiana, Artemisia terraealbae ssp.semiarida)	Steppes containing (Festuca sulcata, Artemisia sublessingiana, Artemisia gracilescens) Caragana balchaschensis

The physical-geographic features of the territory have served as the foundation for scientific-theoretical research and continue to be a subject worthy of in-depth investigation within the framework of various specialized sciences, such as soil science, cartography, hydrology, and others. This ongoing research enables the comparison of different time periods, facilitating the identification of current changes in vegetation cover and other relevant environmental aspects.

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Сарыарқа ұсақ шоқысы солтүстік аймағының физикалық-географиялық жағдайына байланысты өсімдіктер жамылғысының таралу ерекшеліктері

Мақалада Қазақстан жерлерінің табиғи-ландшафтық ерекшелігіне байланысты өсімдік жамылғысының таралу ерекшелігі атап өтілді. Осыған байланысты зерттелетін нысан — Сарыарқаның солтүстік бөлігі, яғни ұсақ шоқының зерттелу аймағының физикалық-географиялық жағдайы: ландшафттық құрылымы, топырақ жамылғысы, климаттық көрсеткіштері, соған байланысты топырақ жамылғысының ерекшелігі мен сәйкесінше таралған өсімдіктер дүниесі қарастырылған. Бұл байланыс табиғи кешеннің біртұтастық заңдылығына негізделген. Аталған нысан өзінің геологиялық ерекшелігіне байланысты еліміздің жер бедерінің негізін құраушы фактор. Тиісінше, ол бірнеше табиғи аймақтарды, оның құрамдас бөліктерінен ерекшеленетін аймақтардың бөліктерін қамтиды. Осыған орай өсімдіктер жамылғысының құрамы солтүстіктен оңтүстікке қарай таралуында үлкен айырмашылыққа ие. Аймақтың солтүстігі су көздері мен өсімдіктердің алуан түрлілігіне бай келеді. Оңтүстікке қарай бұл алуантүрлілік сиреп, шөл дала боз-бетегелі ауданға ұласады. Себебі солтүстіктің қара топырағы құнарлылығын азайтып, кей жерлерінде тұзданған сорға айналады. Сондай-ақ, мұндай ауыспалыққа климаттың да батыстан шығысқа қарай өзгерісі қатты әсер етеді. Жауын-шашын көлемі азайып, температура көрсеткіші артады. Бұл факторға байланысты аймақ 3 бөлікке бөлінеді: қыратты, құрғақ және шөлденген далалар. Ландшафттық құрылымы негізінен: саз-балшықты тақтатастан, эффузивтерден құралған. Жұмыста ұсақ шоқының дала бөлігіндегі негізгі зоналық түрлері мен эдафикалық нұсқаларына талдау жасалған. Онда жазықты мекендеуші қауымдастықтың негізгізгі өкілдері: кальцефитті, петрофитті типтерге сипаттама берілген. Сондай-ақ пайдаланылған карталардың шығу жылы ескі болғанмен, өзектілігі жойылмаған.

Кілт сөздер: Сарыарқа, ұсақ шоқы, физикалық-географиялық, зона, жер бедері, ландшафты, климаты, топырағы, өсімдіктері.

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Особенности распространения растительного покрова в зависимости от физико-географического положения северной части мелкосопочника Сарыарка

В статье отмечена особенность распространения растительного покрова, обусловленная природно-ландшафтной спецификой земель Казахстана. В связи с этим исследуемый объект — северная часть

Сарыарки — характеризуется физико-географическим особенностями: ландшафтным строением, почвенным покровом, климатическими показателями. В соответствии с этими данными характерен почвенный покров, где свойственно распространение растительного мира. Эта связь основана на закономерности единства природного комплекса. Данный объект является основополагающим фактором рельефа страны благодаря своей геологической специфике. Соответственно, он включает в себя несколько природных зон, частей зон, которые отличаются от его составных частей. Из-за этого состав растительного покрова имеет большое различие в распространении с севера на юг. Надземная часть региона богата источниками воды и разнообразием растительности. На юге это разнообразие скуднее и на опустыненных степях переходит в типчаково-ковыльный район. Это связано с тем, что чернозем Севера снижает плодородие и местами становится засоленным сором. Также на такую переменчивость сильно влияет изменение климата с запада на восток. Количество осадков уменьшается, а температурный показатель увеличивается. В зависимости от этого фактора регион разделен на 3 части: холмистые степи, сухие степи и пустынные степи. Ландшафтная структура состоит в основном из глинисто-суглинистого сланца, эффузиев. Авторами проведен анализ основных зональных видов и эдафических порядков степной части мелкосопочника. В нем представлены основные представители равнинных сообществ: кальцефитные, петрофитные типы. Несмотря на год издания использованных в работе карт, они не потеряли свою актуальность.

Ключевые слова: Сарыарка, мелкосопочник, физико-географический, зона, рельеф, ландшафт, климат, почва, растения.

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Влияние отбора подземных вод для орошения на их запасы и ресурсы (Юго-Восточное Прибалхашье)

В настоящее время подземные воды северных предгорий Джунгарского Алатау широко используются для водоснабжения городов, сельских населенных пунктов, обводнения пастбищ. Однако наиболее крупным потенциальным потребителем подземных вод будут являться орошаемые земли. Целью исследования были прогнозная оценка изменения условий формирования подземных вод на подготовленных к орошению участках предгорных равнин Жетысу Алатау, их запасов и ресурсов под влиянием антропогенных процессов — эксплуатации подземных вод для орошения земель; разработка оросительных систем и типовых технологических схем компоновки и размещения оборудования для орошения и способов подачи воды из эксплуатационных скважин на дождевальные машины; рекомендации и оценка перспектив использования подземных вод для орошения земель на аллювиально-пролювиальной равнине северных предгорий Жетысу Алатау. Основная гипотеза данного исследования заключается в предположении о возможности искусственного полива с применением усовершенствованной технологии широкозахватной дождевальной установки, использующей подземные воды. При этом, в первую очередь, рассматривается и анализируется основной источник подачи воды — эксплуатируемый водоносный горизонт, формирование подземных вод, эксплуатационные запасы; во вторую — способы полива земельных угодий. Оценен ресурсный потенциал месторождений подземных вод, разведанных для орошения земель, предложена технология их использования. Основные результаты исследования об улучшении условий водообеспечения орошаемого земледелия при дефиците поверхностных водоисточников с применением дождевальных установок, использующих подземные воды.

