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V.Yu. Kirillov[1], T.N. Stikhareva[1*], A.A. Ivashchenko[2],
M.Zh. Daulenova[1], Zh.S. Dukenov[1]

[1]A.N. Bukeikhan Kazakh Research Institute of Forestry and Agroforestry, Shchuchinsk, Kazakhstan;
[2]Institute of Zoology, Almaty, Kazakhstan
[*]Corresponding author's e-mail: kazniiles@mail.ru

Euonymus semenovii Regel & Herder as an Important Element of Relict Forests: A Summary of Research Experience

The article examines the scientific information available on *Euonymus semenovii* Regel & Herder, a relict species of flora found in Central Asia and China. The article explores several aspects, including distribution, morphological and ecological characteristics, phytocenotic features, introduction experiences, and conservation issues. *Euonymus semenovii* demonstrates wide plasticity and can thrive in moist habitats, withstand some drought, and grow at various altitudes (1100–3200 m above sea level). These characteristics are reflected in the morphological features and coloration of its individual organs. The species is typically found in small abundance in the understory of various types of mountain forests. The composition of plant communities involving *E. semenovii* varies across its range, ranging from apple forests (*Malus sieversii* M. Roem) to spruce forests (*Picea schrenkiana* Fisch & C.A. Mey). *Euonymus semenovii* is considered a relict species in relict plant communities, such as those with *Celtis caucasica* Willd and *Atraphaxis muschketowii* Krasn in Kazakhstan. *Euonymus semenovii* also plays a significant role in landslide succession processes in the mountain forests of the Northern Tien Shan, highlighting its environmental and anti-erosion importance for maintaining the stability of mountain ecosystems. The article suggests practical uses and conservation strategies for *E. semenovii*. It emphasizes the need for further in-depth research on the species to fully understand its potential and the importance of systematic monitoring observations and the development of accelerated propagation methods.

Keywords: Celastraceae, *Euonymus semenovii* Regel & Herder, distribution, morphology, phytocoenology, economic importance, introduction, conservation.

Introduction

Euonymus semenovii Regel & Herder is a plant species belonging to the Celastraceae family, *Euonymus* genus, section *Pseudovyenomus*, and series *Semenovianae*. It is found in Central Asia and adjacent areas of China, specifically in four races from Western and Southwestern China, ranging from Gansu to Yunnan [1].

E. semenovii is considered as a relict of the Turgai forest flora and has a range that follows the Dzhungarian-Pamir-Alai type [2-3]. It is classified as a summer-green shrub biotypically, and ecomorphologically as a sciomesophyte, which means it prefers shade, making it part of the ecological-cenotic group of forest species [4].

Although most literary sources classify *E. semenovii* as a deciduous shrub, its behavior varies in different ecological conditions. For example, in the Transili Alatau, seedlings can retain green foliage throughout the winter [5]. R.V. Kamelin classified it as an evergreen shrub but noted that the species freezes to the level of the snow cover [6].

This species possesses several unique characteristics, including entomophily, ornithochory, resprouting, irruptivity (formation of root suckers), and shade tolerance. It is adapted to a temperate climate characterized

by mesophytism, microthermism, and mesotrophism. As part of forest communities, it plays an important role as an understory assectator [5].

Currently, information on *E. semenovii* is limited and fragmented. The aim of this article is to review and summarize research experience by conducting a comprehensive analysis of the available data on this species. This includes a comparative analysis of its morphological descriptions from floristic surveys of Central Asian countries and China, characterizing the plant communities it participates in, examining its behavior in cultivation (introduction), and considering possibilities for practical use and conservation proposals.

A comparative analysis of descriptions of *E. semenovii* from literary sources provides valuable information for a more complete understanding of this species. This analysis allows for the identification of differences and similarities in the morphological, anatomical, and phenological characteristics of *E. semenovii* in different geographical regions within its natural range. Furthermore, comparing and analyzing these data contributes to a better understanding of the plant's adaptation capabilities to various environmental conditions, particularly when cultivated.

Characterizing plant communities involving *E. semenovii* is a key element in understanding the role of the species and its significance in the functioning of natural ecosystems.

Knowledge of the species' behavior in introduced conditions and its economic significance is fundamentally important for its practical use in forestry, landscape design, and urban greening in various regions, as well as for conservation opportunities. Summarizing the available scientific materials as a whole will contribute to a more effective and rational use of the resources of the studied species.

Experimental

The research methodology involved conducting a comprehensive analysis of information gathered from various sources, including regional botanical surveys such as the Flora of the USSR [7], Flora of Kazakhstan [8], Kyrgyzstan [9], Uzbekistan [10], Tajikistan [11], China [12], including Xinjiang [13], as well as the Plant Identifier of Central Asia [14]. Scientific journals, reference books, and internet resources were also consulted. During the study, descriptions of *E. semenovii* were compared based on key characteristics such as distribution, morphological features (habitat, leaf morphology, flower shape, fruit shape, and seed characteristics), and phenology (flowering and fruiting periods). Additionally, an analysis was conducted on the role of *E. semenovii* in various plant communities, its introduction experience, the economic significance of the species, and its conservation status. Latin names of plants and geographical objects are presented as they appear in the cited sources.

