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ECO-BIOLOGICAL CHARACTERISTICS AND CURRENT STATE ASSESSMENT OF *PHEDIMUS HYBRIDUS* AND *HYLOTELEPHIUM EWERSII* IN THE KOK-ZHAILAU GORGE, FLORA OF THE ILE ALATAU

The article examines the current status of populations of *Phedimus hybridus* (L.) 't Hart (also known as *Sedum hybridum* L. and *Aizopsis hybrida* (L.) Grulich) and *Hylotelephium ewersii* (Ledeb.) H. Ohba (formerly *Sedum ewersii* Ledeb.) in the Kok-Zhailau Gorge, part of the flora of the Ile Alatau. The study explores the biology of these species, including their population dynamics and life forms, as well as their ecological responses to specific ecological-cenotic conditions. *P. hybridus* is valued in traditional medicine for its diverse therapeutic properties, such as anti-inflammatory effects, stimulation of the nervous system, antidepressant and wound-healing actions, and inhibition of leukocytosis. In contrast, *H. ewersii* is commonly cultivated as an ornamental plant. The article also includes a taxonomic, ecological, and geographical analysis of the flora associated with the populations of *P. hybridus* and *H. ewersii* in the Kok-Zhailau Gorge. The flora of the studied populations of *P. hybridus* and *H. ewersii* in the Big Almaty Gorge, Kok-Zhailau Tract, and Kazachka River areas of the Ile Alatau comprises 146 species across 78 genera and 39 families. The main ecological groups of plants within the *P. hybridus* and *H. ewersii* populations are shown: mesophytes – 105 species (71.9%), mesoxerophytes – 30 species (20.5%), and mesohygrophytes – 11 species (7.5%). The analysis revealed different levels of representation of geographical elements in the flora of the populations of *P. hybridus* and *H. ewersii* in the Kok-Zhailau tract of the Trans-Ili Alatau, which emphasizes the heterogeneity of the flora.

Key words: *Phedimus hybridus*; *Hylotelephium ewersii*; coenopopulation; Kok-Zhailau Gorge; Ile Alatau.

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Іле Алатауының Көкжайлау шатқалының флорасындағы *Phedimus hybridus* және *Hylotelephium ewersii* түрінің эко-биологиялық сипаттамасы және қазіргі жағдайын бағалау

Мақала *Phedimus hybridus* (L.) 't Hart (*Sedum hybridum* L., *Aizopsis hybrida* (L.) Grulich.) және *Hylotelephium ewersii* (Ledeb.) H. Ohba (*Sedum ewersii* Ledeb.) түрінің популяцияларының қазіргі жағдайын зерттеуге арналған. Іле Алатауындағы осы түрлердің ценопопуляцияларының флористикалық құрамы. *P. hybridus* популяцияларының биологиясын зерттеу және талдау ұсынылған. *P. hybridus* және *H. ewersii* Көкжайлау шатқалында Іле Алатауының жолында, олардың тіршілік формаларының әртүрлілігі мен нақты экологиялық реакциялардағы экологиялық реакциялары және ценоздық жағдайларда *P. hybridus* қабынуға қарсы, жүйке жүйесін қоздырғыш ретінде қолданылады. антидепрессант және жараларды емдеу әсері бар, сонымен қатар *H. ewersii* лейкоцитозының дамуын тежейді *P. hybridus* және *H. ewersii* түрінің

Мақалада *P. hybridus* және *H. ewersii* популяциясының флорасына таксономиялық, экологиялық және географиялық талдау берілген. Зерттелген популяциялар флорасы *P. Hybridus* және *H. ewersii* Үлкен Алматы шатқалында, Көк-Жайлау шатқалында және Іле Алатауының Казачка өзенінде 39 тұқымдастың 78 туысы мен 146 түрі бар. *P.hybridus* және *H.ewersii* популяциясы өсімдіктерінің негізгі экологиялық топтары көрсетілген: мезофиттер – 105 түр (71,9%), мезоксерофиттер – 30 түр (20,5%) және мезогигрофиттер – 11 түр (7,5%). Талдау нәтижесінде Іле Алатауының Көкжайлау трактідегі *P.hybridus* және *H.ewersii* популяцияларының флорасында географиялық элементтердің әртүрлі деңгейі анықталды, бұл флораның біркелкі еместігін көрсетеді.

Түйін сөздер: *Phedimus hybridus*; *Hylotelephium ewersii*; ценопопуляция; Көкжайлау шатқалы; Іле Алатауы.

