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Review article

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M.B. Zhanayeva[1*], A.I. Shmakov[2]

[1]*Buketov Karaganda National Research University, Karaganda, Kazakhstan;*
[2]*Altai State University: Barnaul, Russia*
[*]*Corresponding author: merey.baibolovna@mail.ru*

Wild-Growing Species of the Genus *Ribes* L. in Central Kazakhstan: Bioecological Characteristics

The genus *Ribes L.(Grossulariaceae)* comprises numerous species of ecological, nutritional, and medicinal importance that are widely distributed across temperate regions of the Northern Hemisphere. Central Kazakhstan represents a biogeographically complex area characterized by diverse landscapes and heterogeneous environmental conditions; however, information on wild-growing *Ribes* species in this region remains fragmented and insufficiently systematized. This review aims to synthesize and critically evaluate the available literature on the bioecological characteristics, phytochemical composition, and research prospects of wild *Ribes* species occurring in Central Kazakhstan, with particular focus on *Ribes aciculare* Pall., *Ribes nigrum* L., and representatives of the *Ribes saxatile* species complex. The review is based on an analysis of regional floristic sources, ecological studies, and phytochemical investigations published in international and regional scientific journals. Data on species distribution, habitat preferences, phenology, and ecological adaptations are summarized, together with information on major groups of bioactive compounds, including anthocyanins, flavonoids, proanthocyanidins, organic acids, and vitamins. Most phytochemical studies of the genus *Ribes* have focused on *Ribes nigrum*, which remains the best-studied species. In contrast, information on other wild *Ribes* taxa remains limited and scattered across different publications, making comprehensive evaluation difficult. Taxonomic uncertainties within the *Ribes* saxatile species complex further complicate regional research and highlight the importance of accurate species identification. The existing literature also reveals several important gaps, particularly regarding region-specific phytochemical characteristics, ecological variation among natural populations, and the influence of environmental factors on secondary metabolite accumulation. Further research integrating bioecological and phytochemical approaches is necessary to better understand wild *Ribes* diversity and support the sustainable use of these species in Central Kazakhstan.

Keywords: Ribes L.; Central Kazakhstan; bioecology; phytochemical composition; currants; medicinal plants, wild-growing species.

Introduction

The genus *Ribes* L., belonging to the family Grossulariaceae, comprises approximately 150–200 species distributed predominantly across the temperate and boreal regions of the Northern Hemisphere (Rehder, 1940; Takhtajan, 1986; Hummer & Barney, 2002). Species of this genus, commonly referred to as currants and gooseberries, are widely recognized as valuable biological resources due to their ecological significance, nutritional properties, and medicinal potential. Both wild and cultivated representatives of *Ribes* play an important role in natural ecosystems and agroecosystems, serving as components of forest understories, shrub communities, and ecotones, as well as sources of food for wildlife and humans (Brennan, 2008; Izteleuova et al., 2025).

From a biochemical and nutritional perspective, *Ribes* species are distinguished by their high content of biologically active compounds. Fruits and leaves contain diverse groups of secondary metabolites, including anthocyanins, flavonoids, proanthocyanidins, phenolic acids, vitamins (particularly vitamin C), organic acids, and polysaccharides, many of which exhibit pronounced antioxidant, anti-inflammatory, antimicrobial, and other health-promoting activities (Koponen et al., 2007; Dobson et al., 2012; Krüger& Dietrich, 2018; Izteleuova et al., 2025). Among the genus, *Ribes nigrum* L. has been studied most intensively, owing to its widespread cultivation and established use in food, pharmaceutical, and nutraceutical industries (Nour et al., 2011; Boda et al., 2025). In contrast, the phytochemical composition and biological properties of many wild-growing *Ribes* species remain poorly characterized, particularly in regions where these taxa occur exclusively or predominantly in natural habitats [1].

Central Kazakhstan represents a biogeographically complex and environmentally heterogeneous region, encompassing steppe, forest-steppe, and low- to mid-mountain ecosystems with pronounced continental climatic conditions. The region is characterized by strong seasonal temperature fluctuations, variable precipitation, and a mosaic distribution of habitats, including rocky slopes, river valleys, forest "islands", and moist microhabitats within predominantly arid landscapes (Takhtajan, 1986; Sagdullaev & Ishmuratova, 2016). Such environmental heterogeneity creates favorable conditions for the persistence of relict, boreal, and mesophilous plant species, including representatives of the genus *Ribes*. However, despite the availability of regional floristic works, information on the ecology, distribution, and biological characteristics of wild *Ribes* species in Central Kazakhstan remains scattered and has not been comprehensively synthesized.