Results and Discussion

Distribution (Fig., a [15]). In Kazakhstan, where the northern boundary of the species' range lies, *E. semenovii* is frequently found in the mountains of the Dzhungarian Alatau and Tien Shan. Specifically, it can be found in the headwaters and upper reaches of the Karatal River, Mount Arasan, Valley of the Usek River, Transili Alatau, Kungei Alatau, Ketmentau, Terskei Alatau, Chu-Ili Mountains (Khantau), Kyrgyz Alatau, Karatau, and Western Tien Shan [8, 14–16]. The most comprehensive information is available for the Transili Alatau, where it is quite abundant in the central part but decreases significantly towards the east. In the Dzhungarian Alatau, it occurs sporadically at the lower points of the southern slopes [17]. V.P. Goloskokov classified it as a rare species in the Dzhungarian Alatau, with its northeastern range limit found here [3]. This indicates the broad ecological plasticity of the studied species and the favorable conditions for its growth, particularly in the central part of the Transili Alatau. Similar sporadic distribution of the studied species is also characteristic of the western boundary of its range, with isolated findings of *E. semenovii* in the Kyrgyz Alatau and Karatau [18-19].

In Tajikistan, *E. semenovii* is found in two floristic regions. These regions include the Gissar-Darvaz region, which encompasses the basins of the Varzob, Karatag, and Shirkent rivers. It can also be found along the road to the Pashmikun tract, in the vicinity of the village of Ramit, on the left bank of the Shurab-Dara river, and in the Pshegit tract. Additionally, it is found in the South Tajikistan region, particularly in the Surkhob ridge and the vicinity of the village of Kosa-Tarosh [11].

In Kyrgyzstan, the distribution of *E. semenovii* is detailed in the summary provided by G.A. Lazkov and B.A. Sultanova [20]. It covers the northern part of the Republic, the Issyk-Kul basin, Western Inner Tien Shan, and the Periphery of the Fergana regions.

In Uzbekistan, *E. semenovii* can be found across all ranges of the Southwestern Tien Shan, including the Chatkal, Kuramin, Ugam, Pskem, Koksu, Karzhantau, and Maidan-Tal [21].

In China, *E. semenovii* has adapted to various habitats, ranging from dry grasslands to forest steppes and forests. It can be found over a significant range of altitudes, from 1000 to 3200 m. In China, it is distributed in 11 provinces: Gansu, Hebei, Henan, Ningxia, Qinghai, Shaanxi, Shanxi, Sichuan, Xinjiang, Tibet, and Yunnan [12-13].

Morphological characteristics. *E. semenovii* is a branched shrub with olive-green shoots. The young branches are rounded and four-angled. The leaves are opposite, dark green on top and lighter underneath. They are glabrous on both sides and have a lanceolate, oblong-ovate, or sometimes ovate or elliptical shape. The base is rounded-cuneate or rounded, and the edges are serrated or crenate-serrated. The inflorescences are 3-7(15)-flowered and located in the lower part of the branches, in the axils of cup-shaped leaves. The flowers are bisexual, measuring 6–8 mm in diameter. They are four-parted, with sepals that are 1 mm long and oblong and green. The petals are 2-3 mm long and oblong-rounded. The stamens have sessile anthers. The fruit is a four-lobed capsule that is leathery and dry. It is pear-shaped and measures 6–9 mm long, with blunt lobes tapering to a short neck at the base. The seeds are oval and shiny, measuring 5–7 mm long. They have an orange-red aril with a lateral opening.

The species has an extensive range, so depending on the region and the growth conditions, the morphological characteristics may vary. These differences most commonly involve the size of the plant itself and its individual organs, as well as their coloration (Table).

T a b l e

Differences in morphological characteristics of *E. semenovii* from several regions

Morphological indicator	Location				
	Kazakhstan	**Tajikistan**	**Kyrgyzstan**	**Uzbekistan**	**China**
Plant height, m	1.0-2.0(3.0)	0.2-1.0	1.5(3.0)	up to 1.0	2.0-3.0
Leaf blade (length × width), cm	1.5-6 × 0.5-2	7(9) × 1-2(3)	1.5-6 × 0.5-2	1.5-6 × 0.5-2	3.5-5 × 1-1.5(2.5)
Peduncle length, cm	1-3	4-5	0.8-2.5	-	1.8-2.5
Petal color	dark purple with a greenish edge	almost purple with a green edge	dark purple with a greenish edge	red with a greenish edge	dark red
Fruit color	ripe pink	raspberry-colored when ripe, then brown	-	green	brown or yellow-brown to red-brown
Seed color	dark brown	brown	dark brown	brown	dark brown or black

In particular, the shortest plant height is recorded for specimens growing in Tajikistan and Uzbekistan, where it does not exceed 1 meter. In contrast, in China, Kyrgyzstan, and Kazakhstan, it reaches up to 3 meters. The dimensions of the leaf blade also vary. In Kazakhstan, Uzbekistan, and Kyrgyzstan, it ranges from 1.5-6 × 0.5-2 cm. In China, it measures 3.5-5 × 1-1.5(2.5) cm, and in Tajikistan, it is 7(9) × 1-2(3) cm. Additionally there are differences in the characteristics of the leaves. In China, the leaves have a papery texture, while in Tajikistan, they have longer petioles measuring 2–8 cm. The petals, fruits, and seeds also showcase variations. The petals can range from dark purple with a greenish edge to red. The fruits come in different colors such as pink, brown, and green with various shades. The seeds vary in color from brown to black. These differences are most likely explained by genetic variability, the influence of environmental conditions (such as slope exposure, lighting, and moisture), and possibly adaptation to the composition of pollinators. Figure, b-h, presents some variations in the morphological features of *E. semenovii* in different phenological phases.

