



Methodological Guide for Geobotanical Research on Rare, Endemic, and Medicinal Plants: A Case Study of the Ranunculaceae Family

Alibek Ydyrys,^{1,2} Nashtay Mukhitdinov,¹ Anna Ivashchenko,³ Zhadyra Ashirova,¹ Muratzhan Massimzhan,^{1,2} Elmira Imanova,⁴ Meruyert Parmanbekova,⁴ Murat Toktar,^{5,6} Birlikbay Yeszhanov,¹ Marzhanay Ilesbek,^{1,2} Gulnaz Askerbay^{1,2,*} and Raushan Kaparbay^{1,2,*}

Abstract

Comprehensive studies of plant communities are essential for preserving rare and valuable species that are diminishing in number. Currently, there is an increasing demand for robust methodologies to conduct population-level research in geobotany, ecological monitoring, and forestry. This article focuses on the rare plant species *Hepatica falconeri*, *Ranunculus polyanthemus* L., *Ranunculus oxyspermus*, and *Ranunculus dilatatus*, which belong to the Ranunculaceae family and are found in the Tien Shan Mountains of Kazakhstan, based on geobotanical research findings. We present a manual that integrates both traditional and modern techniques for studying environmental factors, biotopes, ectopes, phytocenoses, floral composition, and the condition of natural populations of endemic and medicinal plants. This includes methodologies for assessing the biomass reserves of rare, endemic, and medicinal species, as well as evaluating the state of juvenile plants, population density, and the anatomical, morphological, phytochemical, and molecular genetic characteristics of the studied taxa. These parameters are influenced by geographical variations, microclimatic conditions, and soil properties. This article serves as a comprehensive guide for researchers in the fields of geobotany, biodiversity, botany, biology, agriculture, and medicinal plant studies. Additionally, it provides actionable recommendations for developing effective strategies for the conservation, protection, and sustainable utilization of biodiversity.

Keywords: Geobotany; Ecological monitoring; Forestry; Phytocenoses; Floral composition; Soil properties; Microclimatic conditions; Population density; Biodiversity

Received: 26 October 2024; Revised: 25 November 2024; Accepted: 03 December 2024.

Article type: Research article.

1. Introduction

Rare, endemic, and medicinal plants play a vital role in biodiversity and ecosystem balance, but they are often at risk due to habitat destruction, climate change, and overharvesting. To protect these plants, it is essential to understand their population, distribution, and environmental factors such as microclimate, soil properties, floral composition, and

ecological interactions.^[1]

The study of rare, endemic, and medicinal plants is crucial for understanding biodiversity, ecological balance, and the potential therapeutic benefits of flora. These plants often play a significant role in maintaining ecosystem stability and supporting the health of various species, including humans. However, due to their limited distribution and specialized habitat requirements, they are particularly vulnerable to environmental changes and human activities. To ensure their conservation and sustainable use, it is essential to develop accurate methods for determining their population size, distribution patterns, and the ecological factors influencing their survival.^[2-3] Scientific approaches such as remote sensing, ecological niche modeling, and population viability analysis have proven effective in studying these plants. For instance, remote sensing techniques enable researchers to monitor large

¹ Faculty of biology and biotechnology, Al-Farabi Kazakh National University, Almaty, 050040, Kazakhstan

² Biomedical Research Centre, Al-Farabi Kazakh National University, Al-Farabi ave. 71, 050040, Kazakhstan

³ Department of Entomology, Institute of Zoology, al-Farabi Ave. 93, Almaty, 050060, Kazakhstan

⁴ NPJSC, Kazakh Women's Teacher Training University, A05C9Y7, st. Gogol, 114 k1, Almaty, 050013, Kazakhstan

areas and detect changes in plant populations over time, while niche modeling helps predict the distribution of species under various environmental conditions. Additionally, assessing ecological factors such as soil composition, climate, and symbiotic relationships with other organisms allows scientists to gain insights into the specific requirements of these plants.^[4] By integrating these methodologies, researchers can propose effective conservation strategies to protect rare, endemic, and medicinal plants, ensuring their survival in the face of environmental pressures and growing demand for natural resources.^[5]

Geobotanical surveys were conducted in three stages: preparatory, field, and office.^[6] During the preparatory phase, we gathered available archival, literary, and cartographic materials to assess the current understanding of the natural conditions in the study area.^[7]

In the field phase, geobotanical surveys were performed at a scale of 1:50,000 using a route method with a 1 km interval between route turns. Vegetation mapping was conducted, and geobotanical contours were overlaid on a topographic base. Plant communities were described and classified into specific types of forage land, defined as areas (hayfields or pastures) with similar species composition, structure, and dynamic properties linked to particular habitat conditions such as relief and soil types. Vegetation altered by human activity was categorized as modified types of forage land.^[8]

The geobotanical description form included details such as the community name, relief, soil types, moisture conditions, percentage of ground cover by plants, height, phenophase, and plant vitality. Contours were drawn to encompass areas with homogeneous vegetation, typically representing one type of forage land, though multiple types were often included when they could not be distinctly separated at this scale.^[9,10]

Simultaneously, we assessed the yield of forage lands by mowing four 1 m² plots. Herbaceous plants were cut at a height of 1-3 cm, tall grasses at 4-6 cm, and the current year's growth was trimmed or broken off from subshrubs.

For instance, given that *Hepatica falconeri* (*H. falconeri*) is a rare and poorly understood species, we focused particularly on studying its morphological characteristics. To achieve this, we measured both generative and vegetative traits, collecting data from 50-100 specimens at each site. We established a 10-meter transect to assess the juvenile status of plants within each 1 m² plot, as well as to determine the frequency of occurrence of the species. Additionally, we gathered data on the morphological variability of flowers and

fruits, again sampling 50-100 specimens at each location.^[11]

To determine the yield of shrub pastures, we employed the model bush method. On a 100 m² transect, all specimens of the target species were counted. Then, the current year's growth was pruned from the most typical (model) bushes, and the air-dry mass was measured. The yield of the bushes was subsequently calculated based on the number of specimens.^[12-14]

When assessing yield, both the gross mass (including inedible plants) and the forage mass (consumed by at least one type of livestock) were recorded in centners per hectare of dry mass. We also calculated the shrinkage coefficient to convert dry mass into wet mass. For this purpose, once a decade, cut plants were sorted by species or groups and weighed in their raw form.^[15-18]

To determine the yield in dry weight, the cut plants were dried to a brittle state before weighing. All data on the yield of individual plants and their groups in both wet and dry weight were documented in vegetation description forms, with yields calculated in centners per hectare.^[19-21]

A working contour sheet recorded all geobotanical contours identified and plotted on the map, and a diary was maintained throughout the survey. When identifying the floristic composition of the area, plant species with uncertain names were collected for the herbarium to clarify during the office processing period.

The office phase of processing the field geobotanical survey materials involved several key tasks:

- Analyzing materials on floristic composition
- Compiling a final typological list and creating a legend
- Calculating pasture yields and areas
- Estimating forage reserves
- Preparing a contour sheet for the map of natural forage lands
- Assessing pasture quality based on productivity and nutritional value
- Creating a geobotanical map of natural forage lands
- Compiling a cartogram of the cultural and technical condition with recommendations for the rational use of natural forage lands
- Writing a comprehensive report

The map and cartogram maintained the topographic base and boundaries of the contours highlighted on the field map, with contour colors representing the prevailing vegetation. The typological composition of the contours was indicated in a formula format, where the numerator displayed the serial number of the type (or subtype/modification) according to the legend, along with the percentage of the occupied area, while the denominator showed the contour number and the yield of forage lands for the recommended season of use.^[22]

The cartogram illustrated the recommended seasonality of pasture use through color coding, with black and red icons indicating the degree of manifestation of various types of cultural and technical conditions, along with recommendations for rational usage. In the contours of the

⁵ Department of Mine Surveying and Geodesy, Institute Mining and Metallurgical Institute named after O.A. Baikonurov, Satbayev University, Almaty, 050013, Kazakhstan

⁶ Department of Soil Ecology, Kazakh Research Institute of Soil Science and Agrochemistry named after U.U. Usmanov, Al-Farabi Ave. 75, Almaty, 050060, Kazakhstan

*Email: askerbaygulnaz1@gmail.com (G. Askerbay), raushan.kaparbay@mail.ru (R. Kaparbay)

cartogram, the numerator of the fraction indicated the contour area and the calculated forage reserve of dry matter, while the denominator represented the contour number.^[23,24]

2. Materials and methods

The following scientific databases were searched: PubMed, Scopus, Web of Science, ScienceDirect, Google Scholar, Springer, and Wiley using the following MeSH terms: "geobotanical research," "ecological monitoring," "forestry," "environmental factors," "biotopes," "ectopes," "population density," "characteristics/ anatomical, morphological, phytochemical, and molecular genetics," "endemic," "medicinal plants," "microclimatic conditions," "soil properties," and "biodiversity", "Field Survey Methods", "Geographic Information Systems (GIS)" and "population and distribution".

Inclusion requirements: (i) Relevant work on modern research and traditional uses, proposing methods for determining the population, distribution, and ecological factors of rare, endemic, and medicinal plants; (ii) Research addressing abiotic, biotic, and anthropogenic factors, along with their potential mechanisms of influence on plants; (iii) English, Kazakh, Russian -language papers. Exclusion criteria include (i) duplicate and incomplete information, (ii) abstracts, (iii) letters to the editor, and (iv) experiments employing linked homeopathic medications. The plant's chemical components were discovered, and Chem Spider and PubChem were used to confirm their IUPAC (International Union of Pure and Applied Chemistry.) designations, structural formulas, and chemical formulas. According to WFO (World Flora Online), the plant's taxonomy has been verified.

The purpose of the present study is to provide thorough methodological guidance for performing geobotanical research on uncommon, endemic, and medicinal plants, with a particular emphasis on the Ranunculaceae family. It intends to provide researchers with a systematic strategy to examine the distribution, population dynamics, and ecological factors that influence these plants, as well as their traditional and modern applications. The purpose of this article is to highlight major research methodologies for understanding the abiotic, biotic, and anthropogenic elements that influence plant species, with the ultimate goal of contributing to the conservation and sustainable management of these rich plant resources.

3. History of geobotanical research

Geobotany (from the Greek geo-earth and botanicals related to plants) is the science of the composition, structure, productivity, use, and change of plants and their communities on the earth's surface. The main goal of this subject is to study the structure of plant communities and their changes in space over a certain period of time under the influence of factors related to nature and human activities. The term "geobotany" was introduced to science in 1866 by the unrelated F. N. Ruprecht (Russia) and A. Introduced by Griesebach (Germany). F. N.^[25,26] According to Ruprecht, geobotany is the

science of the relationship of plant cover with the physical geographical environment, first of all with the soil. In the 1st half of the 20th century, there were views that considered geobotany and phytocenology from the point of view of synonyms (Alekhin, Shennikov),^[27] or that geobotany should be understood as a discipline consisting of the union of botanical geography and phytocenology (Sukachev, Sochava).^[28] Phytocenology as a science was formed in the USSR, mainly in the first 30 years of the 20th century. In the USSR, there were two centers that laid the foundation for the main concepts of phytocenology. Leningrad (Botany Institute and Leningrad University scientific supervisors academician V. N. Sukachev and professor A. P. Shennikov) and Moscow University (scientific supervisor V. V. Alekhin).^[29]

V. N. Sukachev (1935) explains phytocenosis as a set of plants interacting with each other and with the environment (soil, air, light, temperature, etc. surrounding the organism). Therefore, according to Sukachev, the main features of phytocenoses are the interaction of plants with each other and the presence of interaction between plants and the environment.^[30]

B. A. Bykov (1978) gives the following definition of phytocenosis: "Phytocenosis is a stable, self-regulating form of coexistence of organisms in the environment created by them." In short, it is a form of permanent coexistence of organisms.^[31]

B. M. According to Mirkin (1986), phytocenosis is a set of populations of autotrophic plants due to the similarity of their relationship to the environment.^[32]

4. Population and distribution analysis

The study of the spatial structure of plants and their supraorganismal systems (populations and phytocenoses) represents a complex and important area of ecology, grounded in biological, ecological, and mathematical methods. Central to this study is the examination of morphogenesis and ontogenesis across different life forms of plants.^[33]

The spatial structure of populations refers to the distribution of individual specimens and their groups in space. Typically, individuals within a species' range and within separate populations are distributed unevenly. This distribution is influenced by external environmental conditions and the biological characteristics of the species and individuals in the population, particularly regarding reproductive strategies and vegetative mobility. While the spatial structure of populations in different habitats may vary, the inherent traits of the biomorph will shape the general patterns of distribution, leading to individuals growing in clusters sparsely or forming more complex structures.^[34-36]

The age structure is also crucial for understanding the spatial dynamics of a population. Each individual undergoes a specific sequence of ontogenetic stages characterized by unique features. As individuals mature, attributes such as size, number of metameres or shoots (both aboveground and underground), phytogenic field size, potential root nutrition

area, and crown diameter (in trees) increase. The efficiency of resource utilization and environmental adaptation improves, and in some cases, the life state or even the type of biomorph may change. For instance, many plant species can form clones or turfs or develop partial bushes as they reach adulthood, thereby altering their competitive potential.^[37,38]

Investigating the spatial structure of a coenopopulation reveals mechanisms behind changes in population density and age composition over time, as well as the interactions among species within a cenosis and at the boundaries of different phytocenoses. Additionally, analyzing the spatial-age structure provides insights into the relationships among individuals of different ontogenetic groups within a population.^[38]

The spatial structure is examined from two perspectives: functional and geometric. The functional aspect encompasses resource utilization and the effects of various environmental elements on the population. In contrast, the geometric aspect pertains to the spatial arrangement of individual elements within the coenopopulation, taking into account both vertical and horizontal placement, as well as the size and age (or ontogenetic state) of the individuals.^[39-42]

Cenopopulation (Greek koinos - general and population) is a set of individuals of one species within phytocenoses. Rabotnov (1945, 1950) introduced this concept to science. However, the term "cenopopulation" was introduced later

(Petrovsky, 1961). A comprehensive study of the population composition of plant communities is the key to knowing its current condition, history, and development trends.^[44] Phytocenoses contain a large number of individuals of each type of plant. They are distinguished from each other by age, living conditions and location features. Individuals of the population are located differently in the phytocenosis (Fig. 1). As for accounting units in the study sites, researchers may select either whole individuals (morphological accounting units), particularly when generative plants are clearly delineated, or isolated shoots and partial bushes (phytocenotic accounting units) of vegetative origin. In population studies, the following morphometric parameters are commonly assessed: plant height, number of leaves (flowers, fruits, inflorescences, lateral branches), leaf area (of individual leaves), stem diameter, and total phytomass of the plant or specific organs (leaves, stems, roots). Additional factors may include growth rate, leaf surface formation rate, and duration of leaf formation.