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Экобиологическая характеристика и оценка современного состояния видов *Phedimus Hybridus* и *Hylotelephium Ewersii* во флоре Ущелья Кок-Жайлау Заилийского Алатау

Статья посвящена изучению современного состояния популяций видов *Phedimus hybridus* (L.) 't Hart. (*Sedum hybridum* L., *Aizopsis hybrida* (L.) Grulich.) и *Hylotelephium ewersii* (Ledeb.) N. Ohba (*Sedum ewersii* Ledeb.), флористического состава ценопопуляций этих видов в Большом ущелье, урочища Кок-Жайлау Заилийского Алатау. Приводятся исследование и анализ биологии видов популяций *P. hybridus* и *H. ewersii*, встречающихся в урочище Кок-Жайлау Заилийского Алатау, разнообразия их жизненных форм и экологических реакций в конкретных эколого-ценотических условиях. В народной медицине *P. hybridus* используется как растение с широким спектром терапевтических свойств. Он используется как противовоспалительное, стимулирует нервную систему, оказывает антидепрессантное и ранозаживляющее средство, а также тормозит развитие лейкоцитоза. *H. ewersii* распространен в культуре как декоративное растение. В статье приведен таксономический, экологический, географический анализ флоры популяций видов *P. hybridus* и *H. ewersii*. Флора изученных популяций *P. Hybridus* и *H. ewersii* в Большом Алматинском ущелье, урочище Кок-Жайлау и на р. Казачка Заилийского Алатау включает 146 видов из 78 родов и 39 семейств. Показаны основные экологические группы растений популяций *P. Hybridus* и *H. ewersii*: мезофиты – 105 видов (71,9 %), мезоксерофиты – 30 видов (20,5 %) и мезогигрофиты – 11 видов (7,5 %). Анализ выявил различный уровень представленности географических элементов во флоре популяций *P. Hybridus* и *H. ewersii* в урочище Кок-Жайлау Заилийского Алатау, что подчеркивает неоднородность флоры.

Ключевые слова: *Phedimus hybridus*; *Hylotelephium ewersii*; ценопопуляция; урочище Кок-Жайлау; Заилийский Алатау.

Introduction

The Ile Alatau is the northernmost range of the Tien Shan Mountain system, forming a gently concave arc that extends latitudinally to the south. It stretches approximately 350 km in length and 30–40 km in width. The central part of the ridge reaches an average elevation of 4000 m, with heights decreasing to the east in the Dala-Ashyk and Tyure-Zhailau mountains. The highest point, Talgar Peak, rises to 4951 m in the central Talgar Knot. Elevations gradually decline toward both the eastern and western ends of the range. The northern slopes are deeply dissected by numerous

gorges and valleys, with rivers flowing into the Lake Balkhash basin. About 20–30 km from the watershed, the foothills rise to 800–1000 m before transitioning into the gently sloping Ili basin to the northwest. In contrast, the southern slopes are steep, short, and less developed, with fewer dissected features.

Geographically, the Ile Alatau ridge is situated around 43° N latitude and 75–78° E longitude, extending through parts of Kazakhstan, Kyrgyzstan, and China. It begins in the west near the Chu River and extends 280 km eastward to the Chilik River. To the north, the ridge gently descends toward the Ili River depression and the plains of Kazakhstan,

while to the south, it is separated from the Kungei Alatau by intermountain valleys formed by the Chilik and Chonkemin rivers [1]. The Kok-Zhailau Gorge lies within the Ile Alatau State National Na-

ture Park, situated between the Small and Big Almaty Gorges, approximately 10 km from the city of Almaty, Kazakhstan. The elevation of the area is 2200 m above sea level (a.s.l.) [2].



Figure 1 – Map of the Kokzhailau Gorge of the Ile Alatau

According to Kazakhstan's geographical zoning, the Ile Alatau ridge falls within the North Tien Shan geobotanical province, specifically in the Ile forest-meadow steppe district. This central region of the Ile Alatau extends from the Ulken Almaty in the west to Turgen in the east [3].

The genus *Sedum* L., one of the largest plant genera, comprises nearly 600 species predominantly distributed across the Northern Hemisphere, especially within the subtropical and temperate zones of Eurasia. In Kazakhstan, this genus is represented by 10 species, including one endemic species, *Sedum nugodsharicum* Boriss., found in the Mugalzhar Ridge [4]. Goncharova [5] reported over 300 *Sedum* species in the Old World, with 25 species in the Circumboreal floristic region. The genus is most abundant in the East Asian (70 species), Irano-Turanian (50 species), and Mediterranean (40 species) floristic regions. The highest species concentration is found in the East Himalayan province of the East Asian region (50 species) and the Armeno-Iranian province of the Irano-Turanian region (32 species) [5].