The anatomical structure of *E. semenovii* leaves has been studied by Tajik scientists [22-23] (Fig., i). They discovered that *E. semenovii* leaves have distinct palisade parenchyma on the upper side of the leaf, which are typically dorsiventral mesomorphic leaves or leaves with a combination of xeromorphic features. *E. semenovii* has slightly recessed anisocytic stomata. It is characterized by thickened leaf blades (leaf blade thickness 274.5±4.8 μm, mesophyll thickness 228.0±7.0 μm), large-celled upper (cell height — 35.7±0.5 μm, cell width — 42.7±1.3 μm) and lower (cell height — 24.1±0.5 μm, cell width — 30.5±1.8 μm) epidermis, significant height and width of palisade parenchyma cells (number of cell layers — 2, long axis of cells in the first layer — 56.6±2.5 μm, short axis of cells in the first layer — 15.0±1.4 μm, long axis of cells in the second layer — 56.1±1.5 μm, short axis of cells in the second layer — 15.8±1.2 μm), spongy paren-

chyma (thickness — 115.0±4.5 μm, number of cell layers — 4–6), few large stomata (stomata on the lower side of the leaf: length — 30.5±0.5 μm, width — 22.5±0.5 μm, number per mm^2 — 98.6±8.0), and a small volume of intercellular spaces. Therefore, the leaf anatomical structure of *E. semenovii* is characterized by a predominance of features typically found in plants with xeromesomorphic structure. It appears that environmental factors contribute to some degree of xeromorphism in mesomorphic leaves under normal conditions [22-23].

The morphological and morphometrical characteristics of pollen grains of *E. semenovii* are as follows: the pollen size, measured by polar axis × equatorial axis, ranges from 25–28 × 22–27 μm, and the shape of the pollen grains varies from prolate spheroidal to oblate spheroidal. The number of colpi observed on the pollen grains is three. The endoapertures of the pollen grains are of the type Ora, characterized by an oval shape with equatorial elongation, measuring approximately 4 μm in diameter. The ornamentation of the pollen grains exhibits a reticulate and heterobronchate pattern, with lumina measuring between 0.2–0.3 μm and the width of muri ranging from 0.5–1.5 μm, with an average of 0.2 μm. The exine thickness of the pollen grains falls within the range of 2.0–3.8 μm [24].

In the Central Asian region (Kazakhstan, Kyrgyzstan, Uzbekistan), the flowering period of the species is limited to May-June, while in China, it can extend until July. Secondary flowering of *E. semenovii* occurs in sparse spruce forests (Kazakhstan, Transili Alatau, 27.09.2016, Fig., f). This secondary flowering was noted only once during the entire observation period. The fruiting periods of the species also vary: in most countries, it occurs in August, but in Tajikistan and China, it can last until September or October. These variations are presumably also influenced by the aforementioned factors. There are cases of both abundant flowering and its absence in individual years. For example, in the Transili Alatau (Kazakhstan), *E. semenovii* in the spruce forest (*Picea schrenkiana* Fisch. & C.A. Mey.) with *Malus sieversii* M. Roem. and *Crataegus songarica* K. Koch blooms and bears fruit abundantly for five out of the observed six years [25], while in the Varzob River gorge (Tajikistan), the species under study was never observed to flower [26].

Ecological and phytocenotic characteristics. E. semenovii is a mountainous species that grows at altitudes ranging from 1100 to 3200 m above sea level. It can be found on slopes with various exposures, but it prefers northern and northwestern aspects. According to the ecological scales of L.G. Ramenskiy and I.A. Tsatsenkin [27], it thrives in habitats with moisture conditions ranging from dry to moist, and the soil can be non-saline to fertile. In terms of light conditions, it is considered a shade-tolerant species. However, there is evidence that increased illumination due to windbreaks in the spruce forest has a beneficial effect on the flowering and fruiting of *E. semenovii* individuals, as observed in the following year [28].

E. semenovii is found in the understory of various types of forests. In Kazakhstan, it is most commonly found in the Northern Tien Shan, specifically in the Transili Alatau region. It can be found at altitudes between 1100 and 2600 m above sea level, as part of different forest and shrub communities. It is also present in apple forests, ranging from 1350 m (Aksai Gorge) to 1720 m above sea level (Alma-Arasan Gorge). In these apple forests, *E. semenovii* is abundant in half of the cases, and it is part of communities dominated by *Malus sieversii* M. Roem., *Rubus caesius* L., *Brachypodium sylvaticum* (Huds.) P. Beauv., *Dactylis glomerata* L., *Geum urbanum* L., *Aegopodium alpestre* Ledeb. [29-30]. It is also found in apricot-apple (*Armeniaca vulgaris* Lam., *Malus sieversii*) and aspen-apple-hawthorn (*Populus tremula* L., *Malus sieversii*, *Crataegus songarica* K. Koch) forests [31]. In the Malaya Almatinka River valley (1400–1500 m above sea level), *E. semenovii* is a characteristic species of a unique community that includes *Celtis caucasica* Willd [32]. However, in the eastern part of this region (Karakunuz locality), Winterholler B.A. [33] observed only individual suppressed specimens in more arid habitats. This suggests that *E. semenovii* is capable of adapting to harsh conditions and varying moisture levels. Interestingly, in the central part of the Transili Alatau, *E. semenovii* is part of another rare plant community of *Atraphaxis muschketowii* Krasn. with single trees of *Armeniaca vulgaris* [34].

