The floristic composition of communities of apple and hawthorn forests with the participation of the rare species Gymnospermium altaicum (Pall.) Spach was studied in the Trans-Ili (Zailiyskiy) Alatau. The list of higher plants includes 156 species from 121 genera and 48 families. Most of them (84%) are herbaceous plants; there are 25 tree and shrub species, nine of which are wild non-native species (Ulmus laevis, Ulmus pumila, Morus nigra, Juglans regia, Malus domestica, Acer negundo, Acer platanoides, Viburnum opulus and Parthenocissus quinquefolia). Representatives of ten families make up 65% of the total number of species: Asteraceae, Poaceae, Rosaceae, Lamiaceae, Apiaceae, Fabaceae, Ranunculaceae, Caryophyllaceae, Boraginaceae, and Scrophulariaceae. The floristic core of the surveyed communities consists of 39 species, which mainly belong to the group of forest and forest-meadow ecological elements. Also other rare species listed in the Red Book of Kazakhstan, Malus sieversii, Armeniaca vulgaris and Paeonia intermedia, were found in these communities. We noticed signs of anthropogenic disturbance in the studied communities, including the presence of adventive and wild non-native species. We recommend to organize regular monitoring and strengthen the protection of the communities surveyed.

Key words: Gymnospermium, Berberidaceae, Red Data Book of Kazakhstan, plant communities, floristic composition, Trans-Ili Alatau.

Gymnospermium altaicum (Pall.) Spach (Berberidaceae), An Early Spring Element of Wild Fruit Forests of the Trans-ILI Alatau
Д.М. Абидкулова1*, А.А. Иващенко2, Г. Шрамко3, Н.В. Курбатова1, К.Т. Абидкулова1

1Казахский национальный университет им. аль-Фараби, Казахстан, г. Алматы
2Институт зоологии КН МОН РК, Казахстан, г. Алматы
3МТА-DE ‘Lendulet’ Исследовательская группа эволюционной филогеномики, Венгерская академия наук, Венгрия, г. Дебрецен

*e-mail: mizzadm@gmail.com

**Gymnospermium altaicum** (Pall.) Spach (berberidaceae) – ранневесенний элемент дикоплодовых лесов Заилийского Алатау

Изучен флористический состав сообществ дикоплодовых яблоневых и боярышниковых лесов с участием редкого вида **Gymnospermium altaicum** (Pall.) Spach в Заилийском Алатау. Общий список флоры высших растений включает 156 видов из 121 рода и 48 семейств. Большинство из них (84%) – травянистые растения; древесно-кустарниковых пород всего 25 видов, 9 из которых являются одичавшими интродуцентами (Ulmus laevis, Ulmus pumila, Morus nigra, Juglans regia, Malus domestica, Acer negundo, Acer platanoides, Viburnum opulus и Parthenocissus quinquefolia). Ведущее положение занимают представители 10 основных семейств, составляющих 65% от общего списка флоры: Asteraceae, Poaceae, Rosaceae, Lamiaceae, Apiaceae, Fabaceae, Ranunculaceae, Caryophyllaceae и Scrophulariaceae. Флористическое ядро обследованных сообществ состоит из 39 видов, которые, преимущественно, относятся к группе лесных и лесолуговых экологических элементов. Также выявлено, что в составе данных сообществ встречаются другие редкие виды, занесенные в Красную книгу Казахстана – Malus sieversii, Armeniaca vulgaris, Paeonia intermedia. Отмечена антропогенная нарушенность изученных сообществ, индикаторами которой являются не только адвентивные виды, но и одичавшие интродуценты. В связи с этим рекомендуется организация регулярного мониторинга и усиление охраны обследованных сообществ.

**Ключевые слова:** Gymnospermium, Berberisaceae, Красная книга Казахстана, растительные сообщества, флористический состав, Заилийский Алатау.

**Introduction**

The genus **Gymnospermium** Spach. (Berberidaceae Juss.) was described by the French botanist E. Spach in 1839. Originally, **Gymnospermium** was part of the genus *Leontice* L., and the independence of the former had been repeatedly questioned by various botanists. The history of separation and the distinctive features of these two genera in terms of the structure of seeds and fruits were described in detail by A.L. Takhtadzhyan [1], who noted that the independence of the genera was first adopted in the Flora Europea [2]. According to different authors, the size of the genus *Gymnospermium* varies from 7 to 12 species distributed from Eastern China to the Balkans [3]. We provide a visual representation of the distribution range of the genus **Gymnospermium** (Fig. 1) according to the Plants of the World Online database [4].

Only two species of **Gymnospermium** are found in Kazakhstan: *G. alberti* (Regel) Takht. and *G. altaicum* (Pall.) Spach, which are confined mainly to mountain broadleaved forests; the latter species has been found in the Northern Tien Shan, Dzhungarsky Alatau and Altai, and the former, in Syrdarya Karatau and Western Tien Shan [5,6,7].