Analyzing these morphometric parameters allows for the establishment of age states in *H. falconeri* plants (see Fig. 1) and facilitates the identification of specific characteristics within a given cenopopulation.^[43]

These data indicate that cenopopulation 1 was characterized by a higher density of trees of each age state, which may indicate favorable environmental conditions for

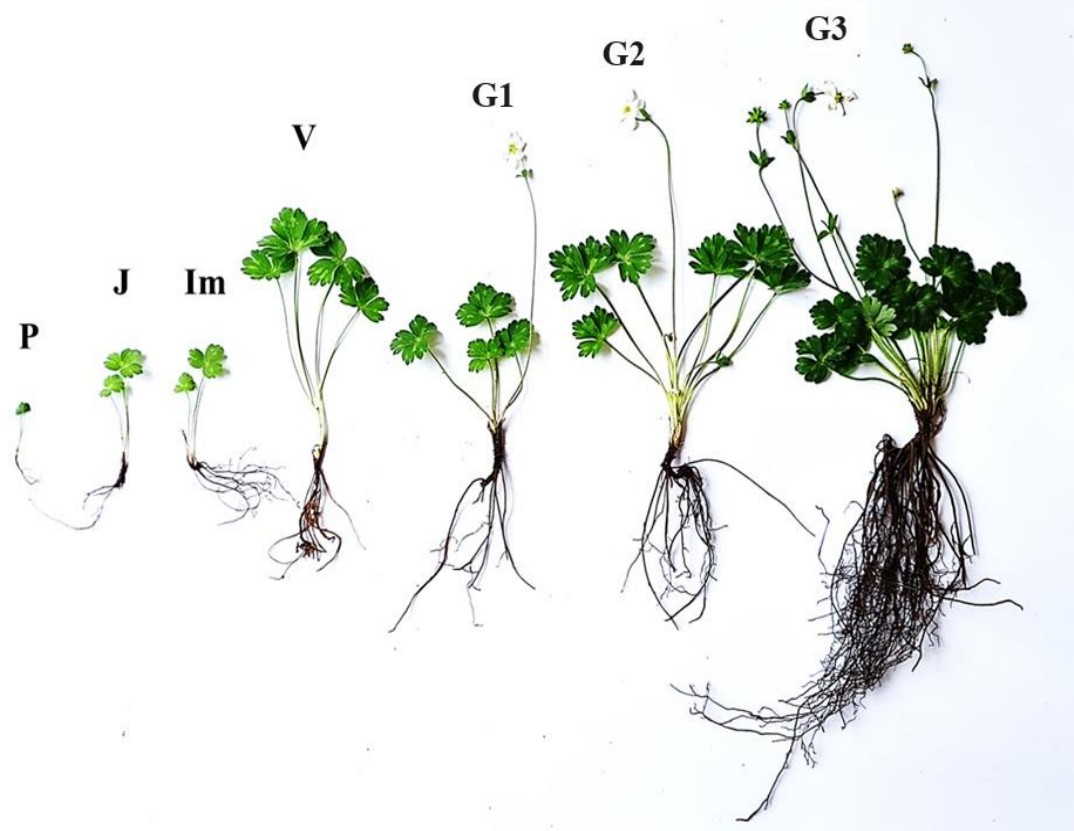


Fig. 1 Periodization of ontogenesis of flowering plants *H. falconeri* qualitative features of age states. A. A. Uranov scheme was used to distinguish youth states: P - sprouts; J - juvenile trees; Im - immature; V - virginal and young vegetative; G1 - young generative; G2 - medium or mature generative; G3 - aged generative.

Table 1. Average density of individuals and range of variation of *H. falconeri* by age groups.

Name	Age groups	Juvenile (j)	Immature (i)	Virginal (v)	Generative (g)
Cenopopulation 1	The average density of ind.	4,5	4,2	4,5	3,6
	Limits of oscillation	(2-7)	(2-6)	(2-7)	(3-5)
Cenopopulation 2	The average density of ind.	3,6	2,6	2,9	1,7
	Limits of oscillation	(0-5)	(0-4)	(0-5)	(0-4)

the stable development of the population. In contrast, cenopopulation 2 exhibits a lower density of trees and a wider range of fluctuations, which may be due to less favorable environmental conditions for growth, for example, a limited area of rocky areas, lack of light, etc. Taking into account the density and age spectrum of cenopopulations is important for monitoring the state of *H. falconeri* populations. This allows us to identify the main environmental factors affecting the dynamics and stability of populations, as well as to develop measures for their protection in conditions of limited habitat. The age structure was studied in two coenopopulations located nearby but in different ecological communities. The first coenopopulation is situated on the left bank of the Taldy River, in a spruce forest on a rubble slope, within a forb-shrub community. The second coenopopulation is found on the right bank of the Taldy River, on a vertical cliff covered with green mosses, with higher plants represented by two species of bladder fern and hepatica. In the vicinity of the cliff, there are isolated trees and shrub thickets. The second coenopopulation, which is small and isolated, exists only on the cliff. Both coenopopulations are healthy and fully represented by all age groups. The average density of cenopopulation 1 is 16.9 (ranging from 12 to 23), with 100% occurrence, while cenopopulation 2 has a density of 10.8 (ranging from 0 to 17) and 80% occurrence. In the age composition of cenopopulation 2, the proportion of juvenile individuals is high (33.3%), while the proportion of generative individuals is minimal (15.7%). In contrast, in cenopopulation 1, the majority of individuals are virginal (26.9%), and the proportion of generative individuals is also minimal (21.5%). Now, as shown above in Table 1, let's give a brief description of the living conditions of plants depending on their age:

1. Sm - a group of independent organisms in the initial state of rest;
2. Pl - assimilation of the first leaves and mixed nutrition due to substances in seeds; has a morphological connection with the seed; preservation of the fetal structure; cotyledon, first cotyledon shoot, root;
3. I - the body structure is simple, signs and properties corresponding to adult-independent organisms are not formed: the forms and arrangement of leaves are different from those of adult plants, and growth branching is different. A shoot is kept in the cotyledon. The contact with the seed is broken and the seed coat is destroyed;
4. Im - the presence of signs and properties corresponding to

the transitional period between the juvenile period and the adult period; development of leaves, shoots, and roots corresponding to semi-adult plants;

5. V - priority of leaves, shoots, and roots corresponding to adult plants;
6. G1- further development of structures related to adult plants; emergence of generative shoots, growth and formation processes in the root and shoot systems increase, there are no signs of wilting or only the first signs;
7. G2 - permanent emergence of a life form: high development of shoot and root systems due to the high productivity of the growth process; the emergence of generative shoots at the highest level, the balance of the processes of new formation and withering;
8. G3 - simplification of life forms: sudden reduction of generative shoots; deterioration of growth and formation processes in shoot and root systems; priority of the process of withering over the process of new formation;
9. Ss - further simplification of the life form: absence of generative shoots, increased branching ability, immature shoots appear again from enlarged buds; overriding the process of withering over the process of new formation;
10. S - simplification of the life form until it reaches the limit: withered and dead parts of plants are collected, in independent organisms leaves appear in their juvenile state; the ability to form new buds is lost.
11. Sc - no living shoots; dead parts of the plant prevail, very rarely swollen buds are found.

Polycarpic plants can be divided into the above life states. Monocarpic plants have only one age-related state during the generative period, and the postgenerative period does not even exist.

Additional biometric indicators, for example, biomorphological, anatomical, ecological and physiological characteristics, which provide quantitative description, can be used to describe the life states of plants depending on their age. For each coenopopulation of shrubs and herbaceous plants, we calculated four types of Ripley functions: a) based on the spatial distribution of individuals in the pregenerative state; b) based on the spatial distribution of individuals in the generative state; c) based on the spatial distribution of all individuals, without differentiating by age groups; and d) the cross-Ripley function, which examines the relative positions of pregenerative and generative individuals. This analysis encompassed coenopopulations growing in various

phytocenoses, different climatic conditions, and areas with distinct management practices and levels of anthropogenic impact. We conducted the most thorough analysis for species that primarily reproduce by seeds (tuber-forming) and certain tussock and short-rhizome species, where the size of an individual (genet) can be precisely determined. Further study is needed to determine the spatial distribution of long-rhizome and vegetatively mobile grass species.^[45]

Our research revealed several general patterns. The distribution of individuals in a coenopopulation by age states is termed the age spectrum or spectrum of age states. This spectrum can be represented as absolute numbers or percentages of the total population and illustrated through tables and histograms. Based on the ratio of age groups, we classify coenopopulations as invasive, normal, or regressive.^[46] An invasive coenopopulation primarily consists of young (virginile) individuals and cannot sustain itself without external introductions. Its age spectrum histogram exhibits left-sided asymmetry. In contrast, normal coenopopulations, capable of self-sustaining through seed and/or vegetative reproduction, include individuals across all age states (a normal complete coenopopulation) or may lack individuals from specific age states (a normal incomplete coenopopulation). Incompleteness may result from external factors or the biological characteristics of the species. A regressive coenopopulation shows a higher proportion of subsenile and senile plants, with almost no virginile individuals, indicating an inability to sustain itself. Over time, these coenopopulations may completely disappear from the community, and their age spectrum histogram typically exhibits right-sided asymmetry.^[47-50]

Stress factors, such as atmospheric industrial pollution, can significantly impact coenopopulations, resulting in incomplete or right-skewed age spectra.^[51]

Analyzing the number of individuals in various age states allows us to calculate the age index (coefficient) of the coenopopulation using equation (1).

$$\Delta I_{603} = \frac{\sum k_i m_i}{M} \quad (1)$$

where M is the total population size, m_i is the size of a specific age group, and K_i is the age coefficient for that age group. The age index ranges from 0 to 1, with higher values indicating an older coenopopulation.

In addition to age status, each individual can also be assigned a calendar (or absolute) age, defined as the time elapsed from its emergence to the observation moment, which is most applicable to woody plants. The distribution of individuals by calendar age is known as the age structure, which, like the age spectrum, can be expressed in absolute numbers or percentages and presented in tables, histograms, or graphs.^[52]

5. Field surveys and sampling

Field surveys are one of the most effective ways to determine the population size and distribution of rare and endemic plants.

By collecting data directly from the natural environment, researchers can assess the abundance and spread of these species across their habitats. Two common methods for field surveys include quadrat sampling and transect surveys.

- (1) **Quadrat sampling:** In this method, the study area is divided into smaller, equal-sized grids called quadrats. A random selection of these quadrats is sampled, and researchers count the number of individuals of the target species within each quadrat. This provides information on population density, which can then be extrapolated to estimate the total population size across the entire area. Quadrat sampling helps reveal the distribution of species, especially if they are clumped, evenly spread, or randomly distributed.^[53]
- (2) **Transect surveys:** This technique involves establishing a straight line, or transect, across the habitat of interest. Researchers walk along this line and record the presence and abundance of the target species at regular intervals. This approach is particularly useful for studying species distribution across environmental gradients, such as altitude or soil type. Transect surveys can highlight patterns in species occurrence and provide insights into how environmental factors influence distribution.^[54]

Both methods contribute valuable data on population density, species frequency, and distribution patterns. These are critical for understanding the ecological requirements of rare and endemic plants, identifying areas of conservation importance, and guiding management strategies to protect and restore plant populations. In the field study, it is essential to describe the area where the plants are located. For instance, we present the research findings on *H. falconeri* (Thomson) Steward, a rare and poorly studied species from the Zhetysu-Himalayan range, which belongs to the Ranunculaceae family.^[55-57]

Based on contemporary phylogenetic and taxonomic research, we determined the systematic position of this species. Our study also enriched the ecological description of *H. falconeri*. Contrary to many literary sources that suggest this species is exclusive to the subalpine zone, we found that it extends to the lower boundary of the forest zone at 1,690 m. This finding allows us to classify it into two ecological-cenotic groups: forest and petro-lithophile.^[58]

H. falconeri primarily grows on various steep and exposed rock slopes, with a distribution predominantly on eastern and northeastern slopes. It was rarely found on northwestern and southeastern slopes and is infrequently observed on southern slopes (Goloskokov, herbarium). This species favors rocky and stony substrates, sometimes growing beneath fir trees, but is very rarely found on grassy slopes (Fig. S1).^[59]

During a detailed survey of the "Kulsay Lakes" MTP through route reconnaissance, we identified the largest population of *H. falconeri* in the Taldy River valley, along with six isolated sites. The research utilized available maps and a GPS navigator (GPS ETREX 20, Garmin). All identified growth points were marked and studied in detail, with geobotanical test sites established according to standard

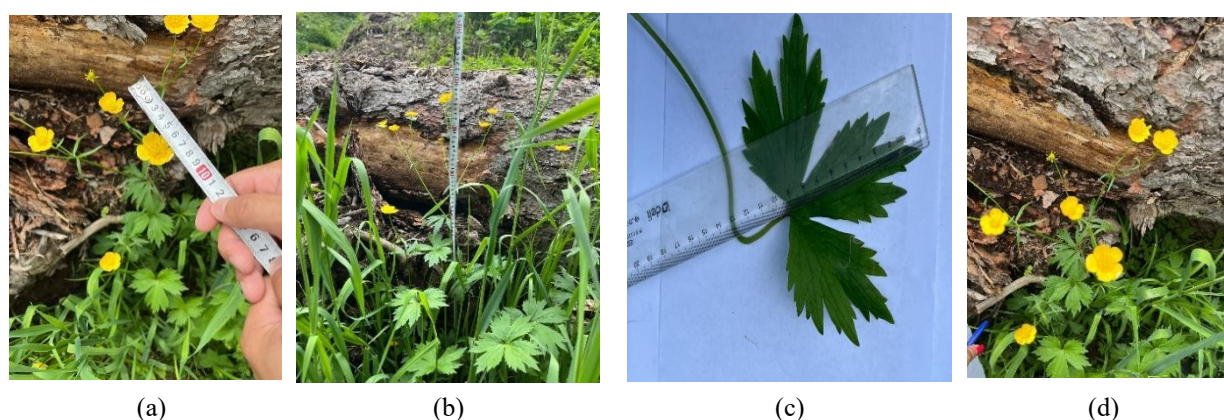


Fig. 2 Morphological features of the *R. polyanthemus* L: a. flower, b. Plant height, c. leaf, d. Morphological appearance.

methodology.^[60]

Turning our attention to the habitat of plants in the Ranunculaceae family, we describe it as follows:

R. polyanthemus reaches heights of 30-80 cm, characterized by a thin, strap-like fringed rhizome and a short, weak mature rhizome. The stem is erect, branched, and multi-flowered, with flowers measuring 2-3 cm in diameter and exhibiting a golden-yellow color (Fig. 2). This perennial plant thrives in dry meadows, steppe depressions, riverbanks, lakeshores, wet groundwater areas, pine forests, thicket forest edges, and roadside habitats, often found in transitions from plains to the forest belt of mountains.^[61-63]