E. semenovii has been recorded in the Dzhungarian Alatau Mountains [3, 35], although it is not found in the apple forests of this region [36]. In the Kyrgyz Alatau, the species is mentioned as part of communities with *Abelia corymbosa* Regel et Schmalh. on the northern and northwestern slopes of the Merke River at an altitude of 1100–1200 m above sea level [37].

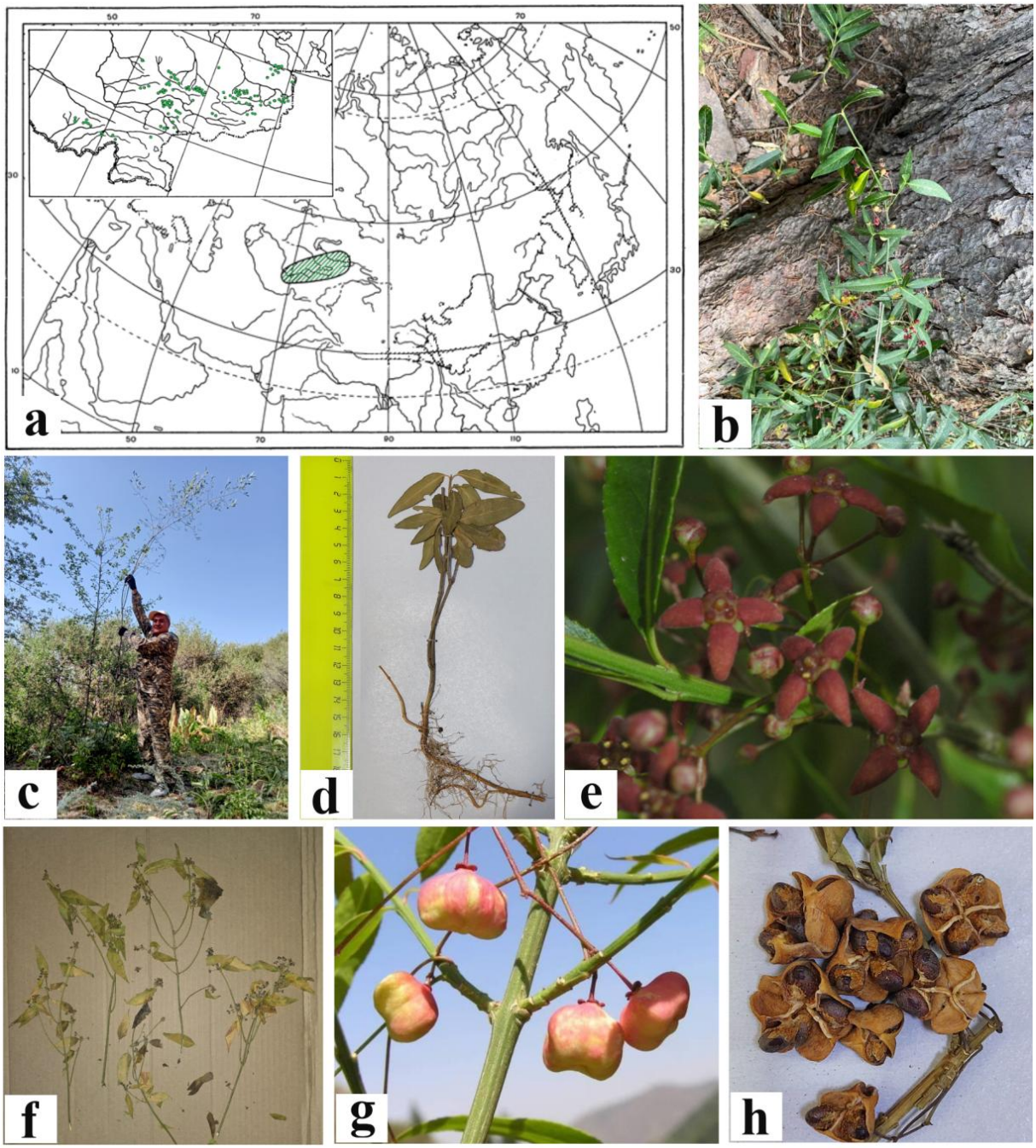
In the Tien Shan, *E. semenovii* is also widely distributed in spruce (*Picea schrenkiana*) forests. It is considered a characteristic or reliable species of this formation [2, 4, 38]. According to B.A. Bykov [38], the species can be found in the following types of spruce forests:

- Mixed forests: walnut (*Piceetum juglandosum*), apple (*Piceetum malosum*), aspen (*Piceetum saxoso-tremulosum*), willow (*Piceetum salicosum*), rowan (*Piceetum sorbosum*);

- Mossy forests: large-mossy (*Piceetum rhytidiadelphosum*) dominated by *Rhytidiadelphus triqueter* (Hedw.) Warnst. in the moss cover; herb-mossy-bearberry (*Piceetum arteto-muscosum*); shield-fern (*Piceetum dryopteriosum*), mixed-herb-mossy of the middle belt of forest (*Piceetum mixto-muscosum (subalpinum)*);

- Herbaceous forests: from the shrub-herbaceous group — honeysuckle (*Piceetum loniceriosum*), from the mixed-herbaceous group — riverside herbaceous (*Piceetum fontinoso-herbosum*).