**Gymnospermium altaicum** (Pall.) Spach is a perennial herbaceous plant with a globular tuber about 1.0–1.5 cm in diameter (Fig. 2). Stem erect, up to 15–20 cm in height with a long petiolate basal leaf and an almost sessile stem leaf located directly under the inflorescence; the latter is a single raceme 4–5 cm long with 6–12 yellow flowers. The stem leaf is terminal, three-leaved and palmate. Its segments have a solid margin; they are oblong or oblong-lanceolate and obtuse at the apex. The fruit is a capsule with the diameter of about 8 mm and 3–4 seeds. The fruit opens at the top with rounded blades even before the seeds ripen. *G. altaicum* is one of the earliest flowering plants in the mountainous regions of eastern and south-eastern Kazakhstan; it blooms in March–April, and its seeds ripen in June. The plants can reproduce by seed and vegetatively. This species grows at 200-1500 m above sea level along mountain foothills, on rocky mountain slopes, among shrubs, in steppe meadows, and in forests. Its distribution range is discontinuous. It extends in the southern and south-western directions (Fig. 3) from Central and Western Altai, and south-west of Siberia to the Trans-II Alatau and Xinjiang in north-west China [5,8-10]. Human activities including intensive pasture management, agricultural plowing, and harvesting of herbs contribute to the reduction in the size of the populations of *G. altaicum*. It is listed as rare in the Red Book of Kazakhstan and other regional reports [4,11,12].
Gymnospermium altaicum (Pall.) Spach (Berberidaceae), an early spring element of wild fruit forests of the Trans-Ili Alatau

Figure 1 – Distribution range of the genus Gymnospermium [3]

Figure 2 – Gymnospermium altaicum (Pall.) Spach. in Turgen gorge of the Trans-Ili Alatau
G. altaicum was described by I. Pallas in 1779 as *Leontice altaica* Pallas based on his collections from Altai [13]; later the species was transferred to the genus *Gymnospermium* Spach described by the French botanist E. Spach in 1839. Various features of representatives of these two genera have been studied by a number of botanists. For instance, D.B. Arkhangelsky and A.L. Takhtajan [14] studied the morphology of pollen grains in representatives of *Leontice* L., *Gymnospermium* Spach and other genera of the family Berberidaceae to find differences between individual species and genera. There is still no consensus on the systematics and size of *G. altaicum*. Some Western European taxonomists [2,15] believe that this species is distributed from Central Asia to Eastern Europe, including Ukraine and Romania. Moreover, they remarked that, despite the geographical separation of the two areas within the distribution range, typical samples from Mountainous Altai were very similar to those from Europe; therefore the division at the species level could not be justified.

However, A.L. Takhtajan [1] considered populations from the Black Sea region as *G. odessanum* (DC.) Takht. Isolated populations from the Peloponnesian (Greece) included in the latter species by the same author were later allocated to the new species *G. peloponnesiacum* (Phitos) Strid [16].

To understand interrelationships and spatio-temporal diversification of European populations of *Gymnospermium*, a group of scientists recently employed modern methods of AFLP, and used nuclear and plastid DNA sequences. The analysis of these indicators made it possible to identify two main evolutionary lineages in the group *G. altaicum*. The results suggest two separate parallel migrations of representatives of the genus to the Balkan Peninsula. One of them gave rise to the Greek endemic *G. peloponnesiacum* and the Pontic species *G. odesanum*, the closest relative of which, *G. altaicum* is distributed in the north of Central Asia. The second line includes the Caucasian species *G. smirnovii* (Trautv.) Takht., which is related to the Balkan species *G. malkoi* Kit Tan & Shuka and *G. scipetarum* Paparisto & Qosja ex E. Mayer & Pulević [17].

Other taxonomists studied relationships between various genera of the family Berberidaceae including *Gymnospermium*. For example, Wang et al. [18] used the sequences of the matK and rbcL chloroplast genes and nuclear ribosomal ITS2 for phylogenetic analysis of Berberidaceae. They identified three main clades. Moreover, they found that the desert xerophytes of Berberidaceae in southwestern Asia arose as a result of changes in climate aridity at different times; *Bongardia* separated from its closest relatives after 46.5 ± 3.6 million years, and *Leontice* separated from *Gymnospermium* after 10.3 ± 3.2 million years. The genetic diversity of the rare endemic species *Gymnospermium microrhynchum* (S. Moore) Takht., which has a limited distribution area in the mountainous regions of the Korean Peninsula, has also been studied to develop successful strategies for its conservation [19]. Some taxonomists continued to revise the size of the genus *Gymnospermium* at the western border of its range, i.e. in the Balkans [20].

The information about Kazakh representatives of the genus *Gymnospermium* is limited. There are
scattered data on the species as elements of the synusia of the ephemeretum of deciduous forests of the Northern and Western Tien Shan and Altai [7,21,22] and their use in traditional medicine [23]. Thus, *Leontice altaica* (syn. *G. altaicum*) is used in traditional medicine to treat epilepsy and the common cold. It has been established that this species contains quinolizidine and benzylisoquinoline alkaloids, as well as triterpene saponins, which have antioxidant, anticholinesterase, and anti-inflammatory activity [24].

*G. altaicum* has passed the initial tests in cultivation in the botanical gardens of Moscow, Almaty and Ridder. Its introduction turned out to be successful; it reproduces well and proved to be self-seeding [25,26]. Other authors point out its popularity as a decorative plant, especially in Western Europe and the Baltic states [27-29].

At the same time, there is insufficient information about this rare ornamental, medicinal and melilferous plant, the main area of which is located in Kazakhstan and requires special protection. Even information about its distribution range in Kazakhstan is far from complete, as we found out after studying all the available literary sources. V.P. Goloskokov [30] classified this distribution range as Altai-Tien Shan. However, in the west, according to most authors, the distribution area is limited to the Chu-Ili mountains [5,31]. The latest summary on the flora of this region [32] does not mention this fact. The distribution range of the species in Altai has been sufficiently studied [33]; there, the species is regarded one of the tertiary relict elements of the Preboreal group. According to the available literature, the species occurs in all regions of the Kazakh part of Altai: Western, Southern and Kalbinskiy Altai, as well as in several specific locations of the Azatau, Kurchum, Southern Altai ranges and in protected areas [22,34-36]. At the same time, there is no specific data on its distribution in Tarbagatai and the Dzungarskiy Altai [21,30]. In the Northern Tien Shan, in particular in the Trans-Ili Alatau, its occurrence is very fragmentary. For example, it is absent from many gorges of the central part of the ridge, but abundant in the valleys of the Turgen, Tauturgen and Kotyrbulak rivers; it is also absent from the west of Almaty, and from Aksai and Kaskelen [37]. After a large, almost 200-kilometer gap, it is found in abundance in the valley of the Karakunuz River [38].