All species of *Sedum* L. are valued as medicinal plants, gaining increasing interest both in Kazakhstan and internationally. In official medicine, *Sedum* species are recognized for their beneficial properties, including nervous system stimulation, antidepressant effects, anti-inflammatory and wound-healing actions, and inhibition of leukocytosis. Infusions are recommended for treating goiter and are also used as laxatives, hemostatic agents, diuretics, stress protectors, and tonics for the nervous system, as well as for gastrointestinal disorders. Fresh leaves are applied to ulcers, wounds, and bruises.

In addition to their medicinal value, *Sedum* species have ornamental qualities and are prized as honey plants [6]. *Phedimus hybridus* (L.) 't Hart (also known as *Sedum hybridum* L. and *Aizopsis hybrida* L. Grulich) is particularly notable for its ornamental features. The flowers of this hybrid sedum come in various shades of pink, purple, or white, making it visually appealing in gardens and landscape designs. Its narrow lanceolate leaves with serrated edges add grace, often displaying a pleasant green hue. *P. hybridus* is easily propagated by seeds, mak-

ing it accessible to gardeners and plant enthusiasts. Its ability to thrive in diverse climatic zones makes it a versatile choice for gardens and parks, including temperate and colder regions. These attributes contribute to its popularity in floriculture, where it is used in flower beds and landscaping in various light and soil conditions.

P. hybridus is a perennial herbaceous polycarpic species native to the mountainous regions of Siberia and the Tien Shan. It is characterized by a long, branched, cord-like, and creeping rhizome. The stems, which can reach heights of 15–20 cm (up to 34 cm), are evergreen, persistent, branched, creeping, prostrate, and rooting. Sterile shoots are short and densely foliated, while fertile ascending shoots have smaller, more widely spaced leaves. The leaves are alternate, measuring 1.5–2.5 cm (up to 3.5 cm) in length and 0.7–1.5 cm (up to 2 cm) in width. They are spatulate-elliptic, gradually narrowing into a long, wedge-shaped, entire petiole, obtuse at the apex, and obtusely serrated along the edge. The leaves are glabrous and smooth. The inflorescence is an apical, dense, paniculate-corymbose semi-umbel. The sepals are pale green, about 3 mm long, lanceolate, obtuse, and fused at the base. The petals are yellow, approximately 6 mm long and 1.5 mm wide, elliptic-lanceolate, acute, and reflexed. Seeds are up to 1 mm in length, elliptical, blunt, and numerous. The species blooms from June and bears fruit from July to August [7]. *P. hybridus* is light-loving, drought-resistant, and undemanding, thriving in nutrient-poor and light-textured soils. It commonly grows in mountain steppes and, less frequently, in the southern parts of the forest zone, particularly on rocky and gravelly soils, in rock crevices, and occasionally on sandy or pebble coastal cliffs. The species is found at altitudes ranging from 435 to 2600 m above sea level [8]. In Kazakhstan, it is distributed across various regions, including the Tobol-Ishim Lowland, Kokchetau, Turgai regions Mugalzhar, Western Uplands, Ulytau, Karkar, Zaisan, Altai, and Tarbagatai, as well as the Zhongar, Zailiysky, Kyrgyz, Kungey, and Terskey Alatau ranges, and the Ketmen Ridge, Chu-Ili Mountains, and Karatau. Globally, it occurs in the European part of the former USSR, Western and Eastern Siberia, Western China, and Northern Mongolia. However, the morphological and biological characteristics of *P. hybridus* in the Zailiysky Alatau region remain largely unstudied.

Hylotelephium ewersii (Ledeb.) H. Ohba, an Altai-mountain-Central Asian-Himalayan species [9], is a perennial, herbaceous polycarpic plant

with a branched, woody rhizome that forms a turf and cord-like roots. The numerous, branched, and ascending stems grow to a height of 10–20 cm (up to 25 cm). They are woody at the base, bare, and reddish. The opposite leaves measure 1–1.5 cm (up to 2 cm) in length and are almost as wide. They are broadly ovate or nearly rounded, cordate at the base, and short with a bluntly pointed apex. The leaves are glaucous-green, finely dotted, with unclear fine serrations. The lower leaves are broadly elliptic and often have brown spots. The inflorescence is complex and corymbose. Sepals are lanceolate, about 2 mm long. The petals are elliptical-lanceolate, acute, pink or light purple, and measure 4–5 mm in length. There are 10 stamens, slightly longer than the petals, with blackish anthers. Hypogynous scales are 0.5 mm long, oblong, and slightly notched at the apex. Leaflets are 3–4 mm long, erect, and bent outward at the tips. Seeds are lanceolate, brown, and about 0.5 mm long. The species blooms from July to October [7–9]. *H. ewersii* is light-loving, drought-resistant, and undemanding in terms of soil quality. It grows on rocky, stony, and gravelly mountain slopes across the lower, middle, and high mountain belts. In Kazakhstan, it is found in Zaisan, Altai, and Tarbagatai, as well as in the Dzungarian, Zailiysky, Kyrgyz, Kungey, and Terskey Alatau ranges, the Ketpen Range, and the Western Tien Shan. It is also present in Western Siberia, Central Asia, Western China, Western Mongolia, and the Himalayas.