Ключевые слова: эксплуатационные запасы подземных вод, ресурсы подземных вод, орошение земель, дождевальная техника.

Введение

Научно-исследовательские разработки по эффективному использованию подземных вод в целях устойчивого развития орошаемого земледелия весьма актуальны и своевременны. Орошение земельных угодий играет основную роль в использовании поверхностных и подземных водных ресурсов региона.

Выбранный объект исследований — предгорная равнина северного склона Жетысу Алатау — сложена четвертичными аллювиально-пролювиальными валунно-галечниками и гравийно-галечниками с песчаным заполнителем мощностью от 40 до 200 м на аллювиально-пролювиальной равнине и от 200 до 300 м в конусах выноса. Ниже по разрезу залегают отложения хоргосской, илийской и павлодарской свит неогена. По составу это преимущественно глины с прослоями песков, галечников и гравийно-галечников [1].

Основная цель исследований — оценка влияния эксплуатации подземных вод для орошения земель на их запасы и ресурсы в северных предгорьях Жетысу Алатау. В соответствии с поставленной целью решены задачи прогнозной оценки изменения условий формирования подземных вод на подготовленных к орошению участках предгорных равнин Жетысу Алатау, их запасов и ресурсов под влиянием антропогенных процессов — эксплуатации подземных вод для орошения земель; разработки оросительных систем и типовых технологических схем компоновки и размещения оборудования для орошения и способов подачи воды из эксплуатационных скважин на дождевальные машины; разработаны рекомендации по перспективе использования подземных вод для орошения земель на аллювиально-пролювиальной равнине северных предгорий Жетысу Алатау.

На основе проработки исходных материалов проведен анализ и оценка состояния водоносных горизонтов, распространенных на изученной территории, с описанием основных гидрогеологических параметров (состав и генетический тип водовмещающей толщи, глубины залегания, гидродинамические показатели). Исследование подтвердило предположение о возможности использования подзем-

ных вод для орошения при дефиците поверхностных водоисточников. Применение предложенных дождевальных установок позволяет рекомендовать широкое использование подземных вод для орошения без ущерба их запасам [2].

Материалы и методы

Подземные воды предгорных равнин северного склона Жетысу Алатау пресные (минерализация 0,4–0,7 г/дм^3), гидрокарбонатно-сульфатные натриево-кальциевые. Общая жёсткость не превышает 4 мг-экв/дм^3. Величина ирригационного коэффициента 23–220, что говорит о пригодности подземных вод для орошения. Соотношение солей кальция и магния меньше 1, поэтому осолонцевания почв при орошении не ожидается [3]. Водоносный комплекс водообилен — дебиты скважин 40–125дм^3/с при понижении уровня воды на 19,6–34,0 м. Водопроводимость пород высокая — 1022–1718 м^2/сут, коэффициент пьезопроводности (3,7–9,6)·10^5 м^2/сут, коэффициент водоотдачи 0,2–0,24. Фильтрационные свойства водовмещающих пород, за исключением конуса выноса р. Лепсы, характеризуются сравнительной однородностью — коэффициент фильтрации преимущественно составляет 15–25 м/сут (в пределах Лепсинского конуса выноса 18–35 м/сут) [4].

Химический состав воды по результатам гидрогеохимических опробований представлен на графиках в виде диаграмм Пайпера, Дурова и в соотношении минерализации к наличию сульфатов (рис. 1). Обработка результатов геохимических опробований выполнена с помощью программного комплекса AquaChem 11, WaterlooHydrogeologic, Канада.

Приведенный анализ свидетельствует о наличии и распространении различных по степени минерализации и пестроте состава подземных вод: в основном это пресные и слабосолоноватые воды с минерализацией до 3,2 г/л, преимущественно гидрокарбонатные кальциевые и натриевые, реже гидрокарбонатно-сульфатные, сульфатно-хлоридные кальциевые и натриевые.

На площади предгорного шлейфа северного склона Жетысу Алатау, являющегося основной областью питания подземных вод Южно-Прибалхашского артезианского бассейна, в результате интенсивной фильтрации поверхностных вод из русел рек, оросительных каналов, и с полей орошения, инфильтрации атмосферных осадков, притока подземных вод со стороны гор формируются мощные грунтовые потоки, основное направление движения которых на север и северо-запад [5]. Значительный уклон (от 0,02 до 0,007), короткие пути фильтрации и высокие фильтрационные свойства водовмещающих пород объясняют большую скорость потока (до 100–340 м/год) и позволяют отнести этот район к зоне весьма активного водообмена со временем водообмена 100–200 лет [6]. Частичная разгрузка подземных вод осуществляется в виде родников, а также по эрозионным врезам, где подземный поток выклинивается, образуя многочисленные речки «карасу», среднегодовой сток которых достигает 1,5–2,0 м^3/с [7].