In all types of spruce forests, *E. semenovii* is classified as a characteristic species with low abundance. Its abundance only reaches 30 % in one type of forest — large-mossy spruce forest. In other cases, the species is noted to occur as individual specimens.



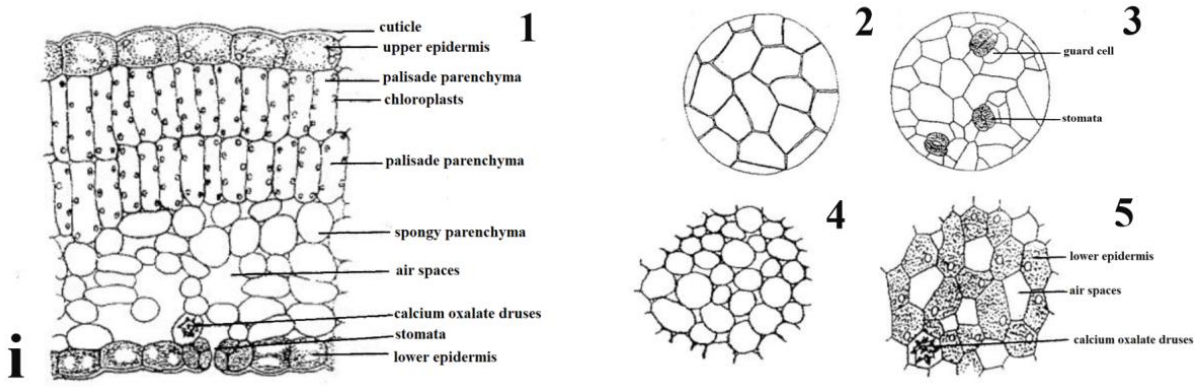


Figure. *Euonymus semenovii* Regel & Herder: species distribution range (© T.G. Leonova, 1974 [15]) (a); in the wild (Kazakhstan, Turgen River Gorge, left bank, 17.07.2023) (b); in the wild, plant height over 3 m (Kazakhstan, Kotyrbulak Gorge, northwest slope, 18.07.2023) (c); in the wild, height up to 20 cm (herbarium, Kyrgyzstan, Alai Range, Gulcha River basin, 15.08.1962) (d); shoot with flowers (Kazakhstan, Tian Shan, Ile Alatau, 15.06.2009; © Epiktetov V., 2009, https://www.plantarium.ru/page/image/id/32354.html) (e); secondary flowering (Kazakhstan, Transili Alatau, Tauturgen Gorge, 27.09.2016, collected by A.A. Ivashchenko) (f); shoot with fruits (Kazakhstan, Ile Alatau, © V.L. Kazenas, A.B. Zhdanko, photographs, 2012) (g); mature fruits with seeds (herbarium, Kyrgyzstan, Kirghiz Alatau, right bank of the Kara-Balta River, northern slope, 11.09.1947) (h); leaf anatomy: cross-section (1) and longitudinal sections through upper (2) and lower (3) epidermis, palisade (4) and spongy (5) leaf parenchyma (©A.A. Ashurov, R.S. Khakimova [22-23]) (i)

The response of *E. semenovii* to processes that often occur in the mountains of the Northern Tien Shan, such as landslides, is of interest. In the spruce forests of the region, one of the stages of landslide succession in the lower half of the coniferous forest belt involves the encroachment of shrubs, including *E. semenovii*. However, the change in species coverage in three successively changing types of spruce forests is minor — from 1 % in large-mossy spruce forest (*Piceetum rhytidiadelphosum*) to 1.5 % in short-legged spruce forest (*Piceetum brachypodiosum*) and further to 0.8 % in mixed-herbaceous spruce forest (*Piceetum mixto-herbosum*) [38].

As a result of detailed studies on the structure of the North Tien Shan spruce forests, I.I. Roldugin identified the presence of *E. semenovii* in the lower belt of spruce forests in the following types:

- graminaceous-aspen-spruce community: This community is composed of 8 spruce trees, 2 aspen trees, and occasionally birch, apple tree, and spindle-tree. The age of the spruce trees is 80–150 years, with a bonitet rating of III. The shrub layer consists of 11-12 species, reaching a height of 1.5–2.5 m. The occurrence of *E. semenovii*, which is classified as an interlayer shrub — liana, is 75 %;

- brachypodium-aegopodium-spruce community: This community consists of 10 spruce trees. The age of the spruce trees is 100–150 years, with a bonitet rating of II. The shrub layer consists of 10 species. *E. semenovii* is poorly represented in this layer, with a height of up to 2.0 m (0.1 %) [4].

E. semenovii occurs less frequently and in insignificant abundance in the North Tien Shan in the subalpine belt. It is found in communities of *Juniperus pseudosabina* Fischer et Meyer and on scree slopes of the upper belt [39].