Distribution: The species is found across various regions, including the Ustyrt, Tobyl-Esil, near the Caspian Sea, Betpakdala, Ulytau, Teriskey Alatau, Eastern small hills, Karkara, Altai, Tarbagatai, Zhetysu Alatau, Kungei Ile Alatau, and Western Tien-Shan. It is important to note that this plant is poisonous.^[64]

The agricultural territory is divided into two geomorphological zones: intermountain valleys and mountainous regions, with 80% of the agricultural land being mountainous. To the south lies the Teriskey Alatau ridge, a medium-sized mountain range with altitudes between 1,800 and 2,600 m. The Laily and Jabar mountains are situated to the north, where the steep terrain is prominent. In the lower parts of these middle mountains, uvalisto-valley terrain leads directly to the valleys.^[65]

The Tekes Valley, which encompasses the main section and the northern part of the Karai section, is a wide, high-mountain plain bordered by the Teriskey Alatau ridge to the south and the Zhabyr mountain range to the north. The elevation of the Tekes Valley ranges from 1,800 to 1,900 m. This valley features relatively well-developed land cover, with a smooth, undulating, closed-basin terrain, primarily consisting of arable land.^[66]

Most species in the *Ranunculus* genus are perennial herbaceous plants. Multi-flowered daisies thrive in a variety of habitats, including meadows, fields, and forests. Some species are toxic, so caution is advised. The family also includes ornamental plants (e.g., peonies) and medicinal plants (e.g., spring adonis). Lilies, known for their beauty, are

remarkably resilient and can adapt to various environmental conditions.^[67]

R. oxyspermus typically grows to a height of 20-36 cm and features tuberous, thickened, oblong roots. The upper part of the stem is highly branched and multi-flowered. The leaves near the base are lanceolate and oval in shape, often wedge-shaped at the base, occasionally rounded, and may have truncate, bluntly toothed segments. This perennial plant produces flowers that measure 2-3 cm in diameter. It commonly grows as a weed in dry meadows, abandoned fields, and along roadsides.^[68,69]

Distribution: Found in regions such as the Ustryt, Tobyl-Esil, Karatau, and Western Tien-Shan. This species is recognized for its medicinal properties.^[70]

Three groups of species can be distinguished in the flora of the formation of phytocenoses and other sections of plant cover (Bykov 1978) endemic, pandemic and epidemic. Endemics are species that are distributed only in a small geographical area and are not found elsewhere; pandemic - appeared in this small area, but the current range has gone beyond the territory of that area; epidemic are species that have appeared outside the territory of the region. At the same time, it is necessary to show rare and relic species.^[71]

R. dilatatus reaches a height of 25-55 cm, with thickened roots resembling a pistil and a fringed root neck. The stem is erect and sticky-branched, supporting a golden-yellow perennial flower with a diameter of 2 cm. This species typically grows in the tree-shrub belt of mountains, in old floodplains, and near roads. **Distribution:** Endemic to the Ile Alatau region.^[72,73]

6. Historical data review

By comparing historical herbarium collections and plant descriptions, we can uncover previously unknown species. For instance, the flowers of *H. falconeri* exhibit notable variations. Each stem typically bears a single, bisexual flower that is radially symmetrical, with its elements arranged spirally; however, the number of floral elements can be inconsistent.^[74,75]

The corolla is simple, with white, leaf-shaped, oval-elongated petals and rounded calyx tips. Reports on the number of sepals vary; while descriptions of the family

indicate there can be 6 to 10 sepals, our observations of this species revealed it typically has 5, with rare occurrences of 6.^[76]

Authors studied 400 flowers across four sites of the *H. falconeri* population, located on the lower sections of both banks of the Taldy River (elevations between 1,694 and 1,710 m), and our findings were quite contradictory. We consistently observed that flowers with 6 petals predominated, comprising an average of 94.5% of our sample. In contrast, 5-petalled flowers accounted for only 3%, while 7-petalled flowers were quite rare at 1.7%, and 8-petalled flowers were observed even less frequently, at 0.3% (Fig. 3).

In the study of rare plants, conducting morpho-anatomical analyses in comparison with previous scientific research is crucial. For example, we examined 400 flowers from four plots of the *H. falconeri* population located along the lower parts of the left and right banks of the Taldy River (elevations ranging from 1694 to 1710 m) and obtained completely contradictory results. Flowers with six petals consistently predominated, making up an average of 94.5%. Flowers with five petals were in second place, accounting for 3%, while flowers with seven petals were rare (1.7%), and those with eight petals were even more infrequent (0.3%) (Fig. 3).

The number of flowering stems in *H. falconeri* populations, as determined by our study, is highly variable and influenced not only by the age of generative individuals but also by habitat conditions. We obtained this data from two cenopopulations on the right bank of the Taldy River: one at a lower elevation (1,710 m) and the other at a higher elevation (the King Gate district, 1,914 m). In the first cenopopulation, the average number of flowering stems per generative individual was 1.68 ± 0.16 , while in the second, it was 1.4 ± 0.16 .

In both habitats, individuals with a single generative stem

(one-flowered) predominated; however, the proportion of robust individuals with three or four generative stems was significantly higher in the lower elevation cenopopulation (15.7% total). In contrast, at the upper elevation, the number of generative stems per individual did not exceed two. The percentage of individuals with a single generative stem was similar in both cases, at approximately 57.9% and 60%, respectively.^[77]

In this context, precise population studies, assessments of the state of species cenopopulations, and evaluations of extinction risk are essential for formulating effective conservation measures.^[78-81] The study of biological diversity, including endemic and rare plant species, is a fundamental component of environmental protection. It is vital to recognize that preserving biodiversity is a shared responsibility, as the loss of species and the destruction of natural ecosystems can profoundly threaten life on Earth.

7. Environmental conditions

Consider variations in altitude, climate, soil types, and hydrology. Fieldwork was conducted during the spring-summer and autumn seasons, focusing on the overall composition of flora, monitoring at stationary sites, and specifically targeting *H. falconeri* populations. Approximately 100 herbarium specimens were collected and processed to clarify the floral composition of the communities. Species identification was based on key collections, including Flora of the USSR (Volumes 1-30, 1934-1964),^[82] Flora of Kazakhstan (Volumes 1-9, 1956-1966),^[83] and Determinant of Central Asia (Critical Synopsis of Flora, Volumes 1-10, 1968-1993).^[84] The vegetation communities where *H. falconeri* occurs often consist of coniferous forests, sparse herbaceous communities, and diverse herbaceous vegetation on rocky outcrops or slopes. The basic youth structure of plant species depends on the

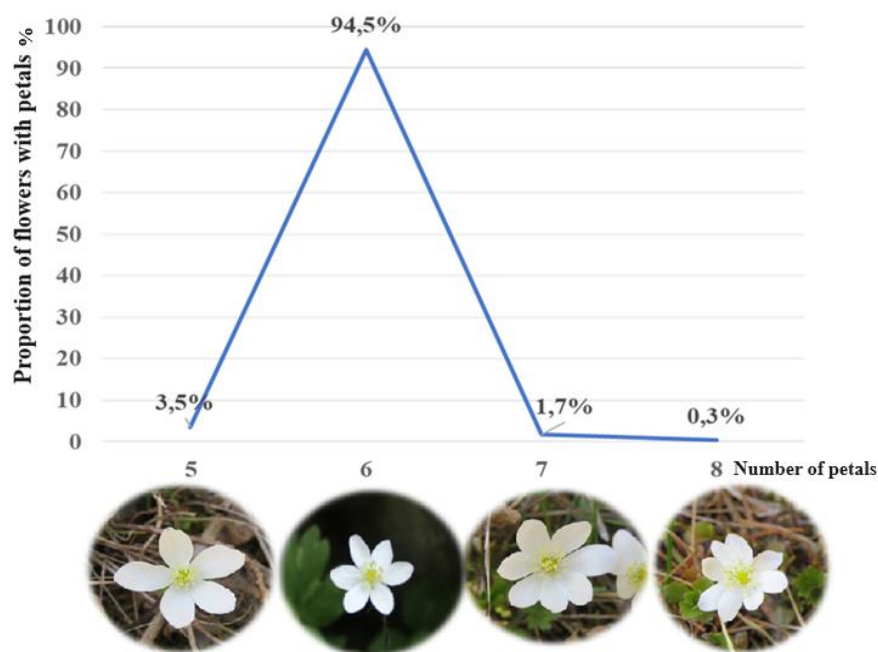


Fig.3 Distribution of *H. falconeri* flowers by the number of petals, %.

resources they extract from their environment and how they utilize them.

In this context, climatic conditions and the composition and properties of the soil—considered essential sources of nourishment for plants—play a crucial role.

In addition to global climate change and biological disturbances, living organisms in the global ecosystem are significantly influenced by the microclimate of their habitats and interactions with other organisms. For example, climate change can alter the structure and function of plant cover, affect the parameters of biological species, and even lead to their extinction. The variability in species composition of flora depends on factors such as thermal regimes, hydrology, and biochemical cycles. Additionally, soil pH, moisture, and structural layers determine the distribution and ontogenetic states of plants.^[85-87]

Differences among plant populations are influenced by microclimatic factors within their ecological niches, particularly the structural and functional characteristics of the soil. Analyzing rare, endemic, and relict species, along with their current population status in the region, requires comprehensive studies encompassing ecology, geography, demography, biological growth, life forms of valuable species, and habitat conditions. Such research enables us to assess the population dynamics at various levels of organization and uncover the mechanisms of resilience in species inhabiting diverse regions.^[88]

7.1 Microclimate studies

Climatic conditions directly influence vegetation primarily through two characteristics: temperature and atmospheric moisture (precipitation regime). According to average indicators, the climatic conditions of the forest-steppe region are generally favorable for the growth of woody vegetation. However, the unpredictable nature of moisture typical in this zone can lead to adverse effects on vegetation. Droughts and dry winds can have particularly detrimental impacts.

Microclimatic observations are conducted to assess how the nature of the underlying surface affects meteorological elements. Microclimate refers to the climate of the surface layers of the atmosphere, formed in small areas due to local factors stemming from the heterogeneity of the underlying surface, which can vary significantly over short distances. This underlying surface differs in absolute height, relief type, soil characteristics, vegetation, moisture levels, and other attributes. Microclimatic features are most pronounced during clear and calm weather. Studies of microclimatic contrasts have demonstrated that the diversity of active surfaces leads to variations in radiation across the territory, resulting in contrasts in temperature, humidity, wind speed and direction, as well as atmospheric and horizontal precipitation.^[89]

Species such as *H. falconeri*, *R. polyanthemus*, and *R. dilatatus* are integral to the microclimatic contrasts of the Tien Shan region.

7.1.1 Relief

The Tien Shan mountains are relatively young, formed by block uplifts and folding over older, more leveled terrains. The western section, known as Kendyk-Tass, stretches from northwest to southeast and features leveled surfaces occupied by several low plateaus (such as Kordai and Argaitin), reaching absolute heights of up to 1,500 meters. The eastern end of the Kungei Alatau lies between the Chilik and Charyn rivers and consists of two parallel ridges: Syugaty in the north and Toraigyr in the south.^[90]

7.1.2 Climate

The climate of the Kungei Alatau, like that of many mountainous regions, is influenced by vertical zonation, latitude and longitude, and proximity to oceans. Its central location within the Eurasian continent, combined with its southern position, contributes to higher temperatures, reduced humidity, and a distinctly continental climate. However, as altitude increases in the foothills, moisture supply rises, summers become milder, and winters less severe.

Over a distance of about 100 km, the climate transitions from hot and very dry to humid and cold, changing from the foothill plain to the snowy peaks. At altitudes of 600 to 1,700 meters above sea level, the average annual temperature is +7.5 °C, with July being the warmest month at +19 °C and December the coldest at approximately -7 °C. Average annual precipitation at this elevation is about 850 mm.

In the spruce-forest belt at altitudes of 1,800 to 2,700 meters, the mountain climate is distinct, featuring mild winters and many sunny days. Negative temperatures persist from November to March, with December averaging -6.3 °C and the annual average at +3.6 °C. July is the warmest month, averaging +15 °C.

At altitudes of 2,700 to 3,360 meters, snow cover lasts for about eight months. The average temperature in February, the coldest month, is -12 °C. Summers are short, and frosts can occur even during the warmest periods of the year. In July, the average temperature is +7.7 °C, while the annual average temperature is -2 °C. As altitude increases, the climate becomes even harsher, with more variable weather patterns. The average annual temperature is around -6.4 °C, and the coldest month can average -15.5 °C.^[91]

Microclimates can significantly influence plant growth and distribution. Establishing portable weather stations in the study area will allow for the regular recording of temperature, humidity, wind speed, and solar radiation. This data will help assess how specific microclimatic conditions affect the survival and reproduction of rare and endemic species.^[92]

The microclimate is greatly influenced by the relief and exposure of slopes. In valleys, daytime temperatures can be higher, while nighttime temperatures can be lower than those at higher elevations. Specific microclimatic characteristics are observed in river floodplains, where the average daily temperature tends to be lower and relative humidity higher compared to elevated terraces. This leads to the growth of

more northern plant species in these conditions.

The natural properties of each landscape depend on several factors, including the length of day and night, the height of the Sun above the horizon, the total amount of solar radiation, the thermal regime of the air and soil, the rhythms of biochemical and biophysical processes in plants and animals, and the phase transformations of moisture in the soil and atmosphere.^[93]

Analyzing the potential effects of microclimate on physical-geographical processes reveals that the mutual influence of two or three microclimatic contrasts is often evident. For example, in winter, the inhomogeneities of the active surface in the atmospheric boundary layer can create significant contrasts in wind speed and direction over short distances, particularly in rugged terrain, affecting the distribution of solid precipitation.

During snow drift, not only does the snow cover erode, but the upper layer of the soil can also be disturbed. The movement of snow in the airflow acts abrasively against any obstacles. The erosive effect of drifting snow increases with higher wind speeds and lower air temperatures. On windward slopes, snow can be blown away, while on leeward slopes, it tends to accumulate. Additionally, soil particles can be displaced and deposited with the snow, decreasing the reflectivity of the snow cover.