Анализ общего водного баланса рассматриваемой территории на ненарушенный период позволил сделать следующие выводы:

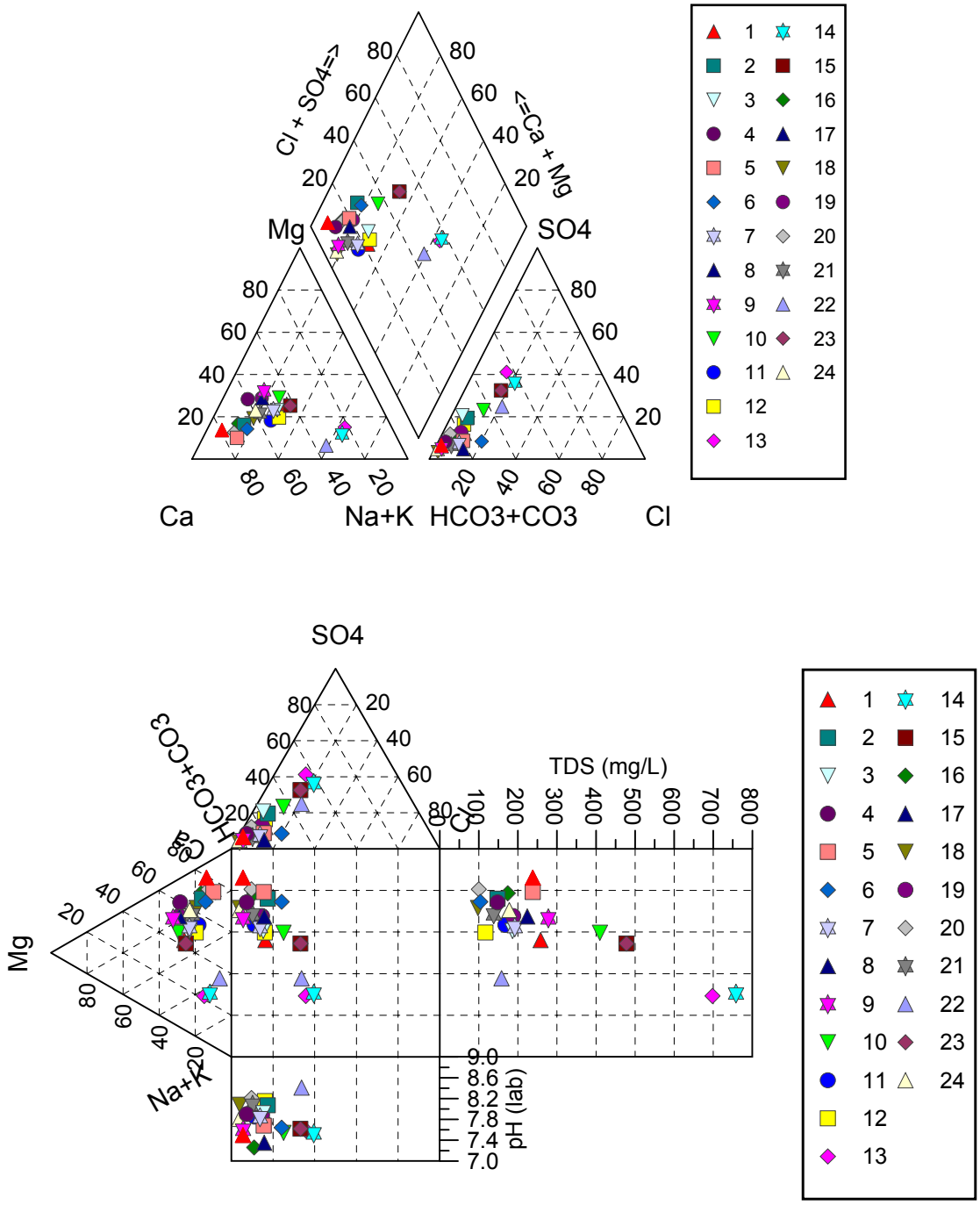
1. На площади предгорного шлейфа происходят интенсивное поглощение поверхностных вод, особенно по конусам выноса рек, инфильтрация атмосферных осадков, фильтрация поливных вод из ирригационных каналов и с полей орошения [8].

2. Средневзвешенный модуль подземного стока на предгорном шлейфе равен 17 дм^3/с с 1 км^2 для восточной части Южно-Прибалхашского бассейна, по конусам выноса он составил 45 дм^3/с с 1 км^2.

3. Общая величина питания подземных вод (ежегодно возобновляемые ресурсы) по предгорному шлейфу северного склона Жетысу Алатау составляет 24,79 м^3/с.

4. В целом подземный поток формируется из следующих составных частей: фильтрационные потери из русел рек — 7,44 м^3/с (30 %), подземный сток с гор — 3,72 м^3/с (15 %), инфильтрация атмосферных осадков — 2,48 м^3/с (10 %), фильтрационные потери из каналов — 6,19 м^3/с (25 %) и с полей орошения — 4,96 м^3/с (20 %).

5. Средний расход потока по периферии предгорного шлейфа составляет 150 дм^3/с на 1 погон. км, при этом значительная часть приходится на конусы выноса рек Лепсы и Баскан.



Условные обозначения: ▲ 1 — содержание химического элемента в пробе, цифра справа соответствует номеру пробы, отобранной в области

Рисунок 1. Диаграмма химического состава проб подземных вод

Прогнозные (потенциальные) региональные эксплуатационные ресурсы подземных вод четвертичных отложений конусов выноса составляют около 35 м^3/с [7]. Модуль их изменяется от 250 до 900 м^3/сут с 1 км^2, при этом наибольший модуль отмечается вблизи областей питания у предгорий Жетысу Алатау.

Эксплуатационные запасы подземных вод в рассматриваемом районе установлены в результате детальных поисково-разведочных работ, проведённых Талды-Курганской гидрогеологической экспе-

дицией Мингео КазССР. Разведаны Молалинское и Аксуское месторождения подземных вод, состоящие из нескольких более мелких месторождений. Разведанные эксплуатационные запасы подземных вод четвертичных отложений Молалинского месторождения по сумме категорий составляют 5,3 $м^3$/с. Общая сумма эксплуатационных запасов подземных вод Аксуского месторождения для условий прерывистой работы водозаборов только в вегетационные периоды составила 14,63 $м^3$/с. Они обеспечены естественными ресурсами, равными 24,79 $м^3$/с.