All this indicates the need for a special study of the distribution of the species in the western part of the range, as well as of the number and state of its populations in order to develop improved conservation strategies for this species. Of particular interest is the study of morphological and genetic variability of plants growing at different locations within the distribution range of the species, in particular, of the isolated Karakunuz population.

These studies have been the main goal of our project. As a first step, we studied and analyzed in detail the floristic composition of forest communities with the participation of *G. altaicum* in the central part of the Trans-Ili Alatau. The results of the study are presented in this article.

**Aim of research.** To establish the characteristic peculiarities of the plant communities with participation of the rare species *G. altaicum* in wild fruit forests of the Trans-Ili Alatau.

**Materials and methods**

The research was carried out in 2008–2014 and in 2020, in different seasons (from April to October). In the central part of the Trans-Ili Alatau, on the northern slope, we examined and described in detail four forest communities with the participation of *G. altaicum*. The dimensions of the plots varied from 20 x 20 m to 40 x 40 m. These plots represent several types of apple tree (*Malus sieversii* (Lede.) M. Roem.) and hawthorn (*Crataegus songorica* C. Koch.) plant communities in the following gorges of the Trans-Ili Alatau:

1) **KB** – Kotyr-Bulak gorge, hawthorn forest, the lower part of the slope (952 m above sea level);
2) **K₁** – the northern slope in the Kuznetsovo tract, a herb and apple tree forest (1600 m above sea level);
3) **K₂** – the Kuznetsovo tract (the right bank of the Tauturgen River), a herb-grass and apple tree forest (1550 m above sea level);
4) **S** – Soldatsay gorge, cocksfoot and ground elder and apple tree forest (1540 m above sea level);

Geobotanical descriptions of the plots were carried out according to generally accepted methods as well as species abundance according to the Drude scale [39], and identification of plants, by using regional and republican summaries, keys and reference books [5,13,31]. The nomenclature of taxa is based on the summary by S.A. Abdulina [6].

**Results and Discussion**

The complete species list of the surveyed communities is presented in Table 1. Species listed in the Red Book of Kazakhstan [12] are in bold, and alien species (adventive and invasive introduced species) are marked with an asterisk (*).
Table 1 – Composition of the cenoflora of the surveyed communities. For abbreviations, see Materials and Methods

| Species                        | Abundance in the surveyed plots |
|-------------------------------|---------------------------------|
|                               | KB  | K₁  | K₂  | S  |
|                               | 1   | 2   | 3   | 4  | 5  |

**Trees and shrubs**

**Ulmaceae Mirb.**

*Ulmus laevis* Pall.  
Un  -  -  -  -

*Ulmus pumila* L.  
Un  -  -  -  -

**Moraceae Link**

*Morus nigra* L.  
Un  -  -  -  -

**Juglandaceae A. Rich. ex Kunth**

*Juglans regia* L.  
Un  -  -  -  -

**Rosaceae Juss.**

*Armeniaca vulgaris* Lam.  
Un  -  -  -  Un

*Crataegus songorica* C. Koch  
Sp–Cop1 -  Sp  Sol

*Malus domestica* Borkh.  
-  Un  -  -

*Malus sieversii* (Lede.) M. Roem.  
Un  Sp  Sp  Sp

*Padus avium* Mill.  
-  -  Sol  Sol

*Rosa albertii* Regel  
-  -  -  Un

*Rosa laxa* Retz.  
-  -  -  Un

*Rosa platyacantha* Schrenk  
-  Sol  Sol  Un

*Rubus caesius* L.  
Sp–Cop1 -  Sp  Sp-

*Rubus idaeus* L.  
-  -  Sol  Sol

**Rhamnaceae Juss.**

*Rhamnus cathartica* L.  
Un  -  Sol  -

**Berberidaceae Juss.**

*Berberis sphaerocarpa* Kar. et Kir.  
-  -  Sol  Un

**Caprifoliaceae Juss.**

*Lonicera altmannii* Regel et Schmalh.  
-  Un  Un  Un

*Lonicera tatarica* L.  
-  -  Sol  Un

**Celastraceae R. Br.**

*Euonymus semenovii* Regel et Herd.  
-  Sol  Sol  Sol

**Aceraceae Juss.**

*Acer negundo* L.  
Un  -  -  Un

*Acer platanoides* L.  
-  -  -  Un

**Salicaceae Mirb.**

*Populus tremula* L.  
-  -  -  Un

*Salix cinerea* L.  
-  -  -  Un

**Viburnaceae Rafin.**

*Viburnum opulus* L.  
-  -  -  Un

**Vitaceae Juss.**

*Parthenocissus quinquefolia* (L.) Planch.  
Un  -  -  -

**Herbs**

*Aspidiaceae Mett. ex Frank*
### Gymnospermium altaicum (Pall.) Spach (Berberidaceae), an early spring element of wild fruit forests of the Trans-Ili Alatau