According to available floristic and regional botanical sources, several wild-growing *Ribes* taxa occur in Central Kazakhstan, including *Ribes aciculare Pall*., *Ribes nigrum* L., and representatives of the *Ribes saxatile* species complex (Sagdullaev & Ishmuratova, 2016; Bai et al., 2025). These taxa differ in ecological preferences, habitat requirements, and morphological traits, while also presenting taxonomic challenges due to synonymy, overlapping diagnostic characters, and varying species concepts adopted by different authors. In particular, the *R. saxatile* complex has been treated inconsistently in the literature, with related taxa such as *R. diacantha* Pall., *R. petraeum*auct. non Wulfen, and *R. rubrum* var. *saxatile* being interpreted either as distinct species or as intraspecific variants, depending on regional and taxonomic approaches (Rehder, 1940; Pikunova et al., 2022; Zhao et al., 2025) [2].

Despite the growing global interest in *Ribes* species as sources of functional foods and phytopharmaceuticals, most phytochemical and pharmacological studies are based on cultivated material or populations from Western and Eastern Europe, East Asia, and North America (Oşmiański&Wojdyło, 2009; McDougall & Stewart, 2005; Minasyan et al., 2025). Consequently, there is a notable lack of data on wild-growing populations from Central Asia, including Central Kazakhstan, where environmental stress factors such as drought, temperature extremes, and edaphic heterogeneity may significantly influence both bioecological traits and secondary metabolite profiles. Understanding these relationships is essential for assessing the adaptive potential of wild *Ribes* species, their value as genetic resources, and their prospects for conservation and sustainable use.

The aim of the present review is to synthesize and critically analyze available literature on the wild-growing species of the genus *Ribes* in Central Kazakhstan, with a focus on their bioecological characteristics, phytochemical composition, and research perspectives. Specifically, this review addresses (i) the taxonomic status and species composition of *Ribes* in the region; (ii) patterns of distribution, habitat preferences, and key bioecological traits; (iii) the current state of knowledge on phytochemical constituents and reported biological activities; and (iv) existing gaps in research and future directions for integrated ecological, phytochemical, and conservation-oriented studies (Fig. 1).

Figure 1. Appearance of blackcurrant populations (Karaganda Region)

Experimental

2. Materials and Methods

2.1. Literature Search Strategy

This review is based on an analysis of scientific publications devoted to wild-growing species of the genus Ribes L., with particular attention to taxa recorded in Central Kazakhstan. Relevant literature was identified through searches in major international databases, including Scopus, Web of Science, PubMed, Google Scholar, and ScienceDirect, as well as in regional botanical publications and national scientific sources.

Additional relevant publications were identified through manual screening of reference lists from key review articles and floristic monographs (Rehder, 1940; Takhtajan, 1986; Sagdullaev & Ishmuratova, 2016; Izteleuova et al., 2025) [3].

Search queries were constructed using combinations of keywords such as *"Ribes"*, *"wild species"*, *"bioecology"*, *"phytochemistry"*, *"anthocyanins"*, *"phenolic compounds"*, *"Central Kazakhstan"*, *"Species distribution"*, and *"Grossulariaceae"*. Both English- and Russian-language publications were considered in order to capture regional floristic and ecological studies that are often underrepresented in international databases. The primary time frame of the literature search covered publications from 1990 to 2025, while earlier classical taxonomic and floristic works were included where necessary to clarify species concepts and nomenclature (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975).

2.2. Inclusion and Exclusion Criteria

Publications were included in the review if they met one or more of the following criteria: (i) provided data on the distribution, ecology, or bioecological characteristics of *Ribes* species occurring in Central Kazakhstan or adjacent regions with comparable environmental conditions; (ii) reported phytochemical composition or biological activity of *Ribes* species, particularly *Ribes nigrum*, *Ribesaciculare*, or taxa related to the *Ribes saxatile* species complex; (iii) addressed taxonomic, systematic, or genetic aspects relevant to species delimitation within the genus *Ribes*.

Priority was given to studies focusing on wild-growing populations rather than cultivated material, especially when discussing ecological traits, habitat preferences, and natural variability. Experimental and analytical studies based on cultivated varieties were included only when data on wild populations were unavailable or when such studies provided essential background information on phytochemical classes or biological activities characteristic of the genus (Dobson et al., 2012; Krüger & Dietrich, 2018; Izteleuova et al., 2025).

Publications were excluded if they:

(i) focused exclusively on unrelated genera or species not taxonomically associated with *Ribes*; (ii) addressed only agronomic practices or commercial cultivation without relevance to wild taxa; (iii) lacked sufficient methodological detail or clear taxonomic identification of the studied material [4].

2.3. Data Extraction and Synthesis

Relevant information was extracted from selected publications and systematically organized into thematic categories corresponding to the objectives of the review. Data on species distribution, habitat characteristics, phenology, life forms, and ecological adaptations were summarized to provide an integrated overview of bioecological traits. Phytochemical data were grouped according to major classes of compounds, including phenolic compounds, anthocyanins, flavonoids, proanthocyanidins, vitamins, organic acids**,** and volatile constituents, with particular emphasis on compounds reported consistently across multiple studies (Koponen et al., 2007; Oszmiański & Wojdyło, 2009; Nour et al., 2011).