Over the past decade, scientific interest in the Crassulaceae family, particularly in *P. hybridus* and *H. ewersii*, has grown significantly. Research has investigated the antioxidant and antibacterial properties of *P. hybridus* [10,11], as well as the phylogenetic relationships within Crassulaceae, including intrafamilial and generic classification [12–14]. Ohba [15,16] contributed to the taxonomic understanding of *Sedum telephium* and related species within Crassulaceae, addressing systematic issues related to the evolution of Asian Sedoideae and Crassulaceae taxonomy. Further studies have focused on cultivated *Sedum* species, plant flowering and nectar production, variation in flavonoids and alkaloids, and photoperiodic control of plant dormancy [17–22]. Additional research has explored the evolution and systematics of Crassulaceae, with a focus on the *Sedum acre* group [13,23].

The current study aims to investigate the population characteristics of *P. hybridus* and *H. ewersii* in natural populations within the Big Almaty Gorge and the Kok-Zhailau Tract of the Ile Alatau.

Materials and Methods

2.1 Research objects

Species Studied: *Phedimus hybridus* (L.) 't Hart (formerly *Sedum hybridum* L. and *Aizopsis hybrida* (L.) Grulich) is classified under the genus *Sedum* L., section Aizoon Koch, series Glabrae A. Bor., within the family Crassulaceae DC. *Hylotelephium ewersii*

(Ledeb.) H. Ohba (formerly *Sedum ewersii* Ledeb.) belongs to the section Telephium S.F. Gray, subsection Humilieaulia Praeger L., series Repentes (Praeger) A. Bor. [24–27]. The studies were conducted from 2022 to 2024 in natural phytocenoses within the Ile Alatau ridge, specifically in the Big Almaty Gorge, the Kok-Zhailau Tract, the Kazachka River area, and the Medeu district of the Almaty region (Table 1).

Table 1 – Cenopopulations of the species *P. hybridus* and *H. ewersii* discovered during field studies.

Species, CP number	Geographical distribution	GPS coordinates & elevation
<i>P. hybridus</i> CP 1	Big Almaty Gorge, Kok-Zhailau tract, NW slope	43°00'923" N 75°57' 082" E 1925 m a.s.l.
<i>P. hybridus</i> CP 2	Big Almaty Gorge, Kok-Zhailau tract, NE slope	43°07'750" N 76°57' 220" E 1634 m a.s.l.
<i>P. hybridus</i> CP 3	Big Almaty Gorge, Kok-Zhailau tract, NW slope	43°07'648" N 076°58' 314"E 1869 m a.s.l.
<i>H. ewersii</i> CP 1	v. Alma-Arasan, Big Almaty Gorge, Kok-Zhailau tract, Kazachka river, N slope	43°00'923" N 75°57' 082" E 1925 m a.s.l.
<i>H. ewersii</i> CP 2	Big Almaty Gorge, Kok-Zhailau tract, NE slope	43°07'750" N 76°57' 220" E 1634 m a.s.l.
<i>H. ewersii</i> CP 3	v. Alma-Arasan, Big Almaty Gorge, Kok-Zhailau tract, Kazachka river, NW slope	43°07'648" N 076°58' 314"E 1869 m a.s.l.

Notes: CP – coenopopulations; N – north, W – west; E – east; a.s.l. – above sea level.

2.2 Research methods

The primary methods employed to study the morphological and biological characteristics of *Phedimus hybridus* and *Hylotelephium ewersii* included examining their morphological traits, biological features, taxonomy, and floristics. Conventional geobotanical research methods were used, focusing on the coenopopulations of *P. hybridus* and their interactions with the environment. A comprehensive geobotanical description of these coenopopulations was conducted, with locations recorded using GPS.

Fieldwork involved the route-reconnaissance method, where plants were detected and collected by walking along designated routes. This approach enabled coverage of extensive areas and facilitated the study of species diversity. Population studies were conducted using established methodologies in modern plant population biology [7,9,24–27].

Herbarium material was collected and processed according to standard procedures. Specimens of *P. hybridus* and *H. ewersii* were placed in herbarium folders, labeled with collection location, date, and collector information. Following fieldwork, the material was dried and examined under binocular

magnifiers. Herbarium collection and processing adhered to widely accepted methods [28].