Continuation of table 1

| Species | Abundance in the surveyed plots |
|---------|---------------------------------|
|         | KB | K₁ | K₂ | S   |
| Dryopteris filix-max (L.) Schott | Sol | - | Un | Un |
| Athyriaceae Alston            |     |    |    |     |
| Cystopteris fragilis (L.) Bernh. | Sol | - | - | - |
| Poaceae Barnhart              |     |    |    |     |
| Agrostis gigantea Roth        | -  | -  | Sp | Sol |
| Brachypodium pinnatum (L.) Beauv. | -  | -  | -  | -  |
| Brachypodium sylvaticum (Huds.) Beauv. | Cop₁ | Cop₂ | Cop₁ | Sol |
| Bromopsis inermis (Leyss.) Holub | -  | -  | Sol | -  |
| Bromopsis benekenii (Lange) Holub | -  | -  | Sol | -  |
| Calamagrostis epigeios (L.) Roth | -  | -  | Un | Sol |
| Dactylis glomerata L.         | -  | Sp | Sp | Cop₁ |
| Elymus tschimganicus (Drob.) Tzvel. | -  | Sol | Sol | Un |
| Elytrigia repens (L.) Nevski   | -  | Sol | Un | -  |
| Festuca gigantea (L.) Vill.   | Sol | Sol | Sol | Sol |
| Helictotrichon pubescens (Huds.) Pilg. | -  | Sol | Sp | -  |
| Melica nutans L.              | -  | -  | Sol | Un |
| Milium effusum L.             | Sol | Sp | Sp | Sol |
| Phalaroides arundinacea (L.) Rauschert | -  | -  | Un | Sol |
| Phragmites australis (Cav.) Trin. ex Steud. | -  | -  | -  | Un |
| Poa angustifolia L.           | -  | -  | Sol | Sol |
| Poa nemoralis L.              | Sol-Sp | Sp-Cop₁ | -  | -  |
| Cyperaceae Juss.              |     |    |    |     |
| Carex polyphylla Kar. et Kir. | -  | Sp | Sol | Un |
| Juncaceae Juss.               |     |    |    |     |
| Juncus sp.                    | -  | -  | -  | Un |
| Liliaceae Juss.               |     |    |    |     |
| Gagea filiformis (Lede.) Kunth | -  | -  | Sol | Sol |
| Gagea turkestanica Pascher    | -  | -  | Sol | Sol |
| Asphodelaceae Juss.           |     |    |    |     |
| Eremurus robustus (Regel) Regel | -  | -  | -  | Un |
| Cannabaceae Endl.             |     |    |    |     |
| Humulus lupulus L.            | Sol | -  | Sol | Sol |
| Urtica dioica L.              | Sol | Sol | Sp | Sol |
| Polygonaceae Juss.            |     |    |    |     |
| Polygonum aviculare L.        | -  | -  | Sol | -  |
| Polygonum coriarium Grig.     | -  | Sol | Sol | Sol |
| Rumex crispus L.              | -  | -  | Un | Un |
| Caryophyllaceae Juss.         |     |    |    |     |
| Cerastium arvense L.          | -  | -  | -  | Sol |
| Cerastium davuricum Fisch. ex Spreng. | -  | Un | Sol | Sol |
| Species                                    | Abundance in the surveyed plots |
|-------------------------------------------|---------------------------------|
|                                           | KB | K₁ | K₂ | S   |
| 1                                         | 2  | 3  | 4  | 5   |
| Silene wallichiana Klotzsch.              | -  | Un | Un | Sol |
| Stellaria media (L.) Vill.                | -  | -  | Sol | -   |
| Melandrium viscosum (L.) Čelak.           | Sol | -  | Un | Un  |

**Paeoniaceae Rudolphi**

| Species                                    | Abundance in the surveyed plots |
|-------------------------------------------|---------------------------------|
| Paonia intermedia C.A. Mey.              | - | - | - | Un |

**Ranunculaceae Juss.**

| Species                                    | Abundance in the surveyed plots |
|-------------------------------------------|---------------------------------|
| Aconitum leucostomum Worosch.             | - | Sol-Sp | Sp | Sol |
| Aquilegia atrovina M. Pop. ex Gamajun.    | - | - |  |  |
| Delphinium iIennis Huth                   | - | Sol | - | - |
| Ranunculus polyanthemus L.                | - | - | - | Sol |
| Ranunculus repens L.                      | - | - | - | Sol |
| Thalictrum flavum L.                      | - | Un | Un | Un |

**Fumariaceae DC.**

| Species                                    | Abundance in the surveyed plots |
|-------------------------------------------|---------------------------------|
| Corydalis glaucescens Regel               | Sol | - | Sol | - |
| Corydalis ledebouriana Kar. et Kir.       | - | - | Sol | Sol |

**Berberidaceae Juss.**

| Species                                    | Abundance in the surveyed plots |
|-------------------------------------------|---------------------------------|
| Gymnospermium altaicum (Pall.) Spach      | Sp | Sol | Sp | Sp |

**Brassicaceae Burnett**

| Species                                    | Abundance in the surveyed plots |
|-------------------------------------------|---------------------------------|
| Berteroa incana (L.) DC.                  | - | - | Sol | - |
| Cardamine impatiens L.                    | - | - | - | Sol |

**Rosaceae Juss.**

| Species                                    | Abundance in the surveyed plots |
|-------------------------------------------|---------------------------------|
| Agrimonia asiatica Juz.                   | - | - | Sol | Sol |
| Alchimilla sibirica Zam.                  | - | - | - | Sol |
| Fragaria vesca L.                         | - | - | - | Sol |
| Geum aleppicum Jacq.                      | - | - | - | Un |
| Geum rivale L.                            | - | - | - | Sol |
| Geum urbanum L.                           | Sp | Sp | Cop | Sp |