В целом на данной территории разведанные эксплуатационные запасы подземных вод достигают 113 $м^3$/с, в том числе для нужд орошения земель разведано 12,6 $м^3$/с подземных вод. Этого количества достаточно для обеспечения 20–25 тыс. га земель. В настоящее время в пределах северных предгорий Жетысу Алатау имеется 12 подготовленных к орошению подземными водами участков общей площадью 4105 га: Кольтабан, Кызылагашский, Жансугуров, Жанакогамский, Кызылтуский, Косагашский, Каракозский, ОХ КИЗа, свх. Карабугет, Валиханов, Бакалинский, Карабугетский. Однако освоение земель идет медленными темпами, что вызвано сомнениями отдельных водохозяйственных организаций в целесообразности использования подземных вод на орошение, особенно там, где они тесно связаны с поверхностными, а также тем, что результаты гидрогеологического обоснования использования подземных вод не всегда подтверждаются практикой эксплуатации подземных вод на полях орошения.

Способы орошения. На описываемой территории аллювиально-пролювиальных равнин, учитывая опыт орошения земель в прошлые годы, рекомендуется применять дождевальный способ орошения подземными водами при помощи широкозахватной поливальной машины «Фрегат» типа ДМУ–463–90 с длиной плеча 463 м, расходом воды 90 л/с и интенсивностью дождя 0,31 мм/мин. Производительность «Фрегата» за 1 ч работы при норме подачи воды 300 $м^3$/ч равна 1,13 га. Обычно одной скважиной поливается площадь 72 га. Скважины в основном оборудуются погружными электронасосами типа ЭЦВ–10–210–85 и ЭЦВ–12–210–85.

Однако в каждой скважине есть свои особенности компоновки оборудования для орошения подземными водами. Компоновка сооружений зависит от проектировщиков, которые в конкретных гидрогеологических условиях предлагают ту или иную технологическую схему их размещения. При этом существует несколько схем подачи воды из эксплуатационных скважин во «Фрегат»: 1) в скважинах более раннего проектирования предусматривается подача воды непосредственно из скважин на «Фрегат» без использования ёмкости для накопления воды. При этом невозможно регулировать расходы «Фрегата»; 2) у некоторых скважин более позднего проектирования и строительства сооружаются ёмкости-бассейны для накопления воды, которая затем при помощи дизельных компрессоров под давлением в 6 атм подаётся на «Фрегат». Иногда вода из нескольких скважин подаётся в один бассейн-накопитель.

В состав оросительной системы при заборе и подаче воды непосредственно из скважины на «Фрегат» входят: 1) скважина диаметром 325 мм с дырчатым фильтром диаметром 219 мм, с латунной сеткой; 2) насос электрический погружной с расходно-напорными характеристиками, соответствующими работе «Фрегата»; 3) дождевальная машина «Фрегат»; 4) дизельный компрессор; 5) напорный трубопровод, уложенный в траншею на глубину 1,0–1,5 м и подающий воду от компрессора к «Фрегату»; 6) домик для размещения пульта управления, вспомогательного оборудования и стола для оператора.

В состав оросительной системы при заборе воды и подаче на «Фрегат» из аккумулирующего бассейна входят: 1) скважина или группа скважин, из которых вода подаётся в бассейн-накопитель; 2) трубопровод, соединяющий скважину (скважины) и аккумулирующую ёмкость; 3) бассейн-накопитель (аккумулирующая ёмкость) объёмом 800–900 $м^3$ при одной скважине и до 2000 $м^3$ при 2–3-х скважинах; 4) насосы на каждую скважину, аналогичные описанным выше; 5) дизельный компрессор; 6) напорный трубопровод, подающий воду из бассейна-накопителя во «Фрегат»; 7) дождевальная машина «Фрегат»; 8) домик для обслуживающего персонала, размещения пульта управления и вспомогательного оборудования.

Обычно одной дождевальной машиной поливается площадь 72 га. Всего на северном предгорье Джунгарского Алатау в настоящее время подготовлено к орошению подземными водами 4105 га земель (12 участков) и имеется 55 скважин, которые могут эксплуатироваться для этих целей.

Влияние использования подземных вод для орошения на их запасы и ресурсы. Результаты режимных наблюдений Института гидрогеологии и геоэкологии им. У.М. Ахмедсафина и исследований предыдущих лет позволили установить общие и основные закономерности формирования подземных

вод в естественных, ненарушенных хозяйственной деятельностью человека, условиях. В последующие годы изучались вопросы влияния орошения на величину подземного стока [9]. Однако исследования влияния эксплуатации подземных вод водозаборами на подземный стоки, следовательно, на их запасы и ресурсы остались слабоизученными. Это было связано, главным образом, с отсутствием на действующих водозаборах подземных вод режимной наблюдательной сети, которая и сейчас имеется только на отдельных крупных водозаборах.

На рассматриваемой территории имеется 55 скважин, которые могут быть использованы для орошения земель и которыми за вегетационный период в зависимости от выращиваемых сельскохозяйственных культур и оросительных норм можно будет отбирать порядка 35–40 млн $м^3$ подземных вод. В межвегетационный период из некоторых скважин самоизливается 2,77 млн $м^3$. Общий водоотбор на массивах орошения будет составлять около 45–50 млн$м^3$в год.