As snow melts, especially under the combined influence of warm air masses and sunlight, favorable conditions for water erosion can develop on previously leeward slopes.^[94]

7.2 Soil property analysis

When describing macrorelief, it's important to consider elements that extend horizontally from 200 meters to 10 kilometers or more. Examples of these elements include mountain ranges, river valleys, and the watershed surfaces between adjacent rivers. The next level of relief features are mesorelief forms, which typically have diameters ranging from tens to several hundred meters, with height differences measured in meters. These include floodplain terraces, ridges, sand dunes, hollows, gullies on slopes, moraine hills, and ravines. The smallest relief forms, known as microrelief, have dimensions that do not exceed several meters and are typically identified within a sample area. Examples include steppe saucer-shaped depressions, riverbank ridges, small depressions, and low sandy hills. Another critical indicator of habitat conditions is the type and degree of moisture present. The type of moisture is influenced by the location of the sample plot within the relief and is determined by the primary source of water supply—whether atmospheric, dripstone, or groundwater. When assessing the degree of moisture, soil moisture serves as a key reference. There are five stages of soil moisture: dry, fresh, damp, moist, and wet. Dry soil is dusty, lacks moisture when touched, and does not cool the hand. Fresh soil feels cold, does not produce dust, and becomes slightly lighter as it dries. Wet soil has noticeable moisture when touched, can moisten paper, becomes significantly lighter when dried, and retains the shape given to it when

squeezed by hand. Moist soil transforms into a doughy mass when squeezed, wetting the hand but not oozing between the fingers. Wet soil releases water when squeezed. Additionally, moisture can be categorized generally as normal, excessive, or insufficient.^[95]

For example, studies on the soil where natural populations of *H. falconeri*, *R. polyanthemus*, and *R. dilatatus* grow provide valuable insights. According to researchers, the diurnal variation in soil temperature at the surface and at depth across different mountain slopes and altitudes primarily depends on the amount of solar radiation reaching the soil and the physical characteristics of the soil itself.^[96]

Throughout the day, the soil temperature on the south-facing slope is significantly higher than that on the north-facing slope. This difference is attributed to the fact that the northern slope receives considerably less solar energy than the southern slope. Additionally, the stony nature of the southern slope's soil allows it to retain heat more effectively than the darker soils found on the north slope. Minor deviations in ridge orientation from true north negatively impact the temperature distribution of the soil surface, with northwest slopes exhibiting warmer temperatures than those facing directly north. As one moves deeper into the soil, there is a consistent decrease in temperature. Differences in soil temperature related to altitude are also clearly evident. The initial focus of soil research is on its properties. The soil profile is divided into distinct layers based on key characteristics. As a result of the prolonged soil-forming process, the appearance and properties of the parent rock undergo significant changes. Preliminary conclusions about the soil's origin, chemical composition, and fertility can be drawn based on external characteristics. The external properties of the soil are examined through the soil profile, which is a vertical section from the soil surface down to the unaltered rock, typically extending to a depth of 1 to 1.5 meters. A vertical section of the soil (see [Table. S1](#)) reveals the heterogeneous soil horizons (layers) that comprise the profile.^[97]

The upper horizon, known as Horizon A, is usually dark in color due to the accumulation of humus. The thickness of Horizon A varies depending on the soil type, ranging from several centimeters (30–40 cm) to over 100 cm in rich soils like chernozems.

Horizon B is the illuvial horizon (wash-in) and serves as a transitional layer to the parent rock. It is characterized by a lower concentration of humus and the leaching of water-soluble substances from the overlying layers. Horizon C consists of the parent rock that contributes to soil formation.^[98] Horizon D is the underlying bedrock. Upon examining the soil profile, the color of the soil stands out as one of the most noticeable morphological features. The soil samples taken from each layer are pre-weighed in aluminum buckets. The wet weight of soil samples (aluminum bag + soil sample) is immediately determined by an electronic scale. In the laboratory, wet soil samples are dried in a drying cabinet at a temperature of 105 °C for 6 hours. The dried soil samples are

cooled in a desiccator, and their weight (aluminum bag + dried soil sample) is re-weighed. Experiments are repeated three times.

The amount of moisture in the soil is calculated according to the following using equation (2).

$$\text{Moisture (\%)} = (B1 - B2)/(B2 - B) \times 100\% \quad (2)$$

where B is the weight of the empty box, $B1$ is the wet soil + weight of the bag, and $B2$ is the dry soil + bulk weight.

To determine the soil pH value, a soil suspension was made from distilled water and soil in a ratio of 1:5, 20 g of soil was weighed, and 5 ml of distilled water was added to it. Soil pH is determined using the CONSORT - C 931 instrument at a temperature of 24.8 °C.

It is important to describe the litter layer, noting its thickness (in centimeters), the composition of its components (such as needles or leaves from tree species, felt, and cereal remnants), as well as the degree of coverage and spatial distribution. Coverage can be uniform, fragmentary, or localized, for example, around tree trunks.^[99]

Particular attention should be given to the characteristics of anthropogenic impacts on the phytocenosis, including the main forms of economic activity present, the existence of paths and roads, and the proximity of settlements. Additionally, the impact of animal activity should be noted.^[100]

As supplementary comments on the environmental characteristics, it is helpful to highlight any specific habitat features, such as the presence of carbonate rock outcrops, moraine boulders, blown sand, stumps, and fallen tree trunks.

7.3 Floral composition and plant community structure

The species composition of plant communities—essentially the list of plant species present—is a critical characteristic of phytocenoses. While the most dominant species, in terms of abundance, are often the focus, it is important to consider all plant species whenever possible. Some species that are quantitatively less significant may still indicate particular environmental conditions and the history of community formation.^[101]

The study of phytocenosis should be started by determining its floral composition and making a list of plant species. Floral composition is an important feature of phytocenosis. In most cases, when describing it, it focuses only on complex plants and lichens. The floral composition of a phytocenosis is the totality of all plant species that grow there. Each species included in the phytocenosis participates in the creation of the biotope in its own way. Some species can be indicators of environmental conditions. Therefore, to get complete information about the community, it is necessary to understand its floral composition, ecological condition, and habitat. At the same time, it is necessary to take into account that fully matured and young plants and sprouts are determined depending on whether they can germinate and grow.

Floral richness is a quantitative indicator of species growing in a specific phytocenosis or association. In order to

make an in-depth analysis of the flora wealth, it is necessary to calculate the number of species for each systematic group (lichens, mosses, ferns, gymnosperms, angiosperms). Depending on the number of species, there are simple floral and complex floral phytocenoses. Simple floral phytocenose consists of one or several species and complex floral phytocenose consists of many species.

The flora richness of the community depends on many factors, such as the diversity of the flora of this area, the microclimate of the place where the community lives, the state of the ecogroup and its changes as a result of the existence of plants, the impact of human life, etc.

The introduction of plant species brought by humans from other regions into phytocenoses or their deliberate introduction into local phytocenoses has shown that phytocenoses with incomplete floral elements can be observed in nature. The incompleteness of the floral organs of phytocenoses is of great practical importance. It is possible to additionally sow the seeds of plant species that are part of such a phytocenosis and have the ability to increase their productivity.

Recording all plant species in the study area, along with their abundance and growth stages, enhances our understanding of the structure of the plant community. This information sheds light on plant competition, ecological succession, and the role of rare plants within their ecosystems. For example, communities with *H. falconeri* are often found in spruce forests, sparse herbaceous areas on rocky terrain, or diverse grassy communities on gravelly or stony slopes.

In our study of the Taldy River valley flora, we identified 107 species belonging to 46 genera. The dominant contributions come from 13 families: Asteraceae (12 species), Fabaceae (9 species), Poaceae and Rosaceae (8 species each), Ranunculaceae (6 species), and Apiaceae (5 species), among others. These families together account for approximately 64.5% of the total floral list. Additionally, 9 genera are represented by 2 species, while 24 genera each contain a single species.^[102]

According to ecobiomorph types, perennial herbaceous plants are predominant, with 15 species of tree-shrub plants and only 3 species of annuals. *H. falconeri* frequently co-occurs with 15 other species, which together form the floral foundation of communities including *Picea schrenkiana*, *Atragene sibirica*, *Ribes meyeri*, *Lonicera stenantha*, *Rosa alberti*, *Sedum hybridum*, *Sedum ewersii*, *Aegopodium alpestre*, *Fragaria vesca*, *Geranium collinum*, *Galium turkestanicum*, *Poa nemoralis*, *Polypodium vulgare*, *Kaufmannia semenovii*, and *Rheum wittrockii*. Notably, the last two species are among those listed in the Red Book of Kazakhstan (2014), along with the species under study.

In a separate study, the floral composition of the area where *R. polyanthemus* occurs includes 46 genera and 283 species. Among these, there are 51 species of marigolds, 28 grasses, 21 legumes, 18 sedges, 13 roses, and various other families. The dominant species in the vegetation cover totals 20. Of these

species, 267 (94.8%) are consumable by cattle, while 21 are toxic and 13 are medicinal.^[103]

7.4 Anatomical study

Plant morphology is the oldest and most fundamental section of botany. It was with descriptive morphology that botany began to develop as a science thanks to the works of Carl Linnaeus in the 17th century. Plant anatomy studies the internal structure of plant organs, including at the tissue and cellular level. Currently, it is generally considered as a component of morphology, together with sections of morphology that study plants using optical microscopy. Studying the anatomy of rare plants is important for several reasons. First, it helps to understand their structural adaptations that allow them to survive in specific environmental conditions. This knowledge can be useful for preserving endangered species and for developing effective methods for their protection.

Second, anatomical studies can reveal unique biochemical and physiological processes that occur in these plants. Understanding these processes can help develop new approaches to agronomy and ecology.

In addition, studying the anatomy of rare plants can

contribute to their use in medicine, cosmetology, and other industries. For example, some rare plants have unique healing properties due to their anatomical features.^[104]

In general, anatomical research of rare plants plays a key role in the protection of biodiversity and the sustainable use of natural resources. Fig. 4 shows the anatomical and morphological structure of the leaf blade structure of *Hepatica falconeri* growing in the Taldy Gorge population (Kazakhstan). On the left side of Fig. 1 are anatomical sections of Falconeri liverwort in the vegetative age state, and on the right are photographs of the generative age state. During a comparative analysis of cross sections of the two age states, it was noted that the structure of the vegetative age state differs from the structure of the generative age state by the following features: the thickness of the leaf blade changes, the vascular bundles are clearly differentiated, their number increases from 1 to 3-5, the development of sclerenchyma cells around the vascular bundles increases; the cells of the upper and lower epidermis change shape during growth from oblong-round to beaded-round; the development of chlorophyll-bearing tissue increases, the cells of the columnar mesophyll are elongated, become more ordered, are arranged in even rows, inclusions appear in the leaf mesophyll.^[105]

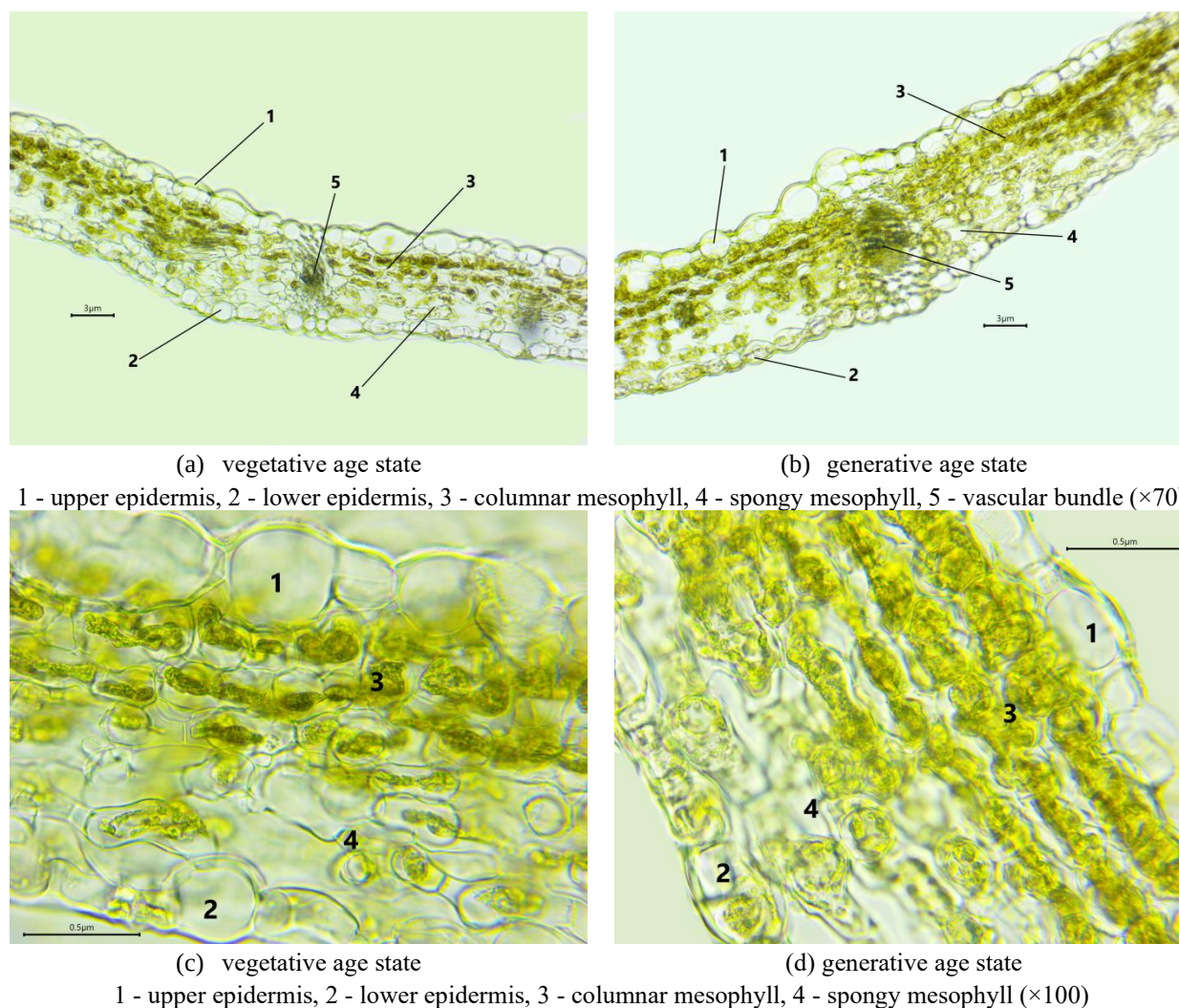


Fig. 4 Anatomical and morphological structure of the leaf blade structure of *H. falconeri* from the Taldy gorge population.

8. Geographical information systems (GIS)

As a source of fundamental knowledge about one of the most important components of the biosphere, the vegetation map is of great scientific importance. Because it is considered an informational basis for solving the problems of ensuring the existence of society and harmonizing the relationship of modern society with the natural environment, its practical role is also very important. For a long time, the role of small-scale survey maps was underestimated. Academician V.B. first spoke about the future of using small-scale maps of plants directly in practice. Sochava said in the 1960s. The role of small-scale overview maps of vegetation increases in the era when regional ecological problems become global with the increasing influence of anthropogenic factors. The geobotanical map of the scientific and informational survey of plant cover covering the territory of the USSR was published in 1954. Its scale was 1:4,000,000. Subsequent plans, *i.e.*, creating a vegetation map on a scale of 1: 2,500,000, were not implemented for various reasons (Kotova, 2011). Significant results in the field of the creation of geobotanical survey maps are associated with the creation of higher educational institutions.