**Fabaceae Lindl.**

| Species                                    | Abundance in the surveyed plots |
|-------------------------------------------|---------------------------------|
| Lathyrus gmelinii (Fisch.)Fritsch         | - | - | - | Un |
| Lathyrus pratensis L.                     | - | - | Sol | Sol |
| Medicago lupulina L.                      | - | Un | Sol | - |
| Trifolium pratense L.                     | - | Un | - | Sol |
| Trifolium repens L.                       | - | - | Sol | - |
| Vicia cracca L.                           | - | Sol | Sol | Sol |
| Vicia sepium L.                           | - | - | Un | Sol |

**Geraniaceae Juss.**

| Species                                    | Abundance in the surveyed plots |
|-------------------------------------------|---------------------------------|
| Geranium divaricatum Ehrh.                | - | - | - | - |
| Geranium pratense L.                      | Sp-Sol | Sol | Sp | Sp |
| Geranium rectum Trautv.                   | - | - | Sol | Sol |
| Geranium robertianum L.                   | Sol | - | - | Sol |

**Balsaminaceae A. Rich.**
### Gymnospermium altaicum (Pall.) Spach (Berberidaceae), an early spring element of wild fruit forests of the Trans-Ili Alatau

Continuation of table 1

| Species                                                                 | Abundance in the surveyed plots | KB | K₁ | K₂ | S |
|------------------------------------------------------------------------|----------------------------------|----|----|----|---|
| Impatiens parviflora DC.                                               |                                  | Sol| Sp | -  | - |
| **Malvaceae Juss.**                                                    |                                  |    |    |    |   |
| Lavatera thuringiaca L.                                                | Sol Un Sol Un                   |    |    |    |   |
| **Rutaceae Juss.**                                                     |                                  |    |    |    |   |
| Dictamnus angustifolius G. Don fil. ex Sweet                           |                                  |    |    | Sol | Un |
| Euphorbia lamprocarpa Proch.                                           |                                  |    |    | Un  | -  |
| **Hypericaceae Juss.**                                                 |                                  |    |    |    |   |
| Hypericum hirsutum L.                                                  | Sol Un Sol Sol                  |    |    |    |   |
| Hypericum perforatum L.                                               |                                  |    |    |    |   |
| **Violaceae Batsch**                                                   |                                  |    |    |    |   |
| Viola collina Bess.                                                    | Sol - - Sol                   |    |    |    |   |
| Viola suavis M. Bieb.                                                  | Sol Un Sol Sol                |    |    |    |   |
| **Onagraceae Juss.**                                                   |                                  |    |    |    |   |
| Epilobium velutinum Nevski                                             |                                  |    |    |    |   |
| **Apiaceae Lindl.**                                                    |                                  |    |    |    |   |
| Aegopodium alpestre Ledeb.                                             |                                  |    |    |    |   |
| Aegopodium tashikorum Schischk.                                        | Sp Sol - -                   |    |    |    |   |
| Anthriscus sylvestris (L.) Hoffm.                                      |                                  |    |    |    |   |
| Bunium setaceum (Schrenk) H. Wolff.                                    |                                  |    |    |    |   |
| Bupleurum aureum Fisch.                                                |                                  |    |    |    |   |
| Conioselinum tataricum Fisch. ex Hoffm.                                |                                  |    |    |    |   |
| Conium maculatum L.                                                    |                                  |    |    |    |   |
| Daucus carota L.                                                       |                                  |    |    |    |   |
| Heracleum dissectum Ledeb.                                             |                                  |    |    |    |   |
| **Polemoniaceae Juss.**                                                |                                  |    |    |    |   |
| Polemonium caucasicum N. Busch                                         |                                  |    |    |    |   |
| **Boraginaceae Juss.**                                                 |                                  |    |    |    |   |
| Echium vulgare L.                                                      |                                  |    |    |    |   |
| Lithospermum officinale L.                                             |                                  |    |    |    |   |
| Myosotis sparsiflora Mikan. ex Pohl                                    |                                  |    |    |    |   |
| Rochelia peduncularis Boiss.                                           |                                  |    |    |    |   |
| Solenanthus circinnatus Ledeb.                                         |                                  |    |    |    |   |
| **Lamiaceae Lindl.**                                                   |                                  |    |    |    |   |
| Clinopodium integerrimum Boriss.                                       |                                  |    |    |    |   |
| Lamium album L.                                                        |                                  |    |    |    |   |
| Leonurus turkestanicus V. Krecz. et Kuprian.                           | Un Sol Un                    |    |    |    |   |
| *Melissa officinalis L.                                                |                                  |    |    |    |   |
| Mentha asiatica Boriss.                                                |                                  |    |    |    |   |
| Nepeta cataria L.                                                      |                                  |    |    |    |   |
| Nepeta pannonica L.                                                    |                                  |    |    |    |   |
### Species Abundance in the surveyed plots

