https://doi.org/10.31489/2025FEB2/96-106

UDC 5502.172:58 Received: 6 March 2025 | Accepted: 28 March 2025

A.N. Danilova, A.A. Sumbembaev*, O.A. Anufrieva, Yu.A. Kotuchov, O.A. Lagus

Altai Botanical Garden, Ridder, Kazakhstan
**Corresponding author: aydars@list.ru*

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

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

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

Introduction

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

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

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

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

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

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

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

Experimental

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

T a b l e

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

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

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

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

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

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

Results and Discussion

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

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

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

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

 ISSN 3080-6836 (Print) ISSN 3080-6844 (Online)

Table 2

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

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

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

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

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

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

Table 3

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

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

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

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

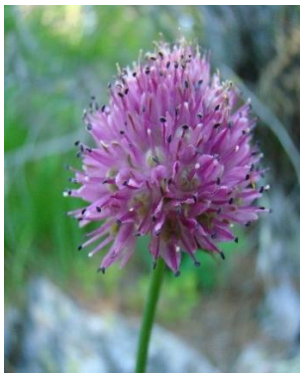
ii)  kk)  11) 

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

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

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

 ISSN 3080-6836 (Print) ISSN 3080-6844 (Online)

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

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

Table 4

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

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

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

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

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

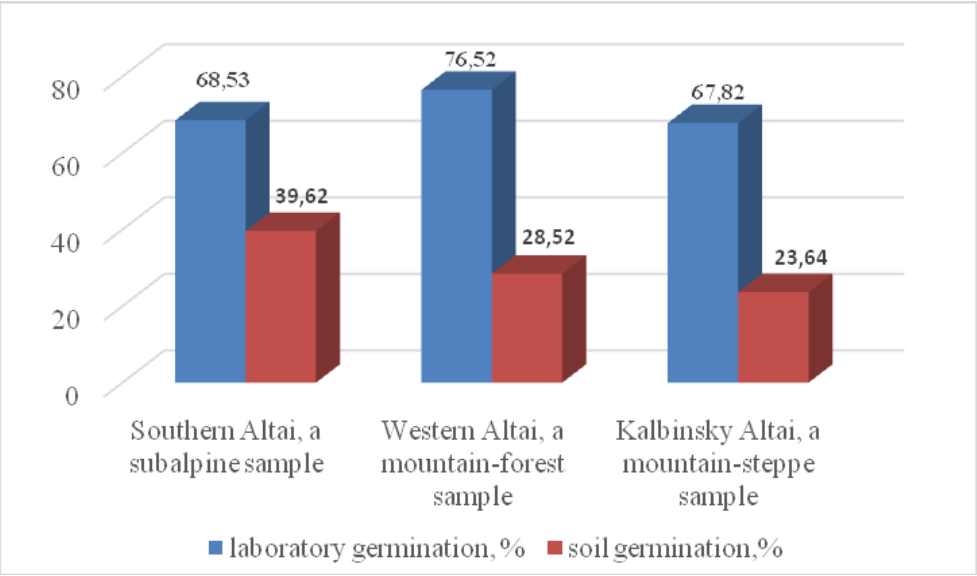


Figure 2. Laboratory and soil germination of seeds in the introduction of 3 accessions of *Allium hymenorhizum* of different ecological and geographical origin

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

Conclusion

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

Acknowledgements

The study was carried out with the financial support of the grant AP19674778 "Study of distribution and current state of rare species (genus Allium) in Eastern Kazakhstan and introduction in Altai Botanical Garden" (2023–2025).

References

1 Vincent H. Rare species perform worse than widespread species under changed climate / H. Vincen, C.N. Bornand, A. Kempel, M. Fischer // Biological Conservation. — 2020. — No. 246. DOI: 10.1016/j.biocon,2020.108586.

2 Андреев Л.Н. Сохранение биоразнообразия растений *ex-situ:* стратегия и план действий / Л.Н. Андреев, Ю.Н. Горбунов // Ботанические исследования в азиатской России. — 2003. — Т. 3. — С. 283–285.

3 Мулдашев А.А. О находке реликтовой популяции *Allium hymenorhizum* Ledeb. (Alliaceae) в Республике Башкортостан / А.А. Мулдашев, Н.В. Маслова, А.Х. Галеева // Флора и растительность Сибири и Дальнего Востока. — Красноярск, 2016. — С. 145–150.