Однако следует отметить, что, по данным наших исследований, большинство действующих скважин в прошлые годы работали как одиночные водозаборы. Они использовались для орошения небольших участков и, как правило, каптируют первые от поверхности водоносные горизонты, работали не круглые сутки, неравномерно, расход их измерялся несколькими десятками литров в секунду. Кроме этого, отдельные скважины имели разные расходы при разведке месторождения и при конкретном освоении массива орошения. Так, при разведке месторождения «Кольтабан» дебиты разведочно-эксплуатационных скважин изменялись от 19 до 120 л/с, а при эксплуатации на орошаемом массиве они изменялись от 48,4 до 84,9 л/с. Обычно расходы скважин при эксплуатации подземных вод ниже, чем при разведочных работах, на 20–30 %. Это объясняется кольматацией фильтра и заменой насосов на менее производительные во время ремонта.

Для изучения влияния эксплуатации водозаборных скважин на запасы и ресурсы подземных вод рассматриваемой территории нами использованы результаты режимных наблюдений за уровнем воды на всех перспективных для орошения подземными водами участках. Они проводились в течение 5 лет с частотой замера 1–2 раза в месяц. Кроме того, они сопровождались одноразовыми наблюдениями за режимом работы существовавших эксплуатационных скважин и восстановлением уровня воды в них после откачки в течение суток. По результатам наблюдений строились графики восстановления и колебания уровня подземных вод (рис. 2).

Уровенный режим в условиях эксплуатации подземных вод для орошения в вегетационный период (апрель–октябрь) имел следующий характер изменения. Во время откачки из скважин с дебитом 50–80 л/с, которая обычно длится 12 ч (с 9 до 21 ч), происходит резкое снижение уровня воды на 8–12 м. Затем в ночное время он частично восстанавливается, причем наиболее интенсивно (скорость составляет 0,1–0,2 м/с) в первые 5–10 мин. Далее скорость подъема уровня воды падает до 0,0005 м/с и последние сантиметры восстанавливаются в течение нескольких часов.

Кроме того, в течение вегетационного периода на отдельных участках орошения происходит сработка упругих запасов подземных вод (перестают самоизливаться многие скважины, и уровни в них устанавливаются ниже поверхности земли).

В целом же за вегетационный период на орошаемом массиве северных предгорий Жетысу Алатау в результате интенсивного отбора подземных вод происходило общее снижение их уровня на 6–10 м. При этом максимальное понижение уровня подземных вод наблюдалось в сентябре. Затем наступает осенне-зимний период, когда дождевальные механизмы не работают и подземные воды не эксплуатируются. В этот период, охватывающий октябрь–апрель, уровни подземных вод постепенно восстанавливались и к концу апреля достигали своей первоначальной отметки. Далее, в связи с началом отбора подземных вод на влагозарядковый полив, цикл повторяется снова.

Таким образом, если водоносные горизонты на участках орошения эксплуатируются только в вегетационный период, причем только в дневные часы, то в остальное время (суток и года) происходит восполнение запасов подземных вод. При этом расход водозабора зависит от режима водопотребления. Так, например, на орошаемом участке «Кольтабан» в апреле, в начале вегетации различных сельскохозяйственных культур, общий водозабор подземных вод составлял 250–300 тыс. $м^3$ в месяц, а в середине вегетации, то есть в мае–августе — 300–1100 тыс. $м^3$/месяц. В конце вегетационного периода (сентябрь–октябрь) количество извлекаемой подземной воды тсоставляло 310–625 тыс.$м^3$/месяц. С октября до середины марта скважины не эксплуатируются, происходит восполнение ресурсов подземных вод.