| Species                                                                 | KB       | K₁       | K₂       | S  |
|------------------------------------------------------------------------|----------|----------|----------|----|
| *Origanum vulgare* L.                                                 | Sol      | -        | Sol      | Sp |
| *Phlomoides pratensis* (Kar. et Kir.) Adyl., R. Kam. et Machmedov       | -        | Un       | Sol      | Sol|
| *Prunella vulgaris* L.                                                | -        | -        | Sol      | Sp |
| *Stachys sylvatica* L.                                                | -        | -        | -        | Sol|
| **Scrophulariaceae Juss.**                                             |          |          |          |    |
| *Scrophularia umbrosa* Dumort.                                        | -        | -        | -        | Sol|
| *Verbascum thapsus* L.                                                | -        | -        | Un       | -  |
| *Veronica chamaedrys* L.                                              | -        | -        | Sol      | Sol|
| *Veronica cordifolia* (Kar. et Kir.) Walpers                         | -        | Sp       | -        | -  |
| **Plantaginaceae Juss.**                                              |          |          |          |    |
| *Plantago major* L.                                                   | -        | -        | -        | Un |
| **Campanulaceae Juss.**                                               |          |          |          |    |
| *Campanula glomerata* L.                                              | -        | -        | -        | Sol|
| *Codonopsis clematidea* (Schrenk) Clarke                              | -        | Un       | -        | -  |
| **Rubiaceae Juss.**                                                   |          |          |          |    |
| *Galium aparine* L.                                                   | -        | Sp       | Sp       | Un |
| *Galium karataviense* (Pavl.) Pobed.                                  | -        | -        | Sol      | Sol|
| *Galium turkestanicum* Pobed.                                         | -        | Sol      | Sol      | Un |
| **Orobanchaceae Vent.**                                               |          |          |          |    |
| *Orobanche sp.*                                                       | -        | -        | Un       | -  |
| **Asteraceae Dumort.**                                                |          |          |          |    |
| *Achillea millefolium* L.                                             | -        | -        | -        | Sol|
| *Arctium leiospermum* Juz. et C. Sergievka                           | -        | Un       | Un       | Sol|
| *Artemisia absinthium* L.                                             | -        | -        | Sol      | Un |
| *Artemisia annua* L.                                                  | Un       | -        | -        | -  |
| *Artemisia dracunculus* L.                                            | -        | -        | Un       | -  |
| *Artemisia vulgaris* L.                                               | -        | Un       | Un       | -  |
| *Cirsium semenovii* Regel                                            | -        | -        | Un       | Un |
| *Cirsium vulgare* (Savi) Ten.                                         | -        | -        | Un       | Un |
| *Cousinia umbrosa* Bunge                                              | -        | -        | Un       | -  |
| *Crepis sibirica* L.                                                 | -        | Sol      | Sol      | -  |
| *Echinops chantaticus* Trautv.                                        | -        | -        | Sol      | -  |
| *Galatella coriacea* Novopokr.                                       | -        | -        | Un       | -  |
| *Hieracium virosum* Pall.                                            | -        | -        | -        | Sol|
| *Inula helenium* L.                                                  | -        | -        | Sol      | Sol|
| *Lapsana communis* L.                                                | -        | -        | -        | Un |
| *Lapsana intermedia* M. Bieb.                                         | Sol      | -        | -        | -  |
| *Ligularia macrophylla* (Ledeb.) DC.                                  | -        | Sp       | Sp       | Sp |
| *Matricaria inodora* L.                                               | -        | -        | Un       | Un |
| *Picris nuristanica* Borm.                                           | -        | -        | Un       | Un |
Gymnospermium altaicum (Pall.) Spach (Berberidaceae), an early spring element of wild fruit forests of the Trans-Ili Alatau

Continuation of table 1

| Species                        | Abundance in the surveyed plots |
|--------------------------------|---------------------------------|
|                                | KB    | K₁  | K₂  | S   |
| Solidago dahurica Kitag.       | -     | -   | Un  | Sol |
| Tanacetum vulgare L.           | -     | -   | Un  | Sol |
| Taraxacum officinale Wigg.     | Sol   | -   | -   | Sol |

Note: Cop2 (copiosae 2) – abundant, there are many individuals of this species; Cop1 (copiosae 1) – quite abundant, plants are found occasionally, scattered; Sp (sparsae) – scattered, plants are found occasionally, scattered, in small numbers; Sol (solitariae) – singly, very few plants (only a few specimens in the plot); Un (unicum) – a single specimen, the species is represented by a single specimen in the plot.

Thus, the flora of the surveyed communities comprised 156 species from 121 genera and 48 families. Of the 25 species of trees and shrubs, nine were non-native, wild introduced species found in apple and hawthorn communities located near summer cottage areas (Kotyrbulak and Soldatsay). Representatives of the following ten families made up 65% of the total number of species: Asteraceae, Poaceae, Rosaceae, Lamiaceae, Apiaceae, Fabaceae, Ranunculaceae, Caryophyllaceae, Boraginaceae, and Scrophulariaceae.

The order of the most species rich families is very similar to that characteristic of the entire flora of the Trans-Ili Alatau [40] with the exception of Brassicaceae and Chenopodiaceae which are not included in the top ten families on our list, being replaced by two others, Apiaceae and Boraginaceae (the fifth and eighth places, respectively). This is explained by the specificity of the habitats of *G. altaicum*, both in terms of the altitudinal distribution (according to Baitulin et al. [40] it occurs in the steppe and shrub-forest-meadow altitudinal belts at 800-1500 m), and in relation to its phytocenotic affiliation (forest communities).