GIS technology helps visualize and analyze spatial data regarding plant distribution. By integrating field data with environmental factors such as topography, climate, and land use, GIS can be used to predict suitable habitats and model future distribution patterns, considering potential environmental changes.

GIS has emerged as a vital tool for studying and managing biodiversity, particularly for rare, endemic, and medicinal plants. These systems enable researchers and conservationists to analyze spatial data, visualize ecological patterns, and make informed decisions about plant conservation and management. This article explores methodologies utilizing GIS to determine the population, distribution, and ecological factors affecting rare and medicinal plants.^[106]

Mapping of vegetation covers, in turn, creates conditions for the development of some sections of geobotany (classification of vegetation cover, dynamics, geobotanical zoning, and geography of phylogenesis). Modern geobotanical maps not only synthesize information about the vegetation cover of the mapped territory (composition, structure, dynamics, history, geography, and its connection with many natural factors), but also analyze them and provide an opportunity to solve new botanical-geographical problems. Geobotanical mapping is currently one of the main methods in the study of vegetation cover and the geography of plant communities. All geobotanical maps are divided into four according to their completeness, accuracy, and scale: 1. Small-scale maps, scale 1: 500000 2. Medium-scale maps, scale 1: 300000 - 1: 100000 3. Large-scale maps, scale 1: 50000 - 1:10000; 4. Full, accurate maps and plans, scale 1: 5000 - 1: 500. Of course, different categories of vegetation cover are captured on maps of different scales. For example, individual phytocenoses and associations cannot be captured on small-

and medium-scale maps because those maps are very small. Individual phytocenoses can be captured only on large-scale and complete, accurate maps. All geobotanical maps are divided into several classes according to their purpose and meaning, the most important of which are as follows: 1. Based on the bioecological classification, maps providing information on the features of the vegetation cover are made - 144 - and legends / explanatory words given to the maps/ are made according to their requirements; 2. Maps provide information on features of plant cover on the basis of genetic or geographic-genetic classification. In this case, the legend of the map is created according to the requirement; 3. Special maps that provide information on some individual features of vegetation cover. For example, maps of animal feed, forests, and general plant resources.^[107]

9. Methods of biologically active substance research in rare, endemic, and medicinal plants

Phytochemical studies encompass a variety of methods used to identify and characterize biologically active compounds in plants.

9.1 Extraction methods

Extraction techniques are used to isolate phytochemical compounds from plant material. The main extraction methods are:

1. Maceration – Involves placing plant material in a solvent and allowing it to sit at room temperature for an extended period. This method is simple and cost-effective but can be time-consuming.
 2. Percolation – A continuous solvent flow is used to extract compounds from plant material placed in a percolator. This method is more efficient and yields faster results compared to maceration.
 3. Soxhlet extraction – Involves a repeated heating and condensation process, where plant material is placed in a Soxhlet apparatus. This method requires heat and is effective in producing highly concentrated extracts.
 4. Supercritical fluid extraction – Uses supercritical carbon dioxide or other fluids to extract phytochemicals. This method produces a pure extract with minimal chemical residue.
 5. Hydrodistillation – Employs steam or hot water to extract essential oils and other volatile compounds from plant material. It is commonly used for extracting aromatic oils.
- Each extraction method has its own advantages and limitations, and the choice of method depends on the type of compound, desired extraction time, temperature, and solvent used.^[108]

9.2 Chromatographic methods

Chromatography is a powerful technique for analyzing the composition of extracts and separating individual components. Common types of chromatography include:

1. Thin-layer chromatography (TLC) – Components are separated on a thin layer of sorbent. This method is primarily used for qualitative analysis of phytochemicals.^[109]

2. High-Performance Liquid Chromatography (HPLC) – A precise and efficient method for separating and quantifying phytochemicals. It is widely used for both qualitative and quantitative analysis.^[110]

3. Gas chromatography (GC) – Used for separating volatile compounds, GC is especially effective for analyzing gaseous or quickly evaporating substances.^[111]

4. Column chromatography – Involves the separation of components using a sorbent packed in a column. This technique is commonly used for larger volume separations and for studying the composition of extracts.^[112]

Spectroscopic methods

Spectroscopy is essential for determining the molecular structure of chemical compounds. Common spectroscopic techniques include:

1. Ultraviolet spectroscopy (UVS) – Used to study compounds that absorb ultraviolet light, providing insight into the electronic structure of molecules, including the presence of π -bonds. It is especially useful for analyzing aromatic and unsaturated compounds.^[113]

2. Infrared spectroscopy (IRS) – Identifies functional groups in a molecule by measuring the absorption of infrared light. Each functional group absorbs infrared light at a specific frequency, producing a unique spectrum that can be used to identify the molecular structure.^[114]

3. Mass spectrometry (MS) – Measures the mass-to-charge ratio of ions to determine the molecular mass and structure of compounds. Mass spectra provide detailed information on the molecular composition and fragmentation patterns, aiding in structural analysis.^[115]

4. Nuclear magnetic resonance (NMR) – A powerful method for elucidating the structure of organic compounds. NMR uses the magnetic properties of atomic nuclei to study molecular bonding and the arrangement of atoms within a molecule. It is particularly useful for determining the complete structure of organic compounds.^[116]

9.3 Electrochemical analysis methods

Electrochemical analysis methods utilize electric current and potential to study the chemical composition and properties of substances.

1. Polarography – This method involves gradually varying the potential at an electrode while measuring changes in current. Polarography is often used to assess antioxidant activity, as it can monitor the oxidation reactions of antioxidant compounds in solution.

2. Cyclic voltammetry – This technique is employed to investigate the oxidation-reduction properties of substances. It measures the oxidation or reduction potential of a compound in solution at the electrode, helping to determine the stability of the compound by analyzing its ability to donate or accept electrons. It also provides information on reaction rates and the products of these reactions.^[117]

9.4 Biological methods for assessing biological activity of

phytochemicals

Several biological methods are used to determine the biological activity of phytochemical compounds:

1. Microbiological tests – These tests evaluate the antimicrobial properties of phytochemicals. They are performed with various microbial strains (bacteria and fungi) to assess the compound's effectiveness in inhibiting microbial growth.

2. Cytotoxicity tests – These tests evaluate the effects of compounds on cell viability. The cytotoxicity of a compound can be determined by exposing cell cultures to the substance and monitoring cell survival.^[118]

3. Antioxidant tests

DPPH Test – This test measures the ability of antioxidants to neutralize free radicals by using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical.

FRAP Test (Ferric Reducing Antioxidant Power) – This method assesses antioxidant activity by measuring the reduction of iron (III) ions to iron (II) ions.

ABTS Test – This test evaluates the ability of antioxidants to neutralize ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)) radicals.^[119]

These methods together provide a comprehensive understanding of the biological activities of phytochemical compounds, including their antimicrobial, cytotoxic, and antioxidant properties.^[120]

9.5 Chemical reactions for identifying plant compounds

Various chemical reactions are used to identify specific compounds in plants and to isolate biologically active substances. Key reactions include:

1. Alkaloids – The Dragendorff's reagent (often combined with iodine or other reagents) is used to identify alkaloids. A characteristic color change, such as brown, indicates the presence of an alkaloid.

2. Flavonoids – Flavonoids react with aluminum salts, producing distinct color changes, typically green or orange-yellow, which confirm their presence.

3. Glycosides – These compounds can be detected by their foaming properties, particularly when dissolved in water. Saponins also produce a similar foaming reaction, aiding in their identification.^[121]

Specialized chemical methods and physical tests are employed to separate and identify these compounds. The results obtained from these methods help in understanding the nature of active compounds in plants and their potential health benefits.

10. Methods of genetic research in rare, endemic, and medicinal plants

Genetic research in plants covers various techniques aimed at studying their genetic structure, inherited traits, and beneficial characteristics for breeding purposes. Some of the key methods used are outlined below:

10.1 Genetic markers

Genetic markers are essential tools in plant genetics and breeding. They help identify specific genetic traits in plants, track useful characteristics, and assist in selective breeding. The primary types of genetic markers include:

DNA Markers

Simple sequence repeats (SSR), or microsatellites, are widely used as genetic markers. SSRs are regions in the plant genome composed of repetitive short sequences. These regions exhibit high polymorphism, meaning they are highly variable between individuals, making them useful for genetic mapping, assessing genetic diversity, and determining genetic relationships.^[122]

Single nucleotide polymorphisms (SNPs) involve the substitution of a single nucleotide within the genome. These genetic variations are common at the population level and are instrumental in studying genetic diversity, disease susceptibility, and specific traits.

Amplified fragment length polymorphisms (AFLP) is a method that involves cutting DNA with enzymes and amplifying the fragments. It allows for the identification of highly diverse DNA fragments, which helps study genetic diversity, kinship, and species divergence.

Restriction fragment length polymorphism (RFLP) analysis is used to assess genetic diversity by cutting DNA with restriction enzymes and separating the resulting fragments by gel electrophoresis. This method is widely applied in plant genetics to study genetic relationships and diversity.

Genetic markers are invaluable tools for improving plant traits, facilitating selective breeding, and enhancing desirable properties.^[123]

10.2 Genetic engineering

Genetic engineering involves modifying a plant's DNA by introducing specific genes that confer desired traits. Key applications of genetic engineering in plants include:

Disease resistance: Genes are inserted into plants to make them resistant to pathogens, thereby improving plant health and yield.^[124]

Increased productivity: Certain genes can be introduced to enhance plant growth rates or yield, ensuring higher crop production.

Environmental adaptation: Genetic modifications can help plants adapt to challenging environmental conditions, such as drought, cold, or saline environments, improving their resilience.^[125]

These techniques are essential for enhancing crop production, improving quality, and making agriculture more sustainable.

10.3 Genome sequencing

Genome sequencing is the process of determining the complete DNA sequence of an organism. In plants, genome sequencing provides detailed insights into gene location,

structure, and function. It is particularly useful for studying traits such as productivity, disease resistance, and environmental adaptability.^[126] Genome sequencing also plays a critical role in plant breeding and genetic improvement by revealing the genetic basis of important traits.

10.4 Hybridization and crossbreeding

Hybridization is the process of crossing two or more different plant varieties or species to combine their beneficial traits. This method creates new plant varieties with improved characteristics such as higher yields, disease resistance, and better adaptability to environmental conditions. Hybridization is widely used to improve major crops like wheat, corn, and rice, and has applications in both plant and animal breeding.^[127]

10.5 Induction of polyploidy

Polyploidy refers to the process of increasing the number of chromosome sets in a plant's cells. Polyploid plants often exhibit enhanced traits such as larger size, increased resistance to diseases, and improved yield. Chemicals like colchicine are commonly used to induce polyploidy by disrupting cell division, leading to the doubling of the chromosome set. Polyploidy is an important method in breeding for larger, more productive crops.^[128]

10.6 Population genetics

Population genetics focuses on studying genetic variation within populations and how it changes over time due to factors like migration, natural selection, and genetic drift. Key methods in population genetics include:

Allele and genotype frequency calculation: This method determines the frequency of alleles and genotypes in a population, helping assess genetic diversity.

Gene flow studies: Gene flow examines the movement of genetic material between populations, helping understand how species spread and adapt.^[129]

Modeling neutral and adaptive processes: This method models the effects of selection and mutation on genetic diversity within a population.

Genetic drift and selection: Genetic drift studies random genetic changes, while selection processes examine how traits evolve in response to environmental pressures.^[130]

Genetic isolation and hybridization: These processes play significant roles in the evolutionary development of species by creating reproductive barriers or promoting gene mixing between populations.^[131]

Population genetics is critical for understanding how plant species evolve and adapt to their environments.

10.7 Phenotyping technologies

Phenotyping involves studying the physical and biochemical traits of plants, which helps link their genotype to their environmental interactions. Modern phenotyping technologies include:^[132]

Image capture and video analysis: Cameras and video

systems are used to measure external plant traits, such as leaf shape, flower color, and plant height. This data helps monitor growth and structure.^[133]

Genetic phenotyping: This approach links plant genotypes (genetic makeup) to phenotypes (observable traits), often using gene mapping and genome-wide association studies (GWAS) to improve traits.

Nano and microscopy technologies: Microscopic techniques allow for the study of plant cells and tissues, offering insights into plant physiology and interactions with the environment.

Remote sensing and spectroscopy: Remote sensing systems are used to assess plant health, growth, and nutrient status, while spectroscopy helps determine the chemical composition of plant tissues.

Robotic and automated systems: Automated systems and robotic tools help monitor plant growth at different stages, providing precise data with minimal human intervention.

Applied biotechnologies (e.g., clustered regularly interspaced short palindromic repeats - CRISPR): Technologies like CRISPR allow for targeted gene editing to improve specific plant traits, enhancing breeding processes and crop development.

These advanced phenotyping technologies enable faster breeding, higher crop yields, and the development of new plant varieties suited to various climates and environmental conditions.^[134]

These diverse genetic research methods are integral to advancing plant breeding, improving crop quality, and ensuring sustainable agricultural practices.^[133] Each method plays a specific role in enhancing plant traits and contributing to the development of more resilient and productive plant varieties.

11. Determining the diet composition of rodents and their impact on plant coverage

This study investigates the diet of several rodent species inhabiting the sandy desert regions of Kazakhstan, including the comb-tailed gerbil (*Spermophilopsis leptodactylus*), small gerbil (*Meriones meridianus*),^[135] woolly gerbil (*Dipus sagitta*),^[136] and the desert or Liechtenstein gerbil (*Eremodipus lichtensteini*). To explore these issues, the digestive tracts of captured individuals were analyzed, along with the identification of food remains and gnawed plants at roosting and feeding sites.

The diet of these rodents was assessed by examining the contents of their digestive tracts and identifying the remains of consumed plants. Rodents were also observed in hand-feeding experiments, where various desert plants and insects were offered to determine their preferences. Key metrics such as rodent density, fat accumulation, and seasonal and age-related variations in fat storage were also recorded to better understand their activity and energy consumption.

11.1 Dietary composition

Comb-tailed gerbil: Primarily herbivorous, this species feeds on the underground parts of plants (roots, rhizomes, and shoots) throughout the year. The comb-tailed gerbil consumes up to 61-67 species of plants in the sandy deserts of Kazakhstan. Around 30 species form the core of its diet, including seeds, fruits, and roots.

Small gerbil: This species feeds on green plant parts and seeds, particularly during the spring and summer breeding seasons, and supplements its diet with insects in the fall. It also consumes toxic plants, such as Adyrspan and Parrot Poppy, throughout the year.

Woolly Gerbil: The woolly gerbil consumes a variety of plant parts, including seeds, fruits, and green shoots, with a preference for around 50-55 plant species. Like the small gerbil, it also includes insects in its diet during the breeding season.

Liechtenstein gerbil: This species is more selective in its diet, consuming a variety of plant parts from 36-46 different plant species. It also feeds on toxic plants year-round.