Species identification and taxonomy were performed in the laboratory using multi-volume reference works [8,29–31]. Species and generic classifications for *P. hybridus* and *H. ewersii* in the Ile Alatau were based on the classifications by Cherepanov and Abdulina [32,33]. Life form analysis was conducted according to Serebryakov's classifications [34].

During the field expedition, three coenopopulations of *P. hybridus* and three coenopopulations of *H. ewersii* were identified. The morphological characteristics of both species were studied on living plants and herbarium specimens.

Results and Discussion

3.1 Plants population identification

To determine the natural habitats of *Phedimus hybridus* and *Hylotelephium ewersii* in the Ile Alatau, Big Almaty Gorge, Kok-Zhailau Tract, and Kazachka River, we plotted expedition routes, established flowering periods, and identified their ecological niches. This process included examining

herbarium material from the main herbarium collection at the Institute of Botany and Phytointroduction and reviewing relevant floristic literature. The typi-

cal habitats of *P. hybridus* and *H. ewersii* in these areas are characterized by stony and rubble soils, rock crevices, and the middle forest belt (Fig. 2).



Figure 2 – Populations of *P. hybridus* and *H. ewersii* identified in the Ile Alatau, Big Almaty Gorge, and Kok-Zhailau tract

As a result of the expeditionary surveys, we documented 3 large and 7 smaller populations of *Phe-dimus hybridus* and *Hylotelephium ewersii* in various ecological and phytocenotic conditions. These included outcrops of parent rock, stone ledges, and rocky areas amidst trees and shrubs (Fig. 2).

3.2 Ecological groups of populations

The flora of the studied populations of *P. hybr-idus* and *H. ewersii* in the Big Almaty Gorge, Kok-Zhailau Tract, and Kazachka River areas of the Ile Alatau comprises 146 species across 78 genera and 39 families. Key marker species include *Picea sch-renkiana* L., *Elytrigia repens* (L.) Nevski, *Melilotus officinalis* (L.) Lam., *Melilotus albus* Medikus, *Berteroa incana*, *Poa pratensis* L., *Poa annua* L., *Dactylis glomerata* L., *Trifolium repens* L., *Trifolium pratense* L., *Geranium transversale* (Kar. & Kir.) Vved., *Geranium divaricatum* Ehrh., *Artemis-*

ia vulgaris L., *Arctium lappa* L., *Capsella bursa-pastoris* (L.) Medik., and *Xanthium strumarium* L. The presence of weed species such as *Urtica can-nabina* L., *A. lappa*, and *X. strumarium* indicates considerable anthropogenic pressure on the natural phytocenoses.

Ecological and biological analyses confirm that the mountain flora in the meadow habitats of *P. hybr-idus* and *H. ewersii* is predominantly mesophytic and mesophyto-xerophytic. Key factors limiting the distribution of these species include intense competi-tion within phytocenoses, anthropogenic impacts, and specific ecological requirements. The main eco-logical groups of plants within the *P. hybridus* and *H. ewersii* populations are shown in Fig. 3: meso-phytes – 105 species (71.9%), mesoxerophytes – 30 species (20.5%), and mesohygrophytes – 11 species (7.5%).

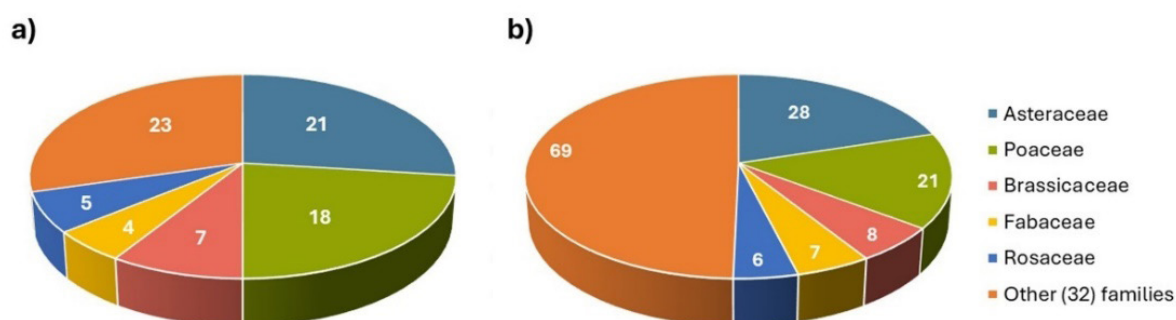


Figure 3 – Leading flora families of *P. hybridus* and *H. ewersii* populations.
a) At the Genus Level; b) At the Species Level

Results indicate that the dominant families within the *Phedimus hybridus* and *Hylotelephium ewersii* populations in the Kok-Zhailau Tract of the Ile Alatau are Asteraceae and Poaceae. These families account for 28 and 21 species, respectively, representing 20.1% and 15.1% of the total flora. Together with Brassicaceae, Fabaceae, and Rosaceae, these five families encompass 70 species out of the 139 identified, making up just over half (50.4%) of the flora in these populations (Fig. 3b). In contrast, the remaining 32 families contribute 69 species, accounting for 49.6%.