In Tajikistan, *E. semenovii* grows in deciduous forests, often found in dense stands of walnut (*Juglans regia* L.) or maple (*Acer turkestanicum* Pax). It also persists in thickets of *Exochorda alberti* Regel or *Cotoneaster suavis* Pojark. and can be found in rosariums (*Rosa divina* Sumnev., *Rosa ovczinnikovii* Kochk.). Sometimes, it occurs in thermophilic juniper groves (*Juniperus seravschanica* Kom.) at the boundary with broad-leaved forests at elevations of 1400–2000 (2300) m [11]. In the Pamir-Alai, *E. semenovii* grows up to 1 m in height and forms part of the herbaceous vegetation layer along with *Aegopodium tadshikorum* Schischk, *Leonurus turkestanicus* V.I. Krecz. & Kuprian., *Cystopteris fragilis* (L.) Bernh., *Carex polyphylla* Kar. et Kir., and others [40]. In the Varzob River valley, *E. semenovii* is found in maple forests with *Acer turkestanicum* Pax at elevations ranging from 1800 to 2300 m above sea level. The shrub can reach a height of up to 50 cm and has well-developed root sprouts. Flowering is observed only in particularly favorable years [41].

In Kyrgyzstan, *E. semenovii* is recorded with moderate frequency in the following types of forests: walnut-fruit, riparian and floodplain, shrub thickets on mountain slopes, and rarely in coniferous forests [42]. In

the Sary-Chelek Biosphere Reserve, the main communities involving *E. semenovii* are formations of deciduous forests: Uzbek poplar (*Populus usbekistanica* Kom.), common pear (*Pyrus communis* L.), and dark coniferous forests: with Schrenk's spruce (*Picea schrenkiana*) — associations of the walnut-spruce group (with *Juglans regia*), the apple-spruce group (with *Malus sieversii* and *Malus niedzwetzkyana* Dieck.), walnut-fir forests (*Juglans regia, Abies semenovii* B. Fedtsch.), and spruce-birch forests (*Betula tianschanica*, *Picea schrenkiana*, *Abies semenovii*). Just like in spruce forests, *E. semenovii* is noted in the vegetation of the petrophytic group of humid screes and rocky slopes: in the rose-hip-hackberry thickets of spirea (*Rosa kokanica, Rosa fedtschenkoana, Celtis caucasica, Spiraea hypericifolia*), and the mixed spirea community (*Spiraea lasiocarpa, Spiraea pilosa*). The altitude range of these formations is 1260–2200 m above sea level, and the height of *E. semenovii* specimens varies from 0.3 to 3 m [43]. In the Chon-Kemin River basin, *E. semenovii* is noted as a characteristic species of spruce forests [44], while in the Chatkal, Talas, Uzun-Akhmat, and Susamyr Ranges, it is a co-edificator in the formation of *Picea schrenkiana — Abies semenovii* [45]. Lavrenko E.M. and Sokolov S.Y. mention *E. semenovii* as an edificator of relict biocenoses, along with *Malus sieversii*, *Acer semenovii*, *Abelia corymbosa*, and *Aflatunia ulmifolia* (Franch.) Vassilcz. [46].

In Uzbekistan, *E. semenovii* is widely distributed in the mountain ranges of the Western Tien Shan. It can be found forming small independent thickets or as part of the understory [47].

Furthermore, *E. semenovii*, along with *Lonicera hispida* Pall. ex Schult., *Aflatunia ulmifolia*, and *Prunus cerasifera* Ehrh., grows in the well-developed understory of walnut-coniferous forests. These forests are formed by *Juglans regia* L., *Picea tianschanica* Rupr., and *Abies semenovii* in the mountains of the Western Tien Shan [48]. *E. semenovii* is also present in mixed maple-walnut (*Juglans regia* L. and *Acer turkestanicum* Pax.) and apple-walnut (*Juglans regia* L. and *Malus kirghisorum* Al. Fed. & Fed.) forests with a rich understory. This understory includes *Prunus cerasifera* Ehrh., *Lonicera korolkowii* Stapf, *Lonicera persica* Jaub. & Spach, *Lonicera karelinii* Bunge, *Crataegus turkestanica* Pojark., *Rhamnus cathartica* L., and other species [49]. The walnut forests of the Fergana Range are home to two species of the *Euonymus* genus: *E. semenovii* and *E. koopmanii* Lauche. [6].

Economic importance and introduction E. semenovii is a shrub that produces gutta-percha. However, the gutta-percha content in its root bark is lower compared to other species [50]. The arils of *E. semenovii* contain the carotenoid zeaxanthin [51]. According to Botanic Gardens Conservation International (BGCI), *E. semenovii* grows in sixteen botanic gardens worldwide (https://plantsearch.bgci.org/taxon/31851). Because of its ornamental qualities, such as diverse leaf colors that range from dark green in summer to yellow-orange in autumn and the bright purple-crimson color of ripe fruits, *E. semenovii* is highly valued for forest park construction and urban landscaping. It is particularly recommended for use in the resort area of Lake Issyk-Kul [40, 50, 52-53].