Impact on desert vegetation: The impact of rodents feeding on desert vegetation was calculated based on their daily and seasonal activity. For example, the full stomach of a small gerbil weighs about 5.0 g, and the gerbil feeds three times a night. Over the course of a year, a single gerbil consumes approximately 5.4 kg of plant mass.

In the South Balkhash region (Saryesik-Atyrau), where there is an average density of 15-16 gerbils per hectare, these rodents collectively consume around 81-86 kg of plant mass annually. This level of consumption is relatively low and is unlikely to cause significant damage to sand pastures, as desert vegetation is resilient and can lose up to 70% of its aboveground phytomass without harm.^[137]

Plant productivity in the region: The aboveground phytomass of desert plants is relatively high. For instance:

Sand sedge (*Agriophyllum arenarium*) produces 1.5-2 quintals of green mass per hectare.^[138]

Camel's bone astragalus (*Astragalus pancijugus*) yields 2.3-2.8 quintals of dry mass per hectare.

Seed productivity can range from 2.0 to 24.0 kg per hectare, depending on the plant species and annual conditions.

11.2 Rodent feeding and plant consumption

Woolly gerbil: The average weight of a full stomach in a woolly gerbil is 9.0 g. Assuming the gerbil eats 18.0 g of plant matter (including green parts and seeds) during each feeding session (which occurs during two peaks of nocturnal activity), it consumes approximately 4.8 kg of plant mass over its 270-day active lifespan. In the South Balkhash region, the woolly gerbil has a density of 6-7 individuals per hectare, collectively consuming 28-34 kg of plant mass annually.

Liechtenstein gerbil: This smaller species has an average population of 3-4 individuals per hectare and an active lifespan of about six months. On average, each Liechtenstein gerbil consumes 16.0 g of various plant parts per night, totaling around 2.8 kg of plant matter during its active life. Therefore,

the collective impact of 3-4 gerbils per hectare results in the consumption of 8.4 to 11.2 kg of plant matter per year.

The overall impact of these sand-dwelling gerbils on desert vegetation is considered to be minimal. For example, the camel's bone astragalus (*Astragalus paucijugus* Schrenk.), which is an important food source for these rodents, yields an average of 2.3-2.8 quintals per hectare of dry mass, with seed productivity varying between 2.0 and 24.0 kg per hectare.^[139] Given that the woolly gerbil feeds on more than 50 species of astragalus and the Liechtenstein gerbil on over 40, the damage caused to vegetation by their feeding habits is relatively low. While some damage may occur in years with lower plant productivity, the overall pest activity of these rodents is not significant enough to affect the desert pasture ecosystem substantially.

In conclusion, while these rodents consume a variety of desert plants, including seeds and fruits, their impact on the plant cover of sandy deserts, particularly in the South Balkhash region, is relatively insignificant, and they do not pose a major threat to the stability of desert ecosystems.

12. Conclusion

In conclusion, this article provides useful insights into the methodologies used to investigate the population, distribution, and ecological variables of rare, endemic, and therapeutic plants, using Ranunculaceae species as examples. By integrating traditional and modern methodologies, researchers can undertake more complete geobotanical and phylogenetic molecular-genetical, biologically active substances research, which is critical for understanding and protecting the natural populations of these important plants. The approaches described in this guide lay a solid foundation for analyzing numerous ecological and physiological features of plant species, which is critical for biodiversity conservation and sustainable management. Future research should focus on the consequences of climate change on the distribution and survival of rare and endemic plant species, especially in vulnerable areas such as the Tien Shan Mountains. Additional research into modern technologies such as remote sensing, GIS, and molecular ecology could improve the precision and size of studies on plant populations and ecosystems. Furthermore, researchers should work on developing more localized conservation methods that take into account the unique biological problems that these species experience in their natural habitats. Improving collaboration among ecologists, conservationists, and local people will also be critical for adopting successful conservation methods and guaranteeing the long-term survival of these unique plant species.

Acknowledgements

This scientific research work was carried out with the funding of the grant project "AP23484931" financed by the Scientific Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan. The community of authors

would like to thank this institution and the Biomedical Research Centre, Al-Farabi Kazakh National University

Conflict of Interest

There is no conflict of interest.

Supporting Information

Applicable.

References

- [1] I. Oprelidelitel Rastenii Kazakhstana, Illustrated determinant of plants of Kazakhstan, *Science Alma-Ata*, 1962, **2**, 1969-1972.
- [2] K. Abidkulova, N. Mukhitdinov, A. Ametov, A. Ydyrys, Morphometric parameters of individuals of some age states of rare and endemic species *Taraxacum kok-saghyz* Rodin. from Kazakhstan, *Modern Phytomorphology*, 2015, **8**, 81-86, doi: 10.5281/ZENODO.159839.
- [3] B. Kuluev, K. Uteulin, G. Bari, E. Baimukhametova, K. Musin, A. Chemeris, Molecular genetic research and genetic engineering of *Taraxacum kok-saghyz* LE Rodin, *Plants*, 2023, **12**, 1621, doi: 10.3390/plants12081621.
- [4] E. Sezik, E. Yeşilada, G. Honda, Y. Takaishi, Y. Takeda, T. Tanaka, Traditional medicine in Turkey X. folk medicine in central Anatolia, *Journal of Ethnopharmacology*, 2001, **75**, 95-115, doi: 10.1016/S0378-8741(00)00399-8.
- [5] W. C. Allee, G. M. Rosenthal Jr, Group survival value for *philodina rosola*, A rotifer, *Ecology*, 1949, **30**, 395-397, doi: 10.2307/1932623.
- [6] A. Ydyrys, N. Mukhitdinov, A. Ametov, B. Tynybekov, A. Akhmetova, K. Abidkulova, The states of coenpopulations of endemic, relict and rare species of plant *Limonium michelsonii* and their protection, *World Applied Sciences Journal*, 2013, **26**, 934-940, doi: 10.5829/idosi.wasj.2013.26.07.13525
- [7] S. Gao, M. Guo, J. Gao, Z. Huang, M. Gan, J. Zhang, Y. Dong, Rapid determination of *Taraxacum kok-saghyz* rubber content using a pyrolyzer hyphenated with a miniaturized mass spectrometer, *Separations*, 2024, **11**, 103, doi: 10.3390/separations11040103.
- [8] M. Imanaliyeva, E. Kyrbassova, A. Aksoy, A. U. A. Turkey, M. C. Vardar, A. U. A. Turkey, G. Sadyrova, M. Parmanbekova, S. Issabayeva, B. Yeszhanov, A. Ametov, Y. Satekov, Z. Askarova, G. Sraïlova, A. Ydyrys, B. Tynybekov, Ecological monitoring of *G. olivieri* Griseb populations, A medicinal and food plant, *ES Food & Agroforestry*, 2024, **17**, 1245, doi: 10.30919/esfaf1245.
- [9] Z. Zhang, Y. Miao, M. Xu, W. Cheng, C. Yang, X. She, Q. Geng, Q. Zhang, TianJiu therapy for α -naphthyl isothiocyanate-induced intrahepatic cholestasis in rats treated with fresh *Ranunculus sceleratus* L., *Journal of Ethnopharmacology*, 2020, **248**, 112310, doi: 10.1016/j.jep.2019.112310.
- [10] A. Ydyrys, B. Yeszhanov, N. Baymurzaev, S. Sharakhmetov, A. Mautenbaev, B. Tynybekov, T. Baidaulet, Technology of landscaping in arid zones by using biohumus from sheep wool, *E3S Web of Conferences*, 2020, **169**, 02012, doi: 10.1051/e3sconf/202016902012.
- [11] B. J. M. Zonneveld, Genome sizes in *Hepatica* Mill: (Ranunculaceae) show a loss of DNA, not a Gain, in polyploids,

- Journal of Botany*, 2010, **1**, 758620, doi:10.1155/2010/758260.
- [12] S. Syraiyl, A. Ydyrys, A. Ahmet, R. Aitbekov, M. T. Imanaliyeva, Phytochemical composition and antioxidant activity of three medicinal plants from southeastern Kazakhstan, *International Journal of Biology and Chemistry*, 2022, **15**, 73-78, doi: 10.26577/ijbch.2022.v15.i1.08.
- [13] A. Seilkhan, S. Syraiyl, G. Turganova, E. Satbayeva, N. Erkenova, Determination of laboratory seed yield of *Artemisia schrenkiana* Ledeb and *Chorispora bungeana* Fisch, *IOP Conference Series: Earth and Environmental Science*, 2021, **699**, 012014, doi: 10.1088/1755-1315/699/1/012014.
- [14] R. E. Kaparbay, A. D. Tolenova, D. M. Almabek, A. A. Ivashchenko, K. T. Abidkulova, B. B. Arynov, Monitoring of rare floristic elements of the northern Tien-Shan forest ecosystems, *Experimental Biology*, 2023, **94**, doi: 10.26577/eb.2023.v94.i1.02.
- [15] Kurmantayeva A. A., Danilov M. P., Shormanova A. A. About rare and endemic species of plants Boraldytau, *Problems of Botany of Southern Siberia and Mongolia*, 2019, **18**, 295-290, doi: 10.14258/pbssm.2019059.
- [16] A. A. Ametov, N. M. Mukhitdinov, K. T. Abidkulova. A. Ydyrys, Modern status *Taraxacum kok-saghyz* Rodin population in conditions of mountainous valley Tekes river, *KazNU Bulletin. Biology Series*, 2015, **1**, 217-223.
- [17] Hamrick JL, Godt MJW. 1989. Allozyme diversity in plant species. In plant population genetics, breeding, and genetic resources, *Annual Review of Ecology, Evolution, and Systematics*, 2003, **34**, 213-237, doi: 10.4236/abb.2013.42024.
- [18] A. Ydyrys, N. Abdolla, A. Seilkhan, M. Masimzhan, L. Karasholakova, Importance of the geobotanical studying in agriculture (with the example of the Sugaty region), *E3S Web of Conferences*, 2020, **222**, 04003, doi: 10.1051/e3sconf/202022204003.
- [19] Y. Imanbayev, Y. Tileuberdi, Y. Ongarbayev, Z. Mansurov, A. Batyrbayev, Y. Akkazin, E. Krivtsov, A. Golovko, S. Rudyk, Changing the structure of resin-asphaltenes molecules in cracking, *Eurasian Chemico-Technological Journal*, 2017, **19**, 147, doi: 10.18321/ectj645.
- [20] Y. Alibek, N. Abdolla, M. Masimzhan, Z. Abdrasulova, S. Syraiyl, Cultivation and resource of *Artemisia schrenkiana* L. for increased pharmaceutical perspective, *Research on Crops*, 2023, **24**, 171-178, doi: 10.31830/2348-7542.2023.roc-881.
- [21] S. Painuli, C. Quispe, J. Herrera-Bravo, P. Semwal, M. Martorell, Z. M. Almarhoon, A. Seilkhan, A. Ydyrys, J. S. Rad, M. M. Alshehri, S. D. Daştan, Y. Taheri, D. Calina, W. C. Cho, Nutraceutical profiling, bioactive composition, and biological applications of *Lepidium sativum* L., *Oxidative Medicine and Cellular Longevity*, 2022, **2022**, 2910411, doi: 10.1155/2022/2910411.
- [22] A. Ydyrys, A. Serbayeva, S. Dossymbetova, A. Akhmetova, A. Zhuystay, The effect of anthropogenic factors on rare, endemic plant species in the Ile Alatau, *E3S Web of Conferences*, 2020, **222**, 05021, doi: 10.1051/e3sconf/202022205021.
- [23] S. Alimova, A. Baishanbo, A brief overview on medicinal plant *Frangula alnus*, *Eurasian Journal of Ecology*, 2017, **4**, 4-11, doi: 10.26577/eje-2017-4-32.
- [24] G. Parolini, Weather, climate, and agriculture: historical contributions and perspectives from agricultural meteorology, *Wiley Interdisciplinary Reviews: Climate Change*, 2022, **13**, e766, doi: 10.1002/wcc.766
- [25] S. P. Pozniak, N. S. Havrysh, Soils in the memory of world nations, *Polish Journal of Soil Science*, 2019, **52**, 13, doi: 10.17951/pjss.2019.52.1.13.
- [26] M. Nicolson, Humboldtian plant geography after Humboldt: the link to ecology, *The British Journal for the History of Science*, 1996, **29**, 289-310, doi: 10.1017/s0007087400034476.
- [27] N. N. Komedchikov, Cartography in the ussr academy of sciences, 1917–1991, *Mapping Sciences and Remote Sensing*, 2000, **37**, 17-39, doi: 10.1080/07493878.2000.10642133.
- [28] S. V. Viktorov, Y. A. Vostokova, D. D. Vyshivkin, Short guide to geo-botanical surveying. international series of monographs on pure and applied biology, division: botany, 2017.
- [29] P. Drozd, Academician of the academy of sciences of USSR YE. Lavrenko's (1900-1987) contribution to the history of plant science, *History of Science and Biographical Studies*, 2017, **1**, 99-144, doi: 10.31073/istnauka201701-08.
- [30] V. N. Sukachev, The terminology of the basic concepts in phytocenology, *Sovremennaya botanika*, 1935, **5**, 11-21.
- [31] B. A. Bykov, The upper boundary of the forest in the Tien Shan, USSR (abstract), *Arctic and Alpine Research*, 1978, **10**, 423-424, doi: 10.1080/00040851.1978.12003978.
- [32] V. B. Golub, B. M. Mirkin, Grasslands of the lower Volga valley, *Folia Geobotanica & Phytotaxonomica*, 1986, **21**, 337-395, doi: 10.1007/BF02853244.
- [33] M. Kenza, N. Umiel, A. Borochoy, The involvement of ethylene in the senescence of Ranunculus cut flowers, *Postharvest Biology and Technology*, 2000, **19**, 287-290, doi: 10.1016/S0925-5214(00)00098-3.
- [34] N. M. Mukhitdinov, A. A. Ametov, A. Ydyrys, K. T. Abidkulova, Number and age structure of natural cenopopulations of *Taraxacum kok-saghyz* LE Rodin, *Bulletin of KazNU. Series Ecology*, 2015, **1**, 503-512.
- [35] S. Syraiyl, A. Ydyrys, G. Askerbay, R. Aitbekov, Chemical composition and biological uses of *Artemisia schrenkiana* Ledeb, *BIO Web of Conferences*, 2024, **100**, 04039, doi: 10.1051/bioconf/202410004039
- [36] Kerimray, A., Baimatova, N., Ibragimova, O. P., Bukenov, B., Kenessov, B., Plotitsyn, P., & Karaca, F. Assessing air quality changes in large cities during COVID-19 lockdowns: The impacts of traffic-free urban conditions in Almaty, Kazakhstan. *Science of the Total Environment*, 2020, **730**, 139179. doi: 10.1016/j.scitotenv.2020.139179
- [37] A. Akhmetova, N. Mukhitdinov, A. Ydyrys, Anatomical structure of vegetative organs of the rare species *Taraxacum kok-saghyz* L.E. Rodin in immature ontogenetic state, 2015.
- [38] S. Shashwat, K. T. Zingre, N. Thurairajah, D. K. Kumar, K. Panicker, P. Anand, M. P. Wan, A review on bioinspired strategies for an energy-efficient built environment, *Energy and Buildings*, 2023, **296**, 113382. doi: 10.1016/j.enbuild.2023.113382.