According to our data, of all plant species only ten were constant companions of *G. altaicum*: *Malus sieversii, Brachypodium sylvaticum, Milium effusum, Urtica dioica, Geum urbanum, Geranium pratense, Lavatera thuringiaca, Hypericum hirsutum, Viola suavis*, and *Bupleurum aureum*. The following 29 species were sometimes abundant in three out of four surveyed plots: *Crataegus songorica, Rosa platyacantha, Rubus caesius, Lonicera almannii, Euonymus semenovii, Dryopteris filix-mas, Dactylis glomerata, Elymus tschimganicus, Festuca gigantea, Carex polypylla, Humulus lupulus, Polygonum cortium, Cerastium davuricum, Silene wallichiana, Melandrium viscosum, Aconitum leucostomum, Thalictrum flavum, Vicia cracca, Hypericum perforatum, Conioselinum tataricum, Heracleum dissectum, Leonurus turkestanicus, Origanum vulgare, Phlomoides pratensis, Galium aparine, Galium turkestanicum, Arctium leiospermum, Crepis sibirica, and Ligularia macrophylla*. Thus, the floristic core of the communities with the participation of *G. altaicum* was represented by 39 species. The overwhelming majority (70%) of them were forest and forest-meadow ecological-cenotic elements, and the rest were meadow and occasionally meadow-steppe species.

With regard to life forms, the overwhelming majority (84%) were herbaceous plants, mainly perennials (109 species). Only 23 species were annuals and biennials. Tree and shrub species made up 16%, including nine non-native species.

Emphasizing the importance of preserving *G. altaicum* as a rare Red Data Book plant, it should be noted that three more species of the same category were recorded in the surveyed plots: *Malus sieversii, Armeniaca vulgaris, and Paeonia intermedia*. It is worth mentioning that on one of the described sites we found Melissa officinalis, a new species for the Ile-Alatau National Park [41], and Lapsana intermedia, a new adventive species for the flora of Kazakhstan previously found only at one point, in the vicinity of the Shymbulak ski base [42]. The presence of these and other adventive and non-native wild species that have appeared in recent years indicates a significant anthropogenic disturbance of the surveyed communities and emphasizes the need to strengthen protection and conduct regular monitoring of their condition.

### Conclusion

*G. altaicum* is an important early spring element of apple and hawthorn forests in the central part of the Trans-Ili Alatau. The floristic core of the com-
munities with its participation is mainly represented by forest and forest-meadow herbaceous species, the majority of which are perennials. The participation of non-native and adventive species in the plant communities of this part of the Trans-Ili Alatau indicates an increasing human impact on the native vegetation, which in turn requires constant monitoring of its condition, especially because of the presence of three other rare species listed in the Red Book of Kazakhstan. We believe that *G. altaicum* deserves a more detailed study, both within the entire range and in the Trans-Ili Alatau, due to the sporadic nature of its distribution in this region.

**Conflict of interests**

All authors have read and were familiar with the content of the article and have no conflict of interest.