 ISSN 3080-6836 (Print) ISSN 3080-6844 (Online)

4 Котухов Ю.А. Конспект луков *(Allium* L.*)* Казахстанского Алтая, Сауро-Манрака и Зайсанской котловины / Ю.А. Котухов, А.Н. Данилова, О.А. Ануфриева // Ботанические исследования Сибири и Казахстана. — 2011. — Вып. 17. — С. 3–33.

5 Музалевская Л.А. Ландшафты Лениногорской впадины / Л.А. Музалевская // География природных ресурсов Казахстана. — Алма-Ата: Наука, 1974. — С. 7–9.

6 Егорина А.В. Физическая география Восточного Казахстана / А.В. Егорина, Ю.К. Зинченко, Е.С. Зинченко. — Усть-Каменогорск: Альфа-Пресс, 2003. — 187 с.

7 Алтайскому ботаническому саду — 80 лет. — Усть-Каменогорск: Медиа-Альянс, 2015. — 59 с.

8 Sumbembayev A.A. Introduction of rare species of the genus *Allium* L. of the Kazakh Altai in the Altai Botanical Garden / A.A. Sumbembayev, A.N. Danilova, O.A. Anufrieva, Yu. A. Kotukhov, O.A. Lagus // Bulletin of the Karaganda University. Series neology, medicine, geography. — 2024. — No 4 (116). — P. 107–116. DOI: 10.31489/2024BMG4/107–116.

9 Методика фенологических наблюдений в ботанических садах СССР. — М.: ГБС, 1979. — 27 с.

10 Фомин Е.С. Изменения фенологии многолетних растений Западной Сибири на фоне глобального потепления / Е.С. Фомин, Т.И. Фомина // Современные проблемы экологии. — 2021. — Т. 14. — С. 434–445.

11 Вайнагий И.В. О методике изучения семенной продуктивности растений / И.В. Вайнагий // Ботанический журнал. — 1974. — Т. 59, № 6. — С. 826–831.

12 Былов В.Н. Принципы создания и изучения коллекции малораспространенных декоративных многолетников / В.Н. Былов, Р.А. Карписонова // Бюлл. ГБС АН СССР. — 1978. — Вып. 107. — С. 77–82.

13 Тухватуллина Л.А. Коллекция рода *Allium* L. Южно-Уральского ботанического сада-института / Л.А. Тухватуллина, Л.М. Абрамова // Труды по прикладной ботанике, генетике, селекции. — 2022. — № 183(4). — С. 192–207. DOI: 10.30901/2227-8834-2022-4-192–207.

14 Буко Т.Е. Результаты первичной интродукции видов рода *Allium* L. (лук) в Кузбасском ботаническом саду / Т.Е. Буко, Т.В. Роднов // Вестник Алтайского государственного аграрного университета. — 2014. — № 7 (117). — С. 92–96.

15 Гемеджиева Н.Г. Обзор современного состояния и перспективы изучения казахстанских видов рода *Allium* L. / Н.Г. Гемеджиева, А.М. Токенова, Н.В. Фризен // Проблемы ботаники Южной Сибири и Монголии. — 2021. — Т. 21. — № 1. — С. 97–101.

16 Фризен Н.В. Луковые Сибири / Н.В. Фризен. – Новосибирск, 1988. — 185 с.

17 Черемушкина В.А. Биология луков Евразии / В.А. Черемушкина. — Новосибирск: Наука, 2004. — 280 с.

18 Friesen N. Phylogeny and new intrageneric classification of *Allium* (Alliaceae) based on nuclear ribosomal DNA ITS sequences / N. Friesen, R.M. Fritsch, F.R. Blattner // Aliso. — 2006. — Vol. 22. — P. 372–395.

19 Кутуева А.Г. Опыт изучения морфологической и кариологической изменчивости *Allium hymenorhizum* Ledeb. при интродукции / А.Г. Кутуева, О.А. Елизарьева, Н.А. Калашник, Н.В. Маслова // Экобиотех. — 2018. — Т. 1. — № 4. — С. 227–240.