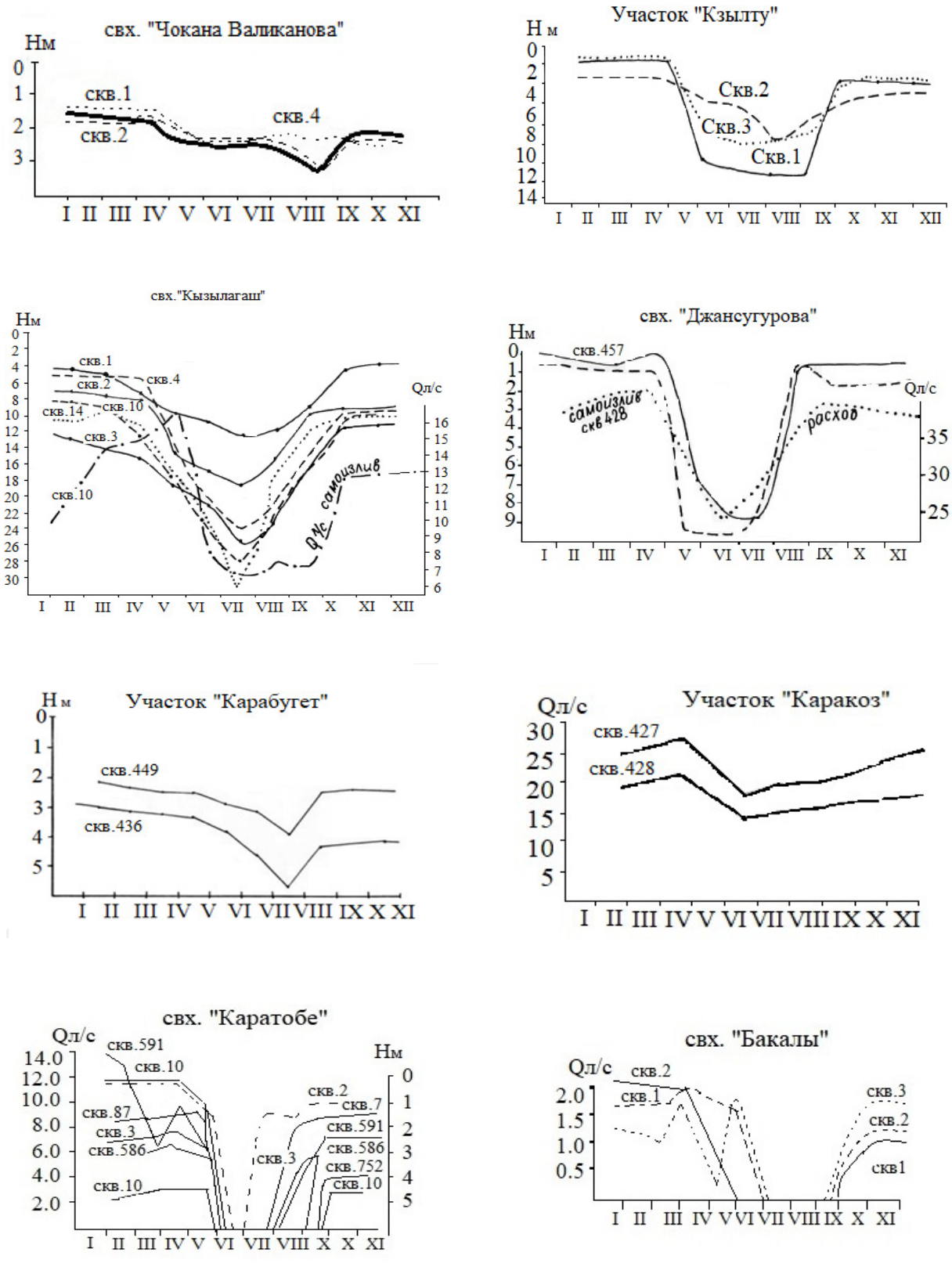


Рисунок 2. Восстановление и колебания уровня подземных вод

Общее количество подземной воды, отбираемой за вегетационный период (апрель–октябрь), достигало 2585 тыс.м^3. Образовавшаяся в результате эксплуатации подземных вод воронка депрессии достигала максимальной величины в июле, в период максимального водоотбора. К концу года депрессионная воронка несколько уменьшалась (рис. 1) и в феврале она полностью заполнялась. Наибольшая глубина залегания подземных вод наблюдается в юго-восточной части участка. Здесь не ожидается вторичное засоление грунтов. Наиболее близко уровни грунтовых вод подходят к дневной поверхности в северной и северо-западной частях участка. Здесь возможно вторичное засоление грунтов. Для предотвращения этого необходимо провести режимные наблюдения за уровнем воды и затем возможно предусмотреть дополнительный дренаж [10].

Весьма незначительный отбор подземных вод на водоснабжение населенных пунктов, обводнение пастбищ и сезонная и в то же время не круглосуточная их эксплуатация для орошения, как показали наши научные исследования и многолетние режимные наблюдения, не влияют на величину запасов подземных вод рассматриваемой территории. Это обусловлено благоприятными гидрогеологическими условиями: а) высокими фильтрационными свойствами водовмещающих отложений (коэффициент фильтрации колеблется от15 до 35 м/сут); б) довольно высокими значениями коэффициента водопроводимости (достигает 1718 м^2/сут), коэффициента уровнепроводности (1,3•10^4 м^2/сут), способствующими развитию небольшой зоны распространения и радиуса влияния депрессионной воронки и быстрым её восполнением (радиус воронки депрессии не превышает 0,5 км) после откачки; в) постоянством мощности подземного потока; г) незначительным общим региональным понижением уровня подземных вод даже при интенсивной их эксплуатации для орошения земель; д) мощным и постоянным источником формирования эксплуатационных запасов подземных вод, которыми являются в основном ежегодно возобновляемые ресурсы (24,79 м^3/с).

Исходя из понижения уровня подземных вод и уменьшения мощности водоносного горизонта в вегетационный период, можно рассчитать уменьшение естественных запасов подземных вод на орошаемых участках по формуле 1:

$$\Delta V = \mu \bullet F \bullet \Delta h \ , \qquad (1)$$

где μ — водоотдача; F— площадь орошаемого участка; Δh — изменение (понижение) уровня воды.

Расчет произведен по всем орошаемым подземными водами участкам. Результаты расчетов сведены в таблице.