The largest families in the flora of *P. hybridus* populations in the Kok-Zhailau Tract include 55 genera (out of 78) and 70 species, representing 50.4% of the total species diversity (Fig. 3a). This dominance of families, characterized by high species richness, reflects patterns typical of the flora in the eastern part of the Ancient Mediterranean but also displays unique features influenced by both ancient Mediterranean and boreal elements.

The floristic diversity of the *P. hybridus* and *H. ewersii* populations in the Kok-Zhailau Tract is closely linked to ecological conditions, particularly climate and regional heterogeneity. The analysis of life forms revealed that herbaceous vegetation, predominantly hemicryptophytes, is the most common, comprising 75–80% of the species. In contrast, shrubs and subshrubs (chamephytes and microphyllphytes) represent a much smaller proportion, accounting for only 0.68–6.85% (Table 2).

The flora of the *Phedimus hybridus* and *Hylotelephium ewersii* populations in the Kok-Zhailau Tract of the Ile Alatau is notably characterized by therophytes, which constitute 18 species, or 12.3% of the total. Overall, the flora is predominantly composed of species typical of mountain meadows and

shrub-forb habitats. As previously noted, the leading life forms in this area are herbaceous perennials and annuals, which exhibit a broad ecological range. In contrast, shrubs are the least represented life form due to their restriction to narrow environmental conditions, and semi-shrubs are also sparse, found primarily in relatively humid habitats. This distribution of life forms in the flora of *P. hybridus* and *H. ewersii* reflects the region's climatic conditions, underscoring its mesophytic and mesoxerophytic characteristics.

Table 2 – Spectrum of dominant life forms found in *P. hybridus* and *H. ewersii* populations.

Life forms	Species	%
Hemicryptophytes	112	76.7
Therophytes	18	12.3
Chamephytes	1	0.68
Microphanerophytes	10	6.85
Phanerophytes	5	3.42
Total	146	100

3.4 Geographical elements of population flora

The geographical analysis of the *Phedimus hybridus* and *Hylotelephium ewersii* populations in the Kok-Zhailau Tract reveals varying degrees of geographical element representation, highlighting the flora's heterogeneity (Table 3). This analysis, as a typological method for studying flora based on the modern distribution ranges of species, illustrates the relationship between the studied flora and neighboring floras. It also sheds light on species migration routes within the region and potential pathways for

flora enrichment. To classify the distribution ranges of the flora species in the Kok-Zhailau Tract, we utilized classification types from previous studies on Central Asian flora [35–39].

The flora within the *P. hybridus* and *H. ewersii* populations in the Kok-Zhailau Tract is highly di-

verse, including species that range from widespread cosmopolitan or pluriregional to narrowly endemic. The study area encompasses 21 habitat types, which were further categorized based on similar characteristics (Table 3). A detailed description of the main habitat groups is provided below.

Table 3 – Geographical connections of plant species found in the population of *P. hybridus* and *H. ewersii* with the flora of other regions.

Geographical element	Herbaceous plants		Tree, shrub, half-shrub	Total	%
	Annual & biennial	Perennial			
Pluriregional	2	9	–	11	7.53
Holarctic	2	19	1	22	15.1
Palaearctic	2	19	3	24	16.4
Eastern Palaearctic	1	5	–	6	4.11
Euro-Ancient Mediterranean	3	8	1	12	8.22
Eastern Mediterranean	–	10	1	11	7.53
Eurasian	1	3	–	4	2.74
Mountain Central Asian	1	11	2	14	9.59
Mountain Central Asian-Iranian	1	7	–	8	5.48
Mountain Central Asian-Himalayan	–	2	1	3	2.05
Mountain Central Asian-Siberian	–	1	–	1	0.68
Altai-Mountain Central Asian	–	8	2	10	6.85
Tarbagatay-Mountain Central Asian	–	2	–	2	1.37
Tien Shan	2	3	4	9	6.16
Siberian-Tien Shan	–	1	–	1	0.68
Altay-Tien Shan	–	2	–	2	1.37
Tien Shan-Pamir-Alai	–	1	–	1	0.68
Northern Tien Shan	–	1	–	1	0.68
Dzungarian Northern Tien Shan	1	1	–	2	1.37
Dzungarian Tien Shan	1	–	–	1	0.68
Tarbagatay-Tien Shan	–	1	–	1	0.68
Total	17	114	15	146	100

Pluriregional: This group comprises 11 species distributed across various regions in both the Northern and Southern Hemispheres. It primarily includes weed and ruderal species, such as *Capsella bursa-pastoris*, *Convolvulus arvensis*, and *Chenopodium album*.