In cultivation, *E. semenovii* is known at the forest-steppe experimental station in the Lipetsk region (Russia), where it sometimes experiences frost damage. In Leningrad, it freezes completely [50]. Live plants of *E. semenovii* from the Transili Alatau (valley of the Malaya Almatinka River) were introduced in 1962 at the Botanical Garden of the Academy of Sciences of Ukraine (Kyiv). These plants have shown resilience and ornamental qualities in cultivation [54]. In Edinburgh Botanical Garden in England, *E. semenovii* grows well and blooms, but does not bear fruit [55]. When introduced in Tashkent (Uzbekistan), it survived winter conditions without damage [56].

There is detailed information available on the introduction of *E. semenovii* in Almaty (Kazakhstan). It has been repeatedly introduced to the Main Botanical Garden in Almaty since 1957 with live plants from the Transili Alatau. It begins vegetating at the end of March, blooms in May-early June, and bears fruit in August. Its height ranges from 0.3-0.5 m. It reproduces vegetatively via root suckers. In cultivation, it is not stable, prefers shade, and is sensitive to soil moisture [57].

Seeds of *E. semenovii* collected in Kyrgyzstan in the Semyonov Gorge (northern shore of Lake Issyk-Kul, at an altitude of 1880 m) on 04.10.1980 were sown in the arboretum of the V.N. Sukachev Institute of Forest, Siberian Branch of the Russian Academy of Sciences (Krasnoyarsk, Akademgorodok). After 206 days of stratification, they were sown on 18.05.1981. A few seedlings appeared in June 1982. In October 1983, the seedlings were transplanted to the nursery [58], but later they froze [59].

In an initial trial in Moscow at the Main Botanical Garden of the USSR Academy of Sciences (now the N.V. Tsitsin Main Botanical Garden of the Russian Academy of Sciences) [60], *E. semenovii* plants either did not freeze at all or froze no more than 50 % of the length of one-year shoots, but did not bloom or bear fruit. Further research showed that in Moscow conditions, *E. semenovii* at the age of 7 years reaches a height

of 0.4 m, vegetates, has high winter hardiness (grade I), and is classified as a 2nd class promising plant – "promising plants" [61].

The existing experience with introducing this species suggests that it is highly recommended to cultivate it extensively in botanical gardens and arboreta. This cultivation is important for studying adaptation processes in various soil and climatic conditions, as well as for expanding the possibilities of practical use.

Conservation. The need for special protection of *E. semenovii* as a crucial element of various relict communities has been emphasized by multiple authors [34, 46, 62-63], among others. In China, this species is considered rare in Xinjiang [13].

In Kazakhstan, *E. semenovii* is protected within two state nature reserves — Almaty and Aksu-Zhabagly, and three state national nature parks — Zhongar-Alatau, Ile-Alatau, and Kolsay Kolderi [18, 35, 64–66].

In Kyrgyzstan, *E. semenovii* is protected in three state reserves — Sary-Chelek, Padysha-Ata, and Issyk-Kul [43, 45, 67].

We believe it is necessary to include *E. semenovii* as a subject of monitoring research due to its status as a rare species of relict plant communities.

Proposals for conservation. We believe that *in vitro* propagation is a crucial method for preserving the gene pool of *E. semenovii*. Firstly, this method allows for the production of genetically identical copies of the plant, which is essential in creating backup populations and preventing species extinction. Secondly, *in vitro* propagation provides a fast and efficient means of reproducing plants, which is particularly relevant for restoring degraded or small populations in natural conditions. Thirdly, utilizing *in vitro* methods enables detailed studies of the plant's physiology, anatomy, and genetics under controlled conditions, thereby contributing to a deeper understanding of the species' biology. Developing effective *in vitro* propagation methods for *E. semenovii* will ensure the long-term conservation of this species. It is worth noting that this propagation method is widely used for other species within the genus *Euonymus* L., highlighting its potential [68–80].

Conclusions

E. semenovii is a relic of the forest flora in the Turgai region and is found in Central Asian countries (Kazakhstan, Tajikistan, Kyrgyzstan, Uzbekistan) and adjacent regions of China. The species has a wide ecological range, thriving in moist habitats, tolerating some drought, and growing at various altitudes. These ecological preferences are reflected in the morphological characteristics and coloration of its individual organs. However, differences in the assessment of the species' life form suggest that there is still a need for further study of its morphological variability.

E. semenovii is a part of the undergrowth in mountain forests, but is not found in large numbers, which makes it vulnerable to negative factors, particularly those caused by human activity. It plays a role in landslide successions in the Northern Tien Shan mountain forests, indicating its ability to regenerate and adapt to environmental changes. This highlights the species' importance in environmental protection and erosion control, which helps to maintain the stability of mountain ecosystems.

Despite being a decorative gutta-percha shrub with arils containing zeaxanthin carotenoid, little research has been done on the chemical composition of *E. semenovii*. Currently, its use is mainly limited to decorative purposes. Initial experiences have shown that the species is not stable in culture and may not survive in certain climatic conditions. Further research is needed to fully understand the potential and characteristics of this species, as well as to determine its practical applications. To conserve the species, systematic monitoring observations and the development of conservation proposals, including accelerated in vitro propagation methods, are necessary.