- [39] R. Aitbekov, G. Zhamanbayeva, A. Aralbaeva, G. Zhunussova, A. Zhumina, A. Dodonova, A. Zhusupova, L. Umbetyarova, B. Yeszhanov, N. Zhaparkulova, M. Murzakhmetova, A. Ydyrys, Pharmacological composition of *Thymus serpyllum* and its components, *ES Food & Agroforestry*, 2024, **17**, 1244, doi: 10.30919/esfaf1244.
- [40] T. Begilov, Y. Grachev, A. Ydyrys, B. Yeszhanov, Ecological and landscape-forming role of saigas of the Ural population in modern conditions, *BIO Web of Conferences*, 2024, **100**, 04004, doi: 10.1051/bioconf/202410004004.
- [41] Y. Zhou, C. Y. Wang, H. Ge, F. A. Hoeberichts, P. B. Visser, Programmed cell death in relation to petal senescence in ornamental plants, *Journal of Integrative Plant Biology*, 2005, **47**, 641-650, doi: 10.1111/j.1744-7909.2005.00112.x.
- [42] V. N. Shanin, P. V. Frolov, I. V. Pripulina, O. G. Chertov, S. S. Bykhovets, E. V. Zubkova, A. M. Portnov, G. G. Frolova, M. N. Stamenov, P. Y. Grabarnik, Modeling the dynamics of forest ecosystems taking into account their structural heterogeneity at different functional and spatial levels, *Forest science*, 2022, **6**, 146-192, doi: 10.31509/2658-607x-202264-135.
- [43] T. Mabuchi, H. Kokubun, M. Mii, T. Ando, Nuclear DNA content in the genus *Hepatica* (Ranunculaceae), *Journal of Plant Research*, 2005, **118**, 37-41, doi: 10.1007/s10265-005-0191-9.
- [44] T. A. Rabotnov, Determination of the age composition of species populations in a community, 1964.
- [45] A. A. Ivashchenko, R. E. Kaparbay, B. B. Arynov, N. M. Mukhitdinov, G. Sramko, K. T. Abidkulova, Places of growth and biological characteristics of *Hepatica falconeri* (thoms.) steward at the northern border of its distribution area, *Experimental Biology*, 2022, **90**, 4, doi: 10.26577/eb.2022.v90.i1.01.
- [46] K. K. Kulymbet, G. A. Ydyrys, A. A. Tastanbekova, Density, number, and age spectrum of the rare, endemic, medicinal species *Adonis tianschanica* lipch (adolf), *Experimental Biology*, 2021, **86**, 37-47, doi: 10.26577/eb.2021.v86.i1.04.
- [47] National strategy and action plan for the conservation and balanced use of biological diversity of the Republic of Kazakhstan. – Kokshetau, 1999.
- [48] M. S. Aslam, B. A. Choudhary, M. Uzair, A. Ijaz, The genus *ranunculus*: a phytochemical and ethnopharmacological review, *International Journal of Pharmaceutics*, 2012, **4**, 15-22, doi:10.3390/plants11121599.
- [49] A. D. Serbayeva, N. M. Mukhitdinov, A. A. Ametov, K. T. Abidkulova, A. Ydyrys, Ecological and phytocoenotical assessment of populations of rare and endemic species *Erysimum croceum* M.Pop, *Experimental Biology*, 2019, **79**, 42-52, doi: 10.26577/eb-2019-2-1420.
- [50] S. Almerikova, N. Shchegoleva, S. Abugalieva, Y. Turuspekova, The molecular taxonomy of three endemic Central Asian species of *Ranunculus* (Ranunculaceae), *PLoS One*, 2020, **15**, e0240121, doi: 10.1371/journal.pone.0240121.
- [51] N. J. Turner, Counter-irritant and other medicinal uses of plants in Ranunculaceae by native peoples in British Columbia and neighbouring areas, *Journal of Ethnopharmacology*, 1984, **11**, 181-201, doi: 10.1016/0378-8741(84)90038-2.
- [52] K. Abidkulova, N. Mukhitdinov, A. Ametov, A. Ydyrys, N. Kudajbergenova, Morphological features of different age state of rare, endemic plants *Ikonnikovia kaufmanniana* (Regel) Lincz, *Modern Phytomorphology*, 2014, **6**, 209, doi: 10.5281/zenodo.160765.
- [53] A. Ydyrys, N. Mukhitdinov, A. Ametov, K. Abidkulova, A. Akhmetova, B. Tynybekov, Assessment species communities of population rare, endemic and medical plant *Ferula iliensis* Krasn. ex Korov. on the left bank of the Ili River Almaty region, *Experimental Biology*, 2016, **68**, 14-23, doi: 10.1901/kbs2016.68.3.
- [54] A. S. Seilkhan, R. A-A. Mizadinov, I. R. Mizadinov, M. A. Kizdarbekova, Degradation of lands in central Asia, *International Multidisciplinary Scientific GeoConference: SGEM*, 2016, **2**, 195-208, doi: 10.1051/e3sconf/20162200195.
- [55] S. Nazir, K. Tahir, R. Naz, Z. U. H. Khan, A.-U. Khan, R. Islam, A. Rehman, I. Khan, *In vitro* screening of *Ranunculus muricatus* for potential cytotoxic and antimicrobial activities, *Journal of Pharmacological Sciences*, 2014, **8**, 427-431, doi: 10.5829/idosi.gjp.2014.8.3.83272.
- [56] S. B. Misra, S. N. Dixit, Antifungal principle of *Ranunculus sceleratus*, *Economic Botany*, 1980, **34**, 362-367, doi: 10.1007/BF02858312.
- [57] R. D. Raabe, A. H. Gold, A virus that causes mosaic of *Ranunculus* (*Ranunculus asiaticus* L.), *Phytopathology*, 2007, **47**, 28, doi: 10.1094/PHYTO-96-0560.
- [58] Goke, A., Martin, P. H. Poor acclimation to experimental field drought in subalpine forest tree seedlings, *AoB Plants*, 2022, **14**, plab077. doi: 10.1093/aobpla/plab077.
- [59] M. Tomczyk, J. Gudej, M. Sochacki, Flavonoids from *ficaria verna* huds, *Journal of Biosciences*, 2002, **57**, 440-444, doi: 10.1515/znc-2002-5-606.
- [60] S. M. Awadh, K. K. Ali, A. T. Alazzawi, Geochemical exploration using surveys of spring water, hydrocarbon and gas seepage, and geobotany for determining the surface extension of Abu-Jir Fault Zone in Iraq: A new way for determining geometrical shapes of computational simulation models, *Journal of Geochemical exploration*, 2013, **124**, 218-229, doi: 10.1016/j.gexplo.2012.10.011.
- [61] A. Lundqvist, A postzygotically acting lethal gene linked to one of the four S-loci in *Ranunculus polyanthemus*, *Hereditas*, 2008, **113**, 87-90, doi: 10.1111/j.1601-5223.1990.tb00702.x.
- [62] P. Uotila, Ecology and area of *Pulsatilla patens* (L.) Mill. in Finland, *Annales Botanici Fennici, Societas Biologica Fennica Vanamo*, 1969, **6**, 105-111. doi: 10.1016/j.biocon.2003.07.0077.
- [63] M. H. Hoffmann, K. B. von Hagen, E. Hörandl, M. Röser, N. V. Tkach, Sources of the Arctic flora: origins of Arctic species in *ranunculus* and related Genera, *International Journal of Plant Sciences*, 2010, **171**, 90-106, doi: 10.1086/647918.
- [64] S. A. Kubentayev, D. T. Alibekov, Y. V. Perezhogin, G. A. Lazkov, A. N. Kupriyanov, A. L. Ebel, B. B. Kubentayeva, Revised checklist of endemic vascular plants of Kazakhstan, *PhytoKeys*, 2024, **38**, 241, doi: 10.3897/phytokeys.238.114475.

- [65] Popescu Viorel, New data concerning the spreading of *Nardus stricta* association in Romania, *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 1966, **2**, 93, doi: 10.15835/nbha2124.
- [66] B. Tomozii, V. Radchenko, *Andrena suerinensis*, The IUCN Red List of Threatened Species, 2015.
- [67] K. P. Bhargava, K. Kishor, M. C. Pant, P. R. Saxena, Identification of tryptamine derivatives in *Ranunculus sceleratus* L., *British Journal of Pharmacology and Chemotherapy*, 1965, **25**, 743-750, doi: 10.1111/j.1476-5381.1965.tb01796.x.
- [68] H. Maroofi, A. Gholipour, H. Maroofi, Two new records from the Genera *linum* and *ranunculus* for the flora of Iran, *The Iranian Journal of Botany*, 2014, **20**, 25-28, doi: 10.22092/ijb.2014.6153.
- [69] K. Kulymbet, N. Mukhitdinov, S. Kubentayev, K. Tynybayeva, A. Tastanbekova, M. Kurmanbayeva, Y. Gafforov, R. Kaparbay, M. Zhumagul, The current state of the cenopopulations of *Adonis tianschanica* (Adolf) Lipsch. (Ranunculaceae) in Southeast Kazakhstan, *Biodiversitas Journal of Biological Diversity*, 2023, **24**, 4359-4372, doi: 10.13057/biodiv/d240817.
- [70] K. Abidkulova, N. Mukhitdinov, A. Ametov, A. Ydyrys, N. Kudaibergenova, The Age Structure of the coenopopulations of rare endemic plant *Ikonnikovia Kaufmanniana* from Kazakhstan, 7th Planta Europa Conference Book of Abstracts, Ortodox Academy of Crete, Kolympari, 2014.
- [71] J. Major, Analytical Biogeography: an integrated approach to the study of animal and plant distributions, 1988.
- [72] N. Abdolla, Abidkulova, A. Ydyrys, N. M. Mukhitdinov, Characteristics of phytochemical composition of *Linaria vulgaris* Mill medicinal plant grown in agrobiostation of Almaty region, *Eurasian Journal of Ecology*, 2022, **72**, 70-80, doi: 10.26577/eje.2022.v72.i3.07.
- [73] A. A. Ivashchenko, Conservation of the gene pool of Ranunculaceae and related families (Paeoniaceae, Berberidaceae) in the National Parks of the northern Tien Shan, *Eurasian Journal of Ecology*, 2023, **76**, 93, doi: 10.26577/eje.2023.v76.i3.08.
- [74] K. Xiang, G. Cao, H. Peng, X. Li, A. S. Erst, L. Lian, T. V. Erst, F. Jabbour, R. D. C. Ortiz, W. Wang, Molecular phylogeny of *Anemone* (Ranunculaceae), with special emphasis on the origin of alpine species, *Taxon*, 2024, doi: 10.1002/tax.13297.
- [75] S. I. Ziman, Morphology and Phylogeny of the Ranunculaceae Family, Kyiv: Naukova Dumka, 1986.
- [76] A. Akhmetova, N. Mukhitdinov, A. Ydyrys, Anatomical indicators of the leaf structure of *Ferula iliensis*, growing in the eastern part of Zailiyskiy Alatau (big boguty mountains), *Pakistan Journal of Botany*, 2015, **47**, 511-515.
- [77] S. B. Hoot, K. M. Kyle, J. C. Manning, Phylogeny and Reclassification of *Anemone* (Ranunculaceae), with an Emphasis on Austral Species, *Systematic Botany*, 2012, **14**, 139-152, doi: 10.1600/036364412X616729.
- [78] N. Daminova, S. Nosirov, F. Akbarov, K. Tojibaev, E. Temirov, Distribution and conservation of the narrow sub-endemic shrub, *Lonicera paradoxa* in Pamir-Alay, Central Asia, *Biodiversitas Journal of Biological Diversity*, 2024, **25**, 439-448, doi: 10.13057/biodiv/d250201.
- [79] N. M. Mukhitdinov, S. T. Aitakova, Root morphology and ontogenesis of some common plant species in Trans-Ili Alatau, Kazakhstan, *Acta Phytogeographica Suecica*, 1996, **81**, 65-67, doi: 10.1111/j.1756-1051.1996.tb01080.x.
- [80] N. V. Kurbatova, A. A. Ametov, N. M. Mukhitdinov, K. T. Abidkulova, Botanical research of the medicinal plant *Polygonum amphibium* L. in the vicinity of Almaty City, *Biologija*, 2014, **59**, 279-286, doi: 10.6001/biologija.v59i3.2790.
- [81] A. Ydyrys, N. Mukhitdinov, A. Abbas, Z. Mukhitdinova, A. Ametov, B. Tynybekov, A. Akhmetova, K. Abidkulova, The states of coenopopulations of endemic, relict and rare species of plant *Ferula iliensis* and their protection, *Journal of Biotechnology*, 2014, **185**, S32-S33, doi: 10.1016/j.jbiotec.2014.07.110.
- [82] V. L. Komarov, Flora of the USSR, 1963.
- [83] N. Ryabushkina, N. Gemedjiev, M. Kobaisy, C. L. Cantrell, Brief review of Kazakhstan flora and use of its wild species, *Asian and Australasian Journal of Plant Science and Biotechnology*, 2008, **2**, 64-71.
- [84] M. Narbayev, V. Pavlova, The Aral Sea, central Asian countries and climate change in the 21st century, 2022.
- [85] R. Zhao, The influence of cushion plants on soil fertility islands under their canopies with ontogenesis in an extreme alpine ecosystem, *Plant and Soil*, 2023, **484**, 379-392, doi: 10.1007/s11104-022-05798-3.
- [86] C. Parmesan, M. E. Hanley, Plants and climate change: complexities and surprises, *Annals of botany*, 2015, **116**, 849-864, doi: 10.1093/aob/mcv169.
- [87] A. Ydyrys, N. Zhaparkulova, A. Aralbaeva, A. Mamataeva, A. Seilkhan, S. Syraiyl, M. Murzakhmetova, Systematic analysis of combined antioxidant and membrane-stabilizing properties of several *Lamiaceae* family Kazakhstani plants for potential production of tea beverages, *Plants*, 2021, **10**, 666, doi: 10.3390/plants10040666.
- [88] H. Loconte, L. M. Campbell, D. W. Stevenson, Ordinal and familial relationships of Ranunculid Genera, *Systematics and Evolution of the Ranunculiflorae*, 1995, **9**, 99-118, doi: 10.1007/978-3-7091-6612-3_10.
- [89] O. Paun, C. Lehnebach, J. T. Johansson, P. Lockhart, E. Hörandl, Phylogenetic relationships and biogeography of *Ranunculus* and allied Genera (Ranunculaceae) in the Mediterranean region and in the European Alpine System, *Taxon*, 2005, **54**, 911-932, doi: 10.2307/25065478.
- [90] J. S. Pei, C.-C. Liu, Y.-N. Hsu, L.-L. Lin, S.-C. Wang, J.-G. Chung, D.-T. Bau, S.-S. Lin, Amentoflavone induces cell-cycle arrest and apoptosis in MCF-7 human breast cancer cells via mitochondria-dependent pathway, *In Vivo*, 2012, **26**, 963-970, doi: 10.3892/iv.2012.964.
- [91] A. Akhmetova, N. Mukhitdinov, A. Ydyrys, Anatomical structure of virginal plants of *Ikonnikovia kaufmanniana* (Regel) Lincz, 2014.
- [92] A. Ydyrys, An Overview of Medical uses and Chemical Composition of *Arctium tomentosum* mill, *Engineered Science*, 2023, **26**, 984, doi: 10.30919/es984.
- [93] A. Ydyrys, G. Zhamanbayeva, N. Zhaparkulova, A.