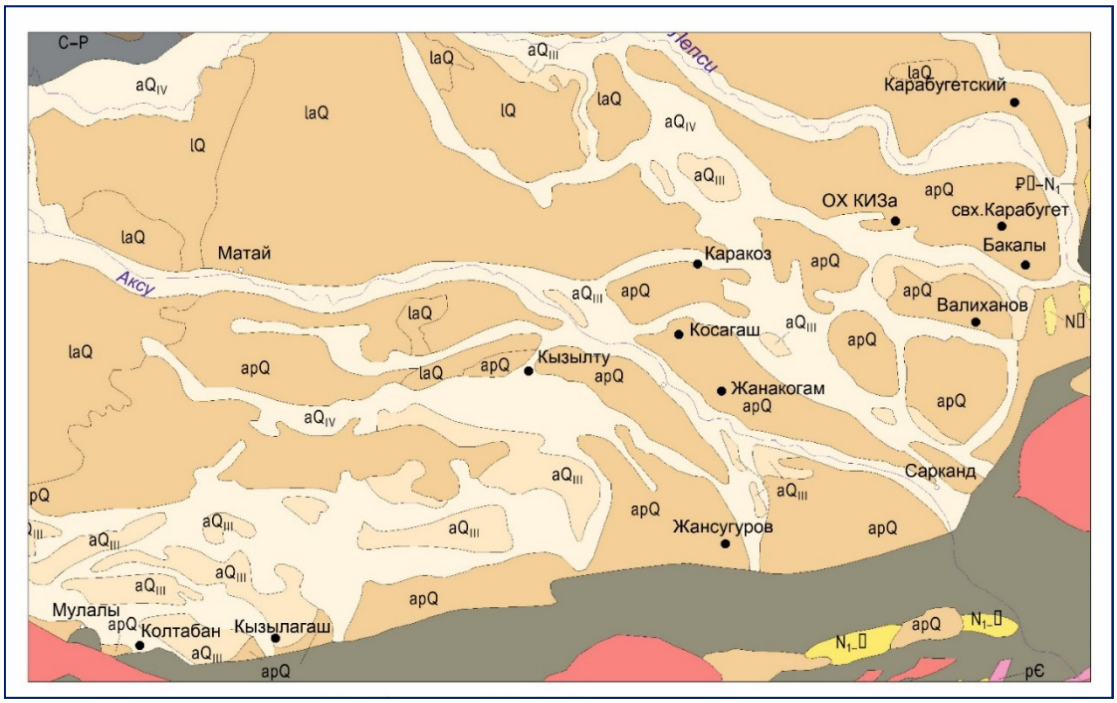
Таблица

Изменение запасов подземных вод под влиянием их отбора на орошение

Перспективные участки орошения	Орошаемая площадь, га	Водоотбор за вегетационный период, млн м^3	Уменьшение запасов подземных вод, млн м^3/год
Кольтабан	864	5,52	5,44
Кызылагашский	514	9,65	9,6
Жансугуров	210	2,75	2,73
Жанакогамский	220	0,41	0,4
Кызылтуский	216	3,42	3,4
Косагашский	144	0,3	0,3
Каракозский	144	0,21	0,12
ОХ КИЗа	144	0,32	0,3
свх. Карабугет	870	8,22	8,0
Валиханов	347	0,97	0,9
Бакалинский	216	2,0	1,93
Карабугетский	216	0,94	0,7
ИТОГО	4105	34,71	33,82

Величина изменения запасов подземных вод, используемых для орошения, близка к количеству отобранной воды. Эта величина полностью восполняется за межвегетационный период.

Таким образом, для орошения перспективных участков на предгорном шлейфе северных предгорий Жетысу Алатау будет извлекаться 34,71 млн м^3 подземной воды, орошается площадь 4105 га. При этом уменьшение запасов подземных вод будет составлять 33,82 млн м^3 в год (рис. 3, табл. 1).



Условные обозначения:

Водоносные горизонты и комплексы

aQ_{IV} — аллювиальные современные
aQ_{III} — аллювиальные верхнечетвертичные
laQ — озерно-аллювиальные четвертичные
apQ — аллювиально-пролювиальные четвертичные

Орошаемые участки

1. Кольтабан
2. Кызылагашский
3. Жансугуров
4. Жанакогамский
5. Кызылтуский
6. Косагашский
7. Каракозский
8. ОХ КИЗа
9. свх. Карабугет
10. Валиханов
11. Бакалинский
12. Карабугетский

Рисунок 3. Перспективные участки орошения

Результаты

Научные исследования, проведённые на предгорном шлейфе северных предгорий Жетысу Алатау, позволили сделать следующие выводы:

1. Создание массивов орошения с использованием подземных вод экономически целесообразно и является резервом для создания прочной кормовой базы животноводства.

2. Почвенно-климатические и гидрогеологические условия рассматриваемой территории позволяют применить широкозахватную дождевальную технику, наиболее удовлетворяющую требованиям оазисного орошения.

3. Установленный режим орошения путём определения суммарного водопотребления биоклиматическим методом наиболее полно удовлетворяет потребность растений в воде.

4. Применение промывного режима орошения значительно улучшает мелиоративное состояние земель.

5. Опыт эксплуатации и использования подземных вод для орошения на предгорной равнине северного склона Жетысу Алатау показывает, что запасы подземных вод не истощаются, несмотря на интенсивный водоотбор. Возобновление их происходит частично в ночное время, когда дождевальные машины не работают, и в межвегетационный период. Образовавшаяся за лето депрессионная воронка полностью восстанавливается в зимнее время.

6. Исследование подтвердило предположение о возможности использования подземных вод для орошения при дефиците поверхностных водоисточников. Применение предложенных дождевальных установок позволяет рекомендовать широкое использование подземных вод для орошения без ущерба их запасам.

Заключение

Выполненный прогноз показал, что при значительном увеличении площади орошаемых земель и интенсивной эксплуатации подземных вод на орошение уменьшатся их естественные запасы, произойдет перераспределение основных источников питания подземных вод, то есть, по-видимому, уменьшится роль инфильтрации атмосферных осадков вследствие увеличения глубины залегания уровня подземных вод, фильтрация поверхностных (речных вод) будет осуществляться преимущественно в зимний период только на реках, имеющих постоянный сток (Аксу, Лепсы), увеличится фильтрация поверхностных вод на полях орошения и из оросительных, магистральных каналов в результате возрастания их площадей и протяженности каналов, произойдет постепенное перемещение, а затем исчезновение зон интенсивной разгрузки подземных вод в виде источников типа «Карасу», сокращение эвапотранспирации в зоне выклинивания, величины глубокого подземного стока, стока с гор, равная на разных участках 4–11 $м^3$/с, останутся без изменений.

Исследование подтвердило предположение о возможности использования подземных вод для орошения при дефиците поверхностных водоисточников. Применение предложенных дождевальных установок позволяет рекомендовать широкое использование подземных вод для орошения без ущерба их запасам.

Региональные гидрогеологические исследования по установлению закономерностей формирования, размещения подземных вод и многолетний опыт изучения использования их для орошения показывают, что ресурсы подземных вод рассматриваемой территории позволяют дальнейшее расширение площадей орошаемых земель. Предгорные равнины Жетысу Алатау являются наиболее перспективными для развития орошаемого земледелия по всем показателям. Здесь распространены мощные водоносные горизонты, приуроченные к четвертичным аллювиально-пролювиальным валунно- и гравийно-галечникам с наиболее производительными скважинами (до 80–100 л/с при понижении уровня воды на 10–45 м) и высоким качеством воды. Разведанные эксплуатационные ресурсы подземных вод достигают 113 $м^3$/с.