20 Govaerts R. World checklist of Amaryllidaceae / R. Govaerts, S. Kington, N. Friesen, R. Fritsch, D.A. Snijman, R. Marcucci, P.A. Silverstone-Sopkin, S. Brullo. — Kew: Royal Botanical Garden, 2021. — [Electronic resource]. — Access mode: https://wcsp.science.kew.org

21 Lin Ch.-Y. Seed testa micromorphology of thirty-eight species of Allium (Amaryllidaceae) from central Asia, and its taxonomic implications / Ch.-Y. Lin, Dun-Yan Tan // Nordic Journal of Botany. — 2017. — P. 189–200. https://doi.org/10.1111/njb.01259.

22 Swacha Grzego. Classification of alpine grasslands in the western Tian Shan Mountains (Kyrgyzstan, Middle Asia) / Grzegorz Swacha, Sebastian Świerszcz, Sylwia Nowak, Marcin Nobis, Arkadiusz Nowak // Acta Societatis Botanicorum. Poloniae. — 2023. — Vol. 92(1). — P. 1–26. DOI: 10.5586/asbp/169036.

23 Зайцев Н.Г. Методика биометрических расчетов. Математическая статистика в экспериментальной ботанике / Н.Г. Зайцев. — М.: Наука, 1973. — 256 с.

24 Фризен Н.В. Род Allium L. / Н.В. Фризен // Флора Сибири. Araceae — Orchidaceae. — Новосибирск: Наука, 1987. — С. 55–96.

25 Волкова Г.А. Биоморфологические особенности видов рода *Allium* L. при интродукции на европейский северо-восток / Г.А. Волкова. — Сыктывкар, 2007. — 200 с.

26 Тухватуллина Л.А. Интродукция дикорастущих луков в Башкортостане: Биология, размножение, агротехника, использование / Л.А. Тухватуллина, Л.М. Абрамова. — Уфа: Гилем, 2012. — 268 с.

27 Елизарьева О.А. Семенная продуктивность редкого реликта *Allium hymenorhizum* Ledeb. (Сем. Alliaceae) в Республике Башкортостан / О.А. Елизарьева, Г.М. Галикеева, Н.В. Маслова, А.А. Мулдашев // Известия Уфимского научного центра РАН. Биология, биохимия и генетика. — 2015. — № 4(1). — С. 48–51.

28 Елизарьева О.А. Семенная продуктивность редкого реликтового вида *Allium hymenorhizum* Ledeb. (сем. Alleaceae) в условиях интродукции / О.А. Елизарьева // Растительные ресурсы: опыт, проблемы и перспективы. Бирск. — 2014. — С. 20–24.

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

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

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

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

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

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

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

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

 ISSN 3080-6836 (Print) ISSN 3080-6844 (Online)

References

1 Vincent, H., Bornand, C.N., Kempel, A., & Fischer, M. (2020). Rare species perform worse than widespread species under changed climate. *Biological Conservation*, 246. DOI: 10.1016/j.biocon.108586.

2 Andreev, L.N., & Gorbunov, Yu.N. (2003). Sokhranenie bioraznoobraziia rastenii *ex-situ*: strategiia i plan deistvii [*Ex-situ* conservation of plant biodiversity: strategy and action plan]. *Botanicheskie issledovaniia v aziatskoi Rossii — Botanical study in Asian Russia, 3*, 283–285 [in Russian].

3 Muldashev, A.A., Maslova, N.V., & Galeeva, A.H. (2016). O nakhodke reliktovoi populiatsii *Allium hymenorhizum* Ledeb. (Alliaceae) v Respublike Bashkortostan [About the discovery of a relict population of *Allium hymenorhizum* Ledeb. (Alliaceae) in the Republic of Bashkortostan]. *Flora i rastitelnost Sibiri i Dalnego Vostoka — Flora and vegetation of Siberia and Far East*. Krasnoyarsk, 145–150 [in Russian].

4 Kotukhov, Yu.A., Danilova, A.N., & Anufrieva, O.A. (2011). Konspekt lukov (*Allium* L.) Kazakhstanskogo Altaia, Sauro-Manraka i Zaisanskoi kotloviny [Synopsis of the onions *(Allium* L.*)* of Kazakhstan Altai, Sauro-Manrak and Zaisan basin]. *Botanicheskie issledovaniia Sibiri i Kazakhstana — Botanical research in Siberia and Kazakhstan, 17*, 3–33 [in Russian].

5 Muzalevskaya, L.A. (1974). Landshafty Leninogorskoi vpadiny [Landscapes of the Leninogorsk depression]. *Geografiia prirodnykh resursov Kazakhstana — Geography of natural resources of Kazakhstan.* Alma-Ata, 7–9 [in Russian].