- Aralbaeva, G. Askerbay, Z. Kenzheyeva, G. Tussupbekova, S. Syraiyl, R. Kaparbay, M. Murzakhmetova, The systematic assessment of the membrane-stabilizing and antioxidant activities of several kazakhstani plants in the Asteraceae family, *Plants*, 2023, **13**, 96, doi: 10.3390/plants13010096.
- [94] K. T. Abidkulova, D. M. Almabek, A. A. Ivashchenko, N. M. Mukhitdinov, N. V. Kurbatova, B. A. Turalin, L. N. Karasholakova, Herbarium as tools in study of plant distribution and ecology (on the examples kazakh species of *Leontice* and *Gymnospermium*, *Eurasian Journal of Ecology*, 2024, **78**, 90-99, doi: 10.26577/EJE.2024.v78.i1.09.
- [95] A. Childibayeva, A. Ametov, N. Kurbatova, A. Akhmetova, B. Tynybekov, G. Mukanova, Structural characteristics of *Rosa iliensis* chrshan. under conditions of the floodplains of the Rivers Ili and sharyn, *Journal of Ecological Engineering*, 2022, **23**, 296-304, doi: 10.12911/22998993/143943.
- [96] A. Nurmahanova, A. Akhmetova, S. Atabayeva, G. Sadyrova, A. Childibayeva, E. Kyrbassova, E. Imanova, M. Parmanbekova, Z. Chundetova, B. Tynybekov, Study of morphogenesis and anatomical structure of *Arctium tomentosum* mill. native to Kazakhstan, *Journal of Ecological Engineering*, 2024, **25**, 325-335, doi: 10.12911/22998993/190264.
- [97] G. Rahman, J. Muhammad, M. Ilyas, M. Subhanullah, K. Ullah, M. Massimzhan, M. Toktar, Y. Bektay, M. Kalybekov, A. Ydyrys, Y. Zhakypbek, Phytoremediation of heavy metals from soil and their effects on plant physiology - A review, *ES Materials & Manufacturing*, 2024, **26**, 1298, doi: 10.30919/esmm1298.
- [98] Kalisz, B., Lachacz, A., & Glazewski, R. Transformation of some organic matter components in organic soils exposed to drainage, *Turkish journal of Agriculture and Forestry*, 2010, **34**, 245-256, doi: 10.3906/tar-0905-33.
- [99] B. Almahan, M. Nashtay, A. Aabibulla, N. Saltanat, K. Ashat, T. Bekzat, A. Karime, Y. Alibek Assessment of the current status of populations of kazakh rare plants (*Berberis iliensis* M. Pop.), *World Applied Sciences Journal*, 2014, **30**, 105-109, doi: 10.5829/idosi.wasj.2014.30.01.14010.
- [100] A. Ydyrys, A. A. Ametov, N. M. Mukhitdinov, K. T. Abidkulova, S. Almerikova, Characteristics of some plant communities with participation narrowly endemic species *Oxytropis almaatensis* Bajt. in Trans-Ili Alatau mountains, *Eurasian Journal of Ecology*, 2016, **49**, 86-96, doi: 10.26577/eje-2016-4-905.
- [101] G. H. Mahran, A. H. Saber, T. el-Alfy, Spectrophotometric determination of protoanemonin, anemonin and ranunculin in *Ranunculus sceleratus* L, *Planta Medica*, 1968, **16**, 323-328, doi: 10.1055/s-0028-1099915.
- [102] J. Sharifi-Rad, N. El Menyiy, A. Ydyrys, N. El Hachlafi, N. El Omari, A. A. Aldahish, F. Sharopov, A. Bouyahya, J. Živković, C. O. Adetunji, O. T. Olaniyan, M. Martorell, E. Sönmez Güre, C. Hano, D. Calina, Bioactive compounds from prosopis species as potential oxidative stress and inflammation modulators: an update on mechanisms, *Minerva Biotechnology and Biomolecular Research*, 2023, **35**, 127, doi: 10.23736/s2724-542x.23.02977-2.
- [103] J. Mlinarec, D. Franjević, L. Bočkor, V. Besendorfer, Diverse evolutionary pathways shaped 5S rDNA of species of tribe Anemoneae (Ranunculaceae) and reveal phylogenetic signal, *Botanical Journal of the Linnean Society*, 2016, **182**, 80-99, doi: 10.1111/boj.12452.
- [104] T. Maver, U. Maver, K. S. Kleinschek, D. M. Smrke, S. Kreft, A review of herbal medicines in wound healing, *International journal of dermatology*, 2015, **54**, 740-751. doi: 10.1111/ijd.12766.
- [105] H. Kraehmer, On vascular bundle modifications in nodes and internodes of selected grass species, *Scientia agriculturae bohemia*, 2017, **48**, 112-121. doi: 10.1515/sab-2017-0018
- [106] K. J. Kim, K. S. Choi, R. K. Jansen, Two chloroplast DNA inversions originated simultaneously during the early evolution of the sunflower family (Asteraceae), *Molecular Biology and Evolution*, 2005, **22**, 1783-1792, doi: 10.1093/molbev/msi174.
- [107] F. Pedrotti, Plant and vegetation mapping, 2012.
- [108] A. Altemimi, N. Lakhssassi, A. Baharlouei, D. G. Watson, D. A. Lightfoot, Phytochemicals: extraction, isolation, and identification of bioactive compounds from plant extracts, *Plants*, 2017, **6**, 42, doi: 10.3390/plants6040042.
- [109] K. Ingle, A. G. Deshmukh, D. A. Padole, M. Dudhare, M. Moharil, K. Vc, Phytochemicals: Extraction methods, identification and detection of bioactive compounds from plant extracts, *Journal of Pharmacognosy and Phytochemistry*, 2017, **6**, 32-36.
- [110] J. Hamuel, Phytochemicals: extraction methods, basic structures and mode of action as potential chemotherapeutic agents, 2012.
- [111] S. Sasidharan, Y. Chen, D. Saravanan, K. M. Sundram, L. Yoga Latha, Extraction, isolation and characterization of bioactive compounds from plants' extracts, *African Journal of Traditional, Complementary, and Alternative Medicines*, 2011, **8**, 1-10. doi: 10.4314/ajtcam.v8i1.60483.
- [112] P. Blackburn, T. Bolander, T. Bräuner, V. de Paiva, J. Villadsen, Preface, *Electronic Notes in Theoretical Computer Science*, 2007, **174**, 1-2, doi: 10.1080/01431160903023058.
- [113] A. Ahmad Dar, P. L. Sangwan, A. Kumar, Chromatography: An important tool for drug discovery, *Journal of Separation Science*, 2020, **43**, 105-119, doi: 10.1002/jssc.201900656.
- [114] K. Robards, D. Ryan, Principles and practice of modern chromatographic methods, 2021.
- [115] P. S. Kalsi, Spectroscopy of organic compounds, 2004.
- [116] N. Zahra, J. Iqbal, M. Arif, B. A. Abbasi, H. Sher, A. F. Nawaz, T. Yaseen, A. Ydyrys, J. Sharifi-Rad, D. Calina, A comprehensive review on traditional uses, phytochemistry and pharmacological properties of *Paeonia emodi* wall. ex royle: current landscape and future perspectives, *Chinese Medicine*, 2023, **18**, 23, doi: 10.1186/s13020-023-00727-7.
- [117] A. J. Bard, L. R. Faulkner, H.S. White, Electrochemical methods: fundamentals and applications, 2022.
- [118] C. Barba-Ostria, S. E. Carrera-Pacheco, R. Gonzalez-Pastor, J. Heredia-Moya, A. Mayorga-Ramos, C. Rodríguez-Pólit, J. Zúñiga-Miranda, B. Arias-Almeida, L. P. Guamán, Evaluation of biological activity of natural compounds: current trends and methods, *Molecules*, 2022, **27**, 4490, doi:

- 10.3390/molecules27144490.
- [119] Z. Akzhigitova, M. A. Dyusebaeva, T. Tokay, A. Ydyrys, L. Xuan, J. Jenis, Phytochemical study of *bergenia crassifolia*, *Chemistry of Natural Compounds*, 2020, **56**, 912-914, doi: 10.1007/s10600-020-03184-y.
- [120] S. M. Pires, R. S. Reis, S. M. Cardoso, R. Pezzani, E. Paredes-Osses, A. Seilkhan, A. Ydyrys, M. Martorell, E. Sönmez Gürer, W. N. Setzer, A. F. Abdull Razis, Phytates as a natural source for health promotion: A critical evaluation of clinical trials, *Frontiers in Chemistry*, 2023, **11**, 1174109, doi: 10.3389/fchem.2023.1174109.
- [121] A. A. Kudaibergen, M. A. Dyusebaeva, A. Ydyrys, A.-F. K. N. University, Y. Feng, J. Jenis, Investigation of chemical constituents of medicinal Plant *Spiraea Hypericifolia* L., *International Journal of Biology and Chemistry*, 2019, **12**, 128-134, doi: 10.26577/ijbch-2019-1-i17.
- [122] R. K. Salgotra, C. N. J. Stewart, Functional markers for precision plant breeding, *International Journal of Molecular Sciences*, 2020, **21**, 4792, doi: 10.3390/ijms21134792.
- [123] B. C. Y. Collard, D. J. MacKinnon, Marker-assisted selection: an approach for precision plant breeding in the twenty-first century, *Philosophical Transactions of the Royal Society of London*, 2008, **363**, 557-572, doi: 10.1098/rstb.2007.2170.
- [124] X. Wang, S. Chang, J. Lu, R. Fray, D. Grierson, Y. Han, Plant genetic engineering and genetically modified crop breeding: history and current status, *Frontiers of Agricultural Science and Engineering*, 2017, **4**, 5, doi: 10.15302/j-fase-2017131.
- [125] D. S. T. Nicholl, An Introduction to Genetic Engineering, 2023.
- [126] A. H. Paterson, M. Freeling, H. Tang, X. Wang, Insights from the comparison of plant genome sequences, *Annual Review of Plant Biology*, 2010, **61**, 349-372, doi: 10.1146/annurev-arplant-042809-112235.
- [127] B. E. Goulet, F. Roda, R. Hopkins, Hybridization in plants: old ideas, new techniques, *Plant Physiology*, 2017, **173**, 65-78, doi: 10.1104/pp.16.01340.
- [128] M. C. Sattler, C. R. Carvalho, W. R. Clarindo, The polyploidy and its key role in plant breeding, *Planta*, 2016, **243**, 281-296, doi: 10.1007/s00425-015-2450-x.
- [129] T. Mitchell-Olds, J. H. Willis, D. B. Goldstein, Which evolutionary processes influence natural genetic variation for phenotypic traits? *Nature Reviews. Genetics*, 2007, **8**, 845-856, doi: 10.1038/nrg2207.
- [130] C. D. Anderson, B. K. Epperson, M. J. Fortin, R. Holderegger, P. M. James, M. S. Rosenberg, K. T. Scribner, S. Spear, Considering spatial and temporal scale in landscape-genetic studies of gene flow, *Molecular Ecology*, 2010, **19**, 3565-3575, doi: 10.1111/j.1365-294X.2010.04757.x.
- [131] J. O. Hanson, A. Marques, A. Verissimo, M. Camacho-Sanchez, G. Velo-Antón, Í. Martínez-Solano, S. B. Carvalho, Conservation planning for adaptive and neutral evolutionary processes, *Journal of Applied Ecology*, 2020, **57**, 2159-2169, doi: 10.1111/1365-2664.13718.
- [132] D. K. Großkinsky, J. Svendsgaard, S. Christensen, T. Roitsch, Plant phenomics and the need for physiological phenotyping across scales to narrow the genotype-to-phenotype knowledge gap, *Journal of Experimental Botany*, 2015, **66**, 5429-5440, doi: 10.1093/jxb/erv345.
- [133] L. Li, Q. Zhang, D. Huang, A review of imaging techniques for plant phenotyping, *Sensors*, 2014, **14**, 20078-20111, doi: 10.3390/s141120078.
- [134] F. Fiorani, U. Schurr, Future scenarios for plant phenotyping, *Annual Review of Plant Biology*, 2013, **64**, 267-291, doi: 10.1146/annurev-arplant-050312-120137.
- [135] Y. Wang, L. Zhao, F. Fang, J. Liao, N. Liu, Intraspecific molecular phylogeny and phylogeography of the meriones meridianus (Rodentia: Cricetidae) complex in Northern China reflect the processes of desertification and the Tianshan Mountains uplift, *Biological Journal of the Linnean Society*, 2013, **110**, 362-383, doi: 10.1111/bij.12123.
- [136] J. Cheng, D. Ge, L. Xia, Z. Wen, Q. Zhang, L. Lu, Q. Yang, Phylogeny and taxonomic reassessment of *jerboa*, *Dipus* (Rodentia, Dipodinae), in inland Asia, *Zoologica Scripta*, 2018, **47**, 630-644, doi: 10.1111/zsc.12303.
- [137] B. D. Abaturon, M.-R. Magomedov, Nutritional value and dynamics of fodder resources as a factor in the state of populations of herbivorous mammals, *Zoological Journal*, 1988, **67**, 223-234, doi: 10.1111/j.1600-0587.1995.tb00337.x
- [138] I. A. Filippenko, *Agriophyllum arenarium* as a new oleiferous and fodder plant, 1934.
- [139] L. Y. Kurochkina, K. N. Karibaeva, L. T. Osmanova, Forage plants of the deserts of Kazakhstan, 1986.

Publisher's Note: Engineered Science Publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access

This article is licensed under a Creative Commons Attribution 4.0 International License, which permits the use, sharing, adaptation, distribution and reproduction in any medium or format, as long as appropriate credit to the original author(s) and the source is given by providing a link to the Creative Commons licence and changes need to be indicated if there are any. The images or other third-party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

©The Author(s) 2024