Where available, information on analytical methods (e.g., HPLC-DAD, LC–MS/MS, GC–MS) was recorded to facilitate comparison between studies and to assess the reliability and comparability of reported results (Lee et al., 2005; Prior et al., 2005). Biological and pharmacological activities were evaluated qualitatively based on experimental models, target systems, and reported effect sizes, without extrapolation beyond the evidence provided in the original sources (Mc Dougall & Stewart, 2005; Minasyan et al., 2025).

The synthesized data were subsequently used to identify patterns, knowledge gaps, and inconsistencies in the current literature, forming the basis for the discussion of research perspectives and future directions presented in later sections of this review [5].

3. Taxonomic Notes and Species Concept

The genus *Ribes* L. is traditionally placed in the family Grossulariaceae, which is widely recognized as a distinct taxonomic unit within the order Saxifragales (Rehder, 1940; Takhtajan, 1986). Representatives of *Ribes* are deciduous shrubs characterized by palmately lobed leaves, racemose or solitary inflorescences, inferior ovaries, and berry-type fruits. The genus includes both currants and gooseberries and is distributed predominantly in temperate and boreal regions of the Northern Hemisphere, with centers of diversity in Eurasia and North America (Hummer & Barney, 2002; Brennan, 2008).

Historically, the taxonomic circumscription of *Ribes* has been subject to debate, particularly regarding its relationship with the genus *Grossularia* Mill. In older classifications, gooseberries were often treated as a separate genus (*Grossularia*), based primarily on morphological characters such as the presence of spines and differences in inflorescence structure (Rehder, 1940). However, most modern taxonomic treatments incorporate *Grossularia* within *Ribes*, recognizing these taxa as part of a single, morphologically variable genus supported by anatomical, cytological, and molecular evidence (Graham et al., 1996; Hummer & Barney, 2002; Pikunova et al., 2022). In the present review, *Ribes* is treated in this broadly accepted sense (*Ribes* sensulato), in accordance with contemporary floristic and systematic sources.

Within the genus, species delimitation remains problematic for several taxonomic groups, particularly those characterized by high morphological plasticity and overlapping diagnostic features. One of the most challenging groups is the *Ribes saxatile* species complex, which has been interpreted differently by various authors depending on geographic region and taxonomic tradition. In the literature, taxa such as *Ribes saxatile* Pall., *Ribes diacantha* Pall., *Ribes petraeum*auct. non Wulfen, and *Ribes rubrum* var. *saxatile* have been treated either as distinct species, subspecies, or intraspecific variants (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975; Pikunova et al., 2022; Zhao et al., 2025) [6].

The name *Ribes petraeum* has frequently been applied in a broad and sometimes incorrect sense (*auct. Non* Wulfen) to rocky or montane forms of *Ribes* with reduced leaf size and compact growth habit. Such usage has contributed to taxonomic ambiguity, particularly in regional floras, where morphological variation may reflect ecological adaptation rather than clear species-level differentiation. Similarly, *Ribes diacantha* Pall. has been variably regarded as an independent species or remember its treatment as part of the *R. saxatile* aggregate, depending on the diagnostic weight assigned to spine development, inflorescence structure, and fruit characteristics (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975).

Molecular and population-level studies conducted on *Ribes* in other regions have demonstrated that morphological traits traditionally used for species delimitation may exhibit considerable plasticity under varying environmental conditions (Graham et al., 1996; Palmieri et al., 2009; Pikunova et al., 2022). These findings support the view that the *R. saxatile* group represents a species complex rather than a set of clearly isolated taxa, particularly in ecologically heterogeneous regions. However, comparable genetic and integrative taxonomic studies are currently lacking for populations occurring in Central Kazakhstan, limiting the possibility of definitive taxonomic conclusions for this region [7].

In floristic treatments of Central Kazakhstan, including regional monographs and checklists, the presence of *Ribes aciculare* Pall., *Ribes nigrum* L., and taxa attributed to the *Ribes saxatile* group has been con-

sistently reported, although the taxonomic interpretation of the latter varies among sources (Sagdullaev & Ishmuratova, 2016; Bai et al., 2025). To avoid taxonomic overinterpretation and to maintain consistency with available data, the present review adopts a conservative approach and refers to these taxa collectively as the *Ribes saxatile complex (sensulato)* when discussing distribution, ecology, and phytochemical data in Central Kazakhstan.

Such an approach allows for the integration of heterogeneous literature sources while acknowledging existing uncertainties in species delimitation. At the same time, it highlights the need for future