**References**

1. Takhtajan A.L. “On the genus Gymnospermium Spach”. Bot. Zhurn. SSSR. Vol. 55. 1970: 1191–1193. [in Russian].
2. Stearn W.T., Webb D.A. “Gymnospermium Spach”. In Flora Europaea. Vol. 1. Lycopodiaceae to Platanaceae, edited by Tutin T.G., Heywood V.H., Burges N.A., Valentine D.H., Walters S.M., Webb D.A. 244. Cambridge: Cambridge University Press, 1964. –
3. Rosati L., Coppi A., Farris E., Fascetti S., Becca G., Peregrym M., Tan K., Selvi F. “The Genus Gymnospermium (Berberidaceae) in Italy: Identity and Relationships of the Populations at the Western Limit of the Genus Range.” Plant Biosystems 153 (6). (2019): 796–808. https://doi.org/10.1080/11263504.2018.1549613.
4. Plants of the World Online (POWO). Available from http://www.plantsoftheworldonline.org/ (accessed 12 January 2021).
5. Pavlov N.V. Flora of Kazakhstan: in 9 vols. Alma-Ata: Academy of Science of KazSSR, 1956–1966. [in Russian].
6. Abdulina S.A. Checklist of vascular plants of Kazakhstan. Alma-Ata: Academy of Sciences, 1999.
7. Kokoreva I.I. Adaptation strategies of polycarpous plant species of the Northern Tien Shan. Almaty, 2011. [in Russian].
8. Yin L. Rare Endangered Endemic Higher Plants in Xinjiang of China. Urumqi: Xinjiang Science & Technology Publishing House, 2006.
9. Ying T.S., Boufford D.E., Brach A.R. Gymnospermium Spach. In Fl. China, vol. 19. Beijing: Science Press; St. Louis: Missouri Botanical Garden, 2011.
10. Baikov K.S. ed. Check-list of flora of Asian Russia: Vascular plants. Novosibirsk: Publishing house of the SB RAS, 2012. [in Russian].
11. Maneyev A.G. ed. Red Book of the Altai Republic (Plants). 3rd Gorno-Altaisk, 2017. [in Russian].
12. The Red Data Book of Kazakhstan. Volume 2. Part 1. Plants. Re-edition, completed and revised. Astana, 2014.
13. Flora of the USSR: in 30 vols. Moscow-Leningrad, 1934-1964. [in Russian].
14. Arkhangel'sky D.B., Takhtajan L. “Morphology of pollen grains of Leontice L., Gymnospermium Spach and allied genera of the family Berberidaceae”. Bot. Zhurn. SSSR. Vol. 57. (1972): 921–926. [in Russian].
15. Stearn W.T., Webb D.A. “Gymnospermium Spach”. In Flora Europaea. Vol. 1. 2 ed.: Psilotaceae to Platanaceae, edited by Tutin T.G. 29–295. Cambridge: Cambridge University Press, 1993.
16. Karl R., Strid A. “Bongardia chrysogonum (Berberidaceae) rediscovered on the East Aegean island of Chios”. Phytol Balcanica vol. 15. (2009): 337–342.
17. Barina Z., Cakovic D., Piško D., Schönswetter P., Somogyi G., Frajman B. “Phylogenetic relationships, biogeography and taxonomic revision of European taxa of Gymnospermium (Berberidaceae)”. Bot. J. Linnean Soc. vol. 184(3). (2017): 298–311. https://doi.org/10.1093/botlinnean/box028
18. Wang W., Zhi-Duan Chen, Yang Liu, Rui-Qi Li, and Jian-Hua Li. “Phylogenetic and Biogeographic Diversification of Berberidaceae in the Northern Hemisphere”. Systematic Botany vol. 32(4). (2007): 731-742. https://doi.org/10.1043/0366-161
19. Lee S.H., Yeon M.H., Shim J.K. “Conservation implications of the genetic diversity of Gymnospermium microrrhynchum in Korea”. Genet. Mol. Res. Vol. 15(4). (2016). DOI: 10.4238/gmr15048843
20. Tan K., Shuka L., Siljak-Yakovlev S., Malo S., Pustahija F. “The genus Gymnospermium (Berberidaceae) in the Balkans”. Phytotaxa vol. 25. (2011): 1–17.
21. Stepanova E.F. Vegetation and flora of the Tarbagatai ridge. Alma-Ata: Academy of Sciences of the Kazakh SSR, 1962. [in Russian].
22. Baytulin I.O., Kotukhov Yu.A. Flora of vascular plants of Kazakhstan Altai. Almaty, 2011. [in Russian].
23. Plant resources of the USSR: Flowering plants, their chemical composition, use; Family Magnoliaceae – Limoniaceae. Leningrad: Nauka, 1984. [in Russian].
24. Jenisa J., Nugrohoa A.E., Hashimotoa A., Deguchia J., Hirasawaa Yu., Wong Ch. P., Kanedaa T., Shirotac O., Moritaa H. “A New Benzylisoquinoline Alkaloid from Leontice altaica”. Natural Product Communications vol. 10 (2). (2015): 291-292.
25. The introduction of plants of the natural flora of the USSR. Moscow: Nauka, 1979. [in Russian].
26. Plants of the natural flora of Kazakhstan in the introduction. Handbook. Alma-Ata: Gyllym, 1990. [in Russian].
27. Poletiko O.M., A.P. Mishenkova. Ornamental herbaceous plants in open ground. Reference book on the nomenclature of genera and species. Leningrad: Nauka, 1967. [in Russian].
28. Brian M. The Smaller Bulbs. London, 1990.
29. Ruksans J. Buried Treasures: Finding and Growing the World’s Choicest Bulbs. Portland, 2007.
30. Goloskokov V.P. Flora of the Dzungarian Alatau. Almaty: Alma-Ata: Science, 1984. [in Russian].
31. Keys to the plants of Central Asia (Critical synopsis of flora): in 10 vols. Tashkent: FAN, 1968-1993. [in Russian].
Gymnospermium altaicum (Pall.) Spach (Berberidaceae), an early spring element of wild fruit forests of the Trans-Ili Alatau

32 Roldugin I.I., V. V. Fisyun. Flora of Chu – Ili mountains (compendium and analysis). Almaty: Ereket-print, 2018. [in Russian].
33 Kamelin R.V. Materials on the history of the flora of Asia. (Altai mountainous country). Barnaul, 1998. [in Russian].
34 Baitulin I.O., Kotukhov Yu.A., Sinitsina V.G., Ivashchenko A.A. “Flora of the Azutau ridge”. in Flora of East Kazakhstan. 24–135. Alma-Ata, 1991. [in Russian].
35 Kotukhov Yu.A., A.A. Ivashchenko, J. Lyman. Flora of vascular plants of the West Altai Nature Reserve. Almaty: Tethys, 2002. [in Russian].
36 Utyasheva T.R. “Ecological-floristic connections of communities with the participation of rare and endangered ephemeral geophytes of the Markakol depression”. News of the NAS RK. Biological series vol. 2. (2007): 34-37. [in Russian].
37 Ivashchenko A.A. “Distribution of rare plant species in the central part of the Zailiyskiy Alatau”. Topical issues of biodiversity conservation in the Northern Tien Shan. Proceedings of the Intern. scientific – prat. confer. to the 10th anniversary of the SSNP “Kulsay kuderi” and Intern. day for the Protection of Snow Leopard. (2017): 222 – 226. [in Russian].
38 Wintergoller B.A. “The hackberry’s forests of the western end of the Zailiyskiy Alatau”. Proceedings of the Botanical Gardens of the Academy of Sciences of the Kazakh SSR. Vol. 8. (1964): 135-148. [in Russian].
39 Lavrenko E.M., A.A. Korchagin. Field Geobotany. Vol. 5. Moscow-Leningrad: Science, 1976. [in Russian].
40 Baitulin I.O., N.P. Ogar, S.G. Nesterova, Z.A. Inelova. Flora of the Ileyskiy Alatau. Almaty: Kazakh University, 2017. [in Russian].
41 Ivashchenko A.A., Zhaksylykova A.A. “Floristic diversity of apple forests on the monitoring sites of the Ile-Alatau National Park”. Bulletin of KazNU. Biological series vol. 1 (63). (2015): 231-238. [in Russian].
42 Ivashchenko A.A. “New for Kazakhstan adventive plants in the flora of the Ile-Alatau National Park”. Innovative ways of developing forestry and special protected natural areas: problems and prospects. (2011): 135-139. [in Russian].