6 Egorina, A.V., Zinchenko, Y.K., & Zinchenko, E.S. (2003). *Fizicheskaia geografiia Vostochnogo Kazakhstana [Physical geography of East Kazakhstan]*. Ust-Kamenogorsk: Alfa-Press [in Russian].

7 (2015). *Altaiskomu botanicheskomu sadu — 80 let [The Altai Botanical Garden is 80 years old]*. Ust-Kamenogorsk: Media-Alians [in Russian].

8 Sumbembayev, A.A., Danilova, A.N., Anufrieva, O.A., Kotukhov, Yu.A., & Lagus, O.A. (2024). Introduction of rare species of the genus *Allium* L. of the Kazakh Altai in the Altai Botanical Garden. *Bulletin of Karaganda University. Series Biology. Medicine. Geography*, 4 (116), 107–116. DOI: 10.31489/2024BMG4/107–116

9 (1979). *Metodika fenologicheskikh nabliudenii v botanicheskikh sadakh SSSR [The methodology of phenological observations in the botanical gardens of the USSR]*. Moscow: Glavnyi botanicheskii sad [in Russian].

10 Fomin, E.S., & Fomina, T.I. (2021). Izmeneniia fenologii mnogoletnikh rastenii Zapadnoi Sibiri na fone globalnogo potepleniia [Changes in the phenology of perennial plants of Western Siberia against the background of global warming]. *Sovremennye problemy ekologii — Modern problems of ecology, 14*, 434–445 [in Russian].

11 Vainagiy, I.V. (1974). O metodike izucheniia semennoi produktivnosti rastenii [On the methodology of studying the seed productivity of plants]. *Botanicheskii zhurnal — Botanical Journal, 59*(6), 826–831 [in Russian].

12 Bylov, V.N., & Karpisonova, R.A. (1978). Printsipy sozdaniia i izucheniia kollektsii malorasprostranennykh dekorativnykh mnogoletnikov [Principles of creating and studying a collection of rare decorative perennials]. *Biulleten Glavnogo botanicheskogo sada Akademii nauk SSSR — Bulletin of Main Botanical Garden, Academy of Sciences of the USSR, 107*, 77–82 [in Russian].

13 Tukhvatullina, L.A., & Abramova, L.M. (2022). Kollektsiia roda *Allium* L. Yuzhno-Uralskogo botanicheskogo sada-instituta [Collection of the genus *Allium* L. South Ural Botanical Garden Institute]. *Trudy po prikladnoi botanike, genetike, selektsii — Works on applied botany, genetics, and breeding*, 183(4), 192–207. DOI: 10.30901/2227-8834-2022-4-192-207.

14 Buko, T.E., & Rodnov, T.V. (2014). Rezultaty pervichnoi introduktsii vidov roda *Allium* L. (luk) v Kuzbasskom botanicheskom sadu [The results of the primary introduction of species of the genus *Allium* L. (onion) in the Kuzbass Botanical Garden]. *Vestnik Altaiskogo gosudarstvennogo agrarnogo universiteta — Bulletin of the Altai State Agrarian University*, 7 (117), 92–96 [in Russian].

15 Gemedzhieva, N.G., Tokenova, A.M., & Friesen, N.V. (2021). Obzor sovremennogo sostoianiia i perspektivy izucheniia kazahstanskikh vidov roda *Allium* L. [Review of the current state and prospects of studying Kazakhstani species of the genus *Allium* L.]. *Problemy botaniki Yuzhnoi Sibiri i Mongolii — Problems of botany in Southern Siberia and Mongolia, 21*(1), 97–101 [in Russian].

16 Friesen, N.V. (1988). *Lukovye Sibiri [Onion Plants of Siberia]*. Novosibirsk [in Russian].

17 Cheremushkina, V.A. (2004). *Biologiia lukov Evrazii [Biology of Eurasian bows]*. Novosibirsk [in Russian].

18 Friesen, N., Fritsch, R.M., & Blattner, F.R. (2006). Phylogeny and new intrageneric classification of *Allium* (Alliaceae) based on nuclear ribosomal DNA ITS sequences. *Aliso, 22*, 372–395.