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В.Ю. Кириллов, Т.Н. Стихарева, А.А. Иващенко,
М.Ж. Дауленова, Ж.С. Дукенов

Euonymus semenovii Regel & Herder реликті ормандардың маңызды элементі ретінде: зерттеу тәжірибесін қорытындылау

Мақалада Орта Азия мен Қытай флорасының реликті түрі — *Euonymus semenovii* Regel & Herder бойынша қолда бар ғылыми материалдардың талдауы келтірілген. Талдауда осы түрдің таралуы, морфологиялық, экологиялық және фитоценоздық ерекшеліктері, жерсіндіру тәжірибесі, қорғау мәселелері сияқты көрсеткіштер қарастырылған. Түр кең иілгіштігімен ерекшеленеді, ылғалды жерлерді ұнатады, құрғақ кезеңдерге төтеп бере алады және әртүрлі биіктікте (теңіз деңгейінен 1100-3200 м аралығында) өседі, бұл жеке органдардың морфологиялық ерекшеліктері мен олардың түсінде көрінеді. Осы түр аз мөлшердегі тау ормандарындағы әртүрлі түрдегі бұталар құрамына кіреді. *E. semenovii* қатысатын өсімдіктер қауымдастығы таралудың әртүрлі бөліктерінде ерекшеленеді, яғни алма ағаштарынан бастап (*Malus sieversii* M. Roem) шыршаға дейін (*Picea schrenkiana* Fisch & C.A. Mey). Реликті өсімдіктер қауымдастығында реликті түр ретінде атап өтілді (Қазақстанда — *Celtis caucasica* Willd. және *Atraphaxis muschketowii* Krasn). Солтүстік Тянь-Шань таулы ормандарындағы көшкін сукцессияларының процестеріне қатысады, бұл оның таулы экожүйелердің тұрақтылығын сақтау үшін қоршаған ортаға және эрозияға қарсы маңыздылығын көрсетеді. *E. semenovii* практикалық қолдану және сақтау бойынша ұсыныстар берілген. Оның әлеуетін толық түсіну үшін осы түрді терең зерттеу қажеттілігі, сондай-ақ бақылауларды жүйелі түрде бақылау және тиімді көбею әдістерін әзірлеу қажеттілігі атап өтілген.

Кілт сөздер: Celastraceae, *Euonymus semenovii* Regel & Herder, таралуы, морфологиясы, фитоценологиясы, шаруашылық маңызы, жерсіндіру, қорғау.

В.Ю. Кириллов, Т.Н. Стихарева, А.А. Иващенко,
М.Ж. Дауленова, Ж.С. Дукенов

Euonymus semenovii Regel & Herder как важный элемент реликтовых лесов: обобщение опыта исследований

В статье приведен анализ имеющихся научных материалов по *Euonymus semenovii* Regel & Herder — реликтовому виду флоры Средней Азии и Китая. Рассмотрены следующие показатели: распространение, морфологические, экологические и фитоценотические особенности и характеристики, опыт интродукции, проблемы охраны данного вида. Вид демонстрирует широкую пластичность, предпочитая влажные местообитания, способность переносить засушливые периоды и произрастать на разных высотах (в диапазоне 1100–3200 м. над уровнем моря), что выражается в морфологических особенностях отдельных органов и их окраске. Входит в состав подлеска различных типов горных лесов в небольшом обилии. Растительные сообщества с участием *E. semenovii* в разных частях ареала отличаются — от яблоневых (*Malus sieversii* M. Roem) до еловых (*Picea schrenkiana* Fisch & C.A. Mey). Отмечен как реликтовый вид в реликтовых растительных сообществах (в Казахстане — с *Celtis caucasica* Willd и *Atraphaxis muschketowii* Krasn). Участвует в процессах оползневых сукцессий в горных лесах Северного Тянь-Шаня, что подчеркивает его важное средозащитное и противоэрозионное значение для сохранения устойчивости горных экосистем. Даны предложения по практическому использованию и сохранению *E. semenovii*. Подчеркивается необходимость углубленного исследования этого вида для полного понимания его потенциала, а также систематического мониторинга наблюдений и разработки эффективных методов размножения.

Ключевые слова: Celastraceae, *Euonymus semenovii* Regel & Herder, ареал, морфология, фитоценология, хозяйственное значение, интродукция, охрана.

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Information about the authors

Kirillov Vitaliy Yurevich — Professor, Candidate of Chemical Sciences, Deputy Chairman of the Management Board for Research, A.N. Bukeikhan Kazakh Research Institute of Forestry and Agroforestry, Shchuchinsk, Kazakhstan; e-mail: *vitaliy.kirillov.82@mail.ru*;

Stikhareva Tamara Nikolaevna — Associate Professor, Candidate of Biological Sciences, Chief Scientific Secretary, A.N. Bukeikhan Kazakh Research Institute of Forestry and Agroforestry, Shchuchinsk, Kazakhstan; e-mail: *kazniiles@mail.ru*;

Ivashchenko Anna Andreevna — Candidate of Biological Sciences, Institute of Zoology, Almaty, Kazakhstan; e-mail: *ivashchenko40@bk.ru*;

Daulenova Meirzhan Zhakypovna — Master of Biotechnology, Junior Researcher, A.N. Bukeikhan Kazakh Research Institute of Forestry and Agroforestry, Shchuchinsk, Kazakhstan; e-mail: *daulenova_m@mail.ru*;

Dukenov Zhenis Serikovich — Master of Agricultural Sciences, Researcher, A.N. Bukeikhan Kazakh Research Institute of Forestry and Agroforestry, Shchuchinsk, Kazakhstan; e-mail: *7078786694@mail.ru*.