Holarctic: This group includes 22 species found mainly in the temperate and high-latitude regions of the Northern Hemisphere. Notable species include *Poa pratensis*, *Eragrostis pilosa*, and *Erigeron lonchophyllus*, along with weed and ruderal species like *Thlaspi arvense*.

Palaearctic: This group consists of 24 species common in Europe and the temperate and high-latitude regions of Asia. These are predominantly mesophilic species thriving in humid environments, mainly meadows. Key species include *Elytrigia repens*, and weeds such as *Plantago major* and *Artemisia annua*.

East Palaearctic: This group includes 6 species with ranges extending across Kazakhstan, Siberia, the Far East, and Central Asia.

European-Ancient Mediterranean: This group unites 12 species (e.g., *Plantago lanceolata*,

Bromus scoparius, and *Achillea millefolium*) predominantly distributed in arid regions, including the Central Asian, Sahara-Sindian, and Irano-Turanian subregions.

Eastern-Ancient Mediterranean: Species in this group have ranges extending from Palestine, Syria, and southern Bulgaria to the Western Himalayas and Tien Shan. This group includes 11 species.

Mountain-Central Asian: This group encompasses species ranging from the Pamir-Alay to Tarbagatay, with notable examples like *Artemisia vulgaris*. A total of 14 species are included.

Mountain-Central Asian-Siberian: This group consists of species distributed in the mountainous regions of Central Asia and Siberia, typically found on rocky slopes, screes, and cliffs.

Altai-Mountain-Central Asian: This group includes 10 species distributed in the mountainous regions of Central Asia and the Altai, with some extending into the Mongolian Altai.

Mountain-Central Asian-Himalayan: Species in this category are found in the mountain systems of the Pamirs, Pamir-Altay, Tien Shan, Hindu Kush, and Himalayas. Examples include *Spiraea lasiocarpa* and *Rosa nanothamnus*. This group includes only 3 species.

Mountain-Central Asian-Iranian: This group includes 9 species with ranges covering the Iranian Plateau and the mountain systems of the Pamir-Alay, Tien Shan, and occasionally Tarbagatay.

Tien Shan-Pamir-Alai: Species in this group are found in the mountain systems of the Pamir-Alai and Tien Shan, with some extending into Tarbagatay. This group includes 1 species.

Tien Shan: Species in this group are confined to the Tien Shan mountain systems, occasionally extending to the Alai Range in the west and the Tarbagatay Range in the north. This group includes 9 species.

The analysis revealed varying levels of representation of these geographic elements within the flora of the *P. hybridus* and *H. ewersii* populations in the Kok-Zhailau Tract of the Ile Alatau, highlighting the flora's heterogeneity (Table 3).

3.5 Plants with economical or industrial importance

Wild useful plants are employed in their natural state and serve as raw materials for various sectors of the national economy and medicine. With growing demand, there is an increasing need for their rational use and for expanding the volume of harvesting. Consequently, research has focused on evaluating the beneficial properties of

these wild plant species and assessing the available resources.

The flora of the *P. hybridus* and *H. ewersii* populations in the Kok-Zhailau Tract of the Ile Alatau encompasses a diverse range of useful plants. These include species with medicinal, food, essential oil, tanning, honey, vitamin, dye, ornamental, fodder, and fatty oil properties (Table 4). The vegetation of the Ile Alatau Ridge provides a vital forage base for livestock farming, featuring some of the region's richest pastures and hayfields. This herbaceous layer includes numerous well-known medicinal plants, such as *Origanum vulgare* and *Hypericum perforatum*.

Table 4 – Plant groups with economic & industrial importance within the *P. hybridus* and *H. ewersii* populations.

Plant group	Species	%
Weed	35	10.5
Forage	103	31.0
Medicinal	37	11.1
Poisonous	7	2.11
Melliferous	49	14.8
Food (edible)	28	8.43
Essential oils	10	3.01
Ornamental	25	7.53
Dye	12	3.61
Industrial	22	6.63
Vitamin-bearing	4	1.20
Total	332	

The flora of the *P. hybridus* and *H. ewersii* populations in the Kok-Zhailau Tract of the Ile Alatau presents significant opportunities for the development of medicinal, alkaloid-bearing, essential oil, tannin-bearing, and honey plants. Although beekeeping currently plays a modest role in the region's economy, the area's favorable natural conditions offer considerable potential for its expansion. The flora in this region is both diverse and rich in economically valuable or promising species. The variety of herbaceous and shrub species in the Kok-Zhailau Tract contributes to the abundance of economically useful plants. According to classifications by Ilyin [40] and Pavlov [41], the plant resources and floristic diversity of the area support the identification of 11 economically valuable plant groups (Table 4).