19 Kutueva, A.G., Elizarieva, O.A., Kalashnik, N.A., & Maslova, N.V. (2018). Opyt izucheniia morfologicheskoi i kariologicheskoi izmenchivosti *Allium hymenorhizum* Ledeb. pri introduktsii [Experience in studying morphological and karyological variability of *Allium hymenorhizum* Ledeb. at introduction]. *Ekobiotekh — Ecobiotech, 1*(4), 227–240 [in Russian].

20 Govaerts, R., Kington, S., Friesen, N., Fritsch, R., Snijman, D.A, Marcucci, R., Silverstone-Sopkin, P.A., & Brullo, S. (2021). World checklist of Amaryllidaceae. Kew: Royal Botanical Garden. Retrieved from https://wcsp.science.kew.org

21 Lin, Ch.-Y., & Dun-Yan, Tan. (2017). Seed test for micromorphology of thirty-eight species of *Allium* (Amaryllidaceae) from central Asia, and its taxonomic implications. *Nordic Journal of Botany*, 189–200. https://doi.org/10.1111/njb.01259. P.

22 Grzego, Swacha, Grzegorz, Swacha, Sebastian, Świerszcz, Sylwia, Nowak, Marcin, Nobis, & Arkadiusz, Nowak (2023). Classification of alpine grasslands in the western Tian Shan Mountains (Kyrgyzstan, Middle Asia). *Acta Societatis Botanicorum. Poloniae, 92*(1), 1–26. DOI: 10.5586/asbp/169036.

23 Zaitsev, N.G. (1973). *Metodika biometricheskikh raschetov. Matematicheskaia statistika v eksperimentalnoi botanike [Methods of biometric calculations. Mathematical statistics in experimental botany]*. Moscow: Nauka [in Russian].

24 Friesen, N.V. (1987). Rod *Allium* L. [Genus *Allium* L.]. *Flora Sibiri. Araceae — Orchidaceae — Flora of Siberia. Araceae — Orchidaceae*. Novosibirsk [in Russian].

25 Volkova, G.A. (2007). *Biomorfologicheskie osobennosti vidov roda Allium* L. *pri introduktsii na evropeiskii severo-vostok [Biomorphological features of species of the genus Allium L. during the introduction to the European Northeast]*. Syktyvkar [in Russian].

26 Tukhvatullina, L.A., & Abramova, L.M. (2012). *Introduktsiia dikorastushchikh lukov v Bashkortostane: Biologiia, razmnozhenie, agrotekhnika, ispolzovanie [Introduction of wild onions in Bashkortostan: Biology, reproduction, agrotechnics, use]*. Ufa [in Russian].

27 Elizarieva, O.A., Galikeeva, G.M., Maslova, N.V., & Muldashev, A.A. (2015). Semennaia produktivnost redkogo relikta *Allium hymenorhizum* Ledeb. (Sem. Alliaceae) v Respublike Bashkortostan [Seed productivity of a rare relic of *Allium hymenorhizum* Ledeb. (Family Alliaceae) in the Republic of Bashkortostan]. *Izvestiia Ufimskogo nauchnogo tsentra Rossiskoi Akademii nauk. Biologiia, biokhimiia i genetika — Proceedings of Ufa Scientific Center of the Russian Academy of Sciences. Biology, biochemistry and genetics*, 4(1), 48–51 [in Russian].

28 Elizarieva, O.A. (2014). Semennaia produktivnost redkogo reliktovogo vida *Allium hymenorhizum* Ledeb. (sem. Alleaceae) v usloviiakh introduktsii [Seed productivity of a rare relict species *Allium hymenorhizum* Ledeb. (family Alleaceae) in conditions of introduction]. *Rastitelnye resursy: opyt, problemy i perspektivy — Plant resources: experience, problems and prospects* (pp. 20–24). Birsk [in Russian].

Information about the authors

Danilova Aleftina Nikolayevna — Candidate of Biological Science, Leading researcher, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: *a-n-danilova@yandex.ru*

Sumbembayev Aidar Aitkaziyevich — PhD, Leading researcher, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: *aydars@list.ru*

Anufrieva Olga Alexandorvna — Senior researcher, Altai Botanical Garden, Ridder; e-mail: *altai_bs@mail.ru*

Kotuchov Yuri Andreevich — Candidate of Biological Science, Leading researcher, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: *altai_bs@mail.ru*

Lagus Olga Anatolyevna — Researcher, Altai Botanical Garden, Ridder, Kazakhstan; e-mail: *lelik_ridder1994@mail.ru*