Результаты исследования имеют не только научное, но и прикладное значение, позволяющее применить их на практике непосредственно на массивах орошения. К примеру, на массиве орошения правобережье р. Лепсы, где разведано Шиликтинское месторождение подземных вод, и на левобережье, где для орошения используются, в основном, поверхностные воды. Базой для орошения этих площадей может служить Аксу-Лепсинское месторождение подземных вод. Здесь можно орошать до 5 тыс. га земель. Однако при улучшении КПД оросительной системы, применении дождевальной техники площади орошения могут быть увеличены почти вдвое или же уменьшено водопотребление поверхностных вод. Так, только по Аксускому району Жетысуской области площади орошения возможно довести к 2040 г. до 30–35 тыс. га.

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А.М. Джабасов, А.М. Ерменбай, А.Ж. Жакибаева, Ю.Н. Ливинский, Г.Е. Тукешова

Суару үшін жерасты суларын іріктеу және олардың қорлар мен ресурстарға әсері (Оңтүстік–Шығыс Балқаш өңірі)

Қазіргі уақытта Жоңғар Алатауының солтүстік етегіндегі жерасты сулары қалаларды, ауылдық елдімекендерді сумен қамтамасыз ету, жайылымдарды суару үшін кеңінен пайдаланылады. Дегенмен, жерасты суларының ең үлкен әлеуетті тұтынушысы суармалы жерлер. Зерттеудің мақсаты Жетісу Алатауының тау бөктеріндегі жазықтардағы суаруға дайындалған учаскелеріндегі жерасты суларының қалыптасу жағдайларының өзгеруін, олардың қорлары мен антропогендік процестердің әсерінен ресурстарын — жерасты суларын суару үшін пайдалануды болжамды бағалау; суару жүйелерін және суару жабдықтарын орналастыру және орналастырудың типтік технологиялық схемаларын және пайдалану ұңғымаларынан суды жаңбырлатқыш қондырғыларға беру тәсілдерін әзірлеу; Жетісу Алатауының солтүстік бөктеріндегі аллювиалды-пролювийлік жазықтағы жерлерді суару үшін жерасты суларын пайдалану перспективаларына ұсыныстар мен баға беру. Зерттеудің негізгі гипотезасы жерасты суларын пайдаланатын кең таралған жаңбырлату жүйесінің жетілдірілген технологиясын қолдана отырып, жасанды суару мүмкіндігін болжау. Бұл ретте, ең алдымен, сумен қамтамасыз етудің негізгі көзі — пайдаланылатын сулы горизонт, жерасты суларының қалыптасуы, пайдалану қорлары қарастырылған және талданған; екіншіден, жерді суару әдістері. Зерттеу әдістері: қарастырылатын аумақтың жалпы су балансының элементтерін есептеу әдістемесі мен талдауы; Жетісу Алатауының солтүстік баурайындағы тау етегіндегі шлейфтің төрттік шөгінділерінің жерасты суларының барланған пайдалану қорларын және аллювиалды желдеткіштердің жыл сайын жаңартылатын жерасты суларының ресурстарын бағалау әдістемесі (қайта толтыру мөлшері); жоспарлы бақылауларды (мониторинг) жүргізу және талдау әдістемесі, қолданылатын жабдықтың конструкциясының толық сипаттамасы мен жерасты суларымен суарудың жаңбырлату әдісі. Жерді суару үшін барланған жерасты сулары кен орындарының ресурстық әлеуеті бағаланып, оларды пайдалану технологиясы ұсынылды. Жерасты суларын пайдаланатын жаңбырлату қондырғыларын қолдана отырып, жерүсті су көздерінің тапшылығы кезінде суармалы егіншілікті сумен қамтамасыз ету жағдайларын жетілдіру зерттеудің негізгі нәтижелері.

Кілт сөздер: жерасты суларының эксплуатациялық қорлары, жерасты суларының ресурстары, жерді суару, жаңбырлату технологиясы.

A.M. Dzhabasov, A.M. Ermenbay, A.Zh. Zhakibaeva, Yu.N. Livinsky, G.E. Tukeshova

The Impact of Groundwater Withdrawal for Irrigation on Its Reserves and Resources (South-Eastern Balkhash region)

Currently, groundwater from the northern foothills of the Dzungarian Alatau is widely used for water supply of cities, rural settlements, and pasture irrigation. However, the largest potential consumer of groundwater will be irrigated lands. The objective of the research: predictive assessment of changes in the conditions of groundwater formation in areas of the foothill plains of Zhetysu Alatau prepared for irrigation, their reserves and resources under the influence of anthropogenic processes — exploitation of groundwater for land irrigation; development of irrigation systems and typical process flow charts for the layout and placement of irrigation equipment and methods of water supply from production wells to sprinkler machines; recommendations and assessment of the prospects for using groundwater for irrigation of lands on the alluvial-proluvial plain of the northern foothills of Zhetysu Alatau. The main hypothesis of this study is the assumption of the possibility of artificial irrigation using an improved technology of a wide-capture sprinkler system using groundwater. In this case, first of all, the main source of water supply is considered and analyzed — the exploited aqui-

fer, the formation of groundwater, and operational reserves; secondly — methods of irrigation of land. Research methods: methodology and analysis of calculating the elements of the general water balance of the territory under consideration; methodology for assessing the explored operational reserves of groundwater in the Quaternary deposits of the foothill apron of the northern slopes of Zhetysu Alatau and annually renewable resources of groundwater in alluvial fans (recharge value); methodology for conducting and analyzing regime observations (monitoring), a method of sprinkling irrigation with groundwater with a detailed description of the design of the equipment used. The resource potential of groundwater deposits explored for land irrigation is estimated, and a technology for their use is proposed. The main results of the study are about improving the conditions of water supply for irrigated agriculture with a deficit of surface water sources using sprinkler systems that use groundwater.

Keywords: operational reserves of groundwater, groundwater resources, land irrigation, sprinkler equipment.

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