The largest group within the flora of these populations is forage plants, comprising 103 species

(31.0%). Cattle breeding in the Ile Alatau Ridge relies heavily on year-round natural forage lands. This group is dominated by cereals, legumes, sedges, and composites, with legumes such as *Medicago falcata*, *Trifolium pratense*, *Vicia cracca*, *V. tenuifolia*, *Lathyrus pratensis*, *Trigonella cancellata*, *T. arcuata*, and *T. orthoceras* being particularly valuable. Many forb species, such as *Ajania fastigiata*, *Geranium saxatile*, and several *Asteraceae* species (*Taraxacum*, *Tragopogon*), are also readily consumed by cattle and sheep. The distribution of other plant groups is as follows: weeds – 35 species (10.5%); food plants – 28 species (8.43%); medicinal plants – 37 species (11.1%); melliferous plants – 49 species (14.8%); essential oil plants – 10 species (3.01%); ornamental plants – 25 species (7.53%); dye plants – 12 species (3.61%); vitamin-bearing plants – 4 species (1.20%); and technical plants (including rubber-bearing, resin-bearing, gum-bearing, paper, wicker, etc.) – 22 species (6.63%).

The cereal family in the flora of these populations includes 18 genera and 21 species, most of which contribute to the formation of forage mass. Notably, species such as *Elytrigia repens*, *Phleum phleoides*, and *Dactylis glomerata* play a critical role in shaping low-mountain meadows, essential for grass formation.

Food and vitamin-rich plants are predominantly found in the Rosaceae family, which includes fruit and berry crops high in vitamins. Rose hips are particularly valuable, offering natural multivitamin concentrates with high biological activity. For instance, *Rosa alberti* Regel is noted for its high vitamin content. The fruit pulp contains up to 20% vitamin C, as well as vitamins B2, B1, E, and K. These fruits are used to produce medicinal drinks, infusions, decoctions, extracts, and syrups, and are also utilized in the food, confectionery, and cosmetics industries. Rosehip seeds can be processed into oil comparable in quality to sea buckthorn oil.

The region also supports various industrial plants, categorized into ornamental wood plants (7 species), wicker plants (5 species), and fiber-spinning plants (4 species). Additionally, the area includes plants used for tanning, dyeing, essential oil production, and other technical purposes. Essential oils, which are volatile compounds with strong odors, are extracted from various plant parts through distillation with water vapor. Essential oil plants in the region include species from the Umbelliferae family (19 species), such as *Daucus carota*, *Carum carvi*, and *Aegopodium alpestre*; from the Composi-

tae family (5 species), including *Conyza canadensis*, *Achillea millefolium*, *Arctium tomentosum*, *Artemisia vulgaris*, and *A. absinthium*; and from the Labiatae family (6 species), such as *Origanum vulgare*, *Ziziphora clinopodioides*, and *Z. tenuior*.

Conclusion

This study provides a comprehensive analysis of the populations of *Phedimus hybridus* (L.) ‘t Hart and *Hylotelephium ewersii* (Ledeb.) H. Ohba in the Kok-Zhailau Gorge of the Ile Alatau. Through detailed examination of their biological and ecological characteristics, we have highlighted the significant adaptive abilities and ecological plasticity of these species. *Phedimus hybridus*, with its notable therapeutic properties, and *Hylotelephium ewersii*, primarily valued for its ornamental appeal, both exhibit robust survival strategies and high reproductive rates in their natural habitats.

The research underscores the diverse and rich flora of the Kok-Zhailau Tract, which includes a wide array of economically valuable and promising plant species. This flora supports various sectors, including medicine, agriculture, and industry. The findings indicate that the Kok-Zhailau region’s plant communities are characterized by their adaptability to different ecological conditions, with notable potential for further development in medicinal, ornamental, and economic applications.

Our study identifies key ecological and geographical patterns within the plant populations, revealing a complex interaction between species and their environments. The results highlight the importance of preserving these diverse plant communities, as they contribute significantly to both local biodiversity and economic resources.

Overall, this research contributes valuable insights into the ecological dynamics and economic potential of the plant species in the Kok-Zhailau Tract, providing a foundation for future studies and sustainable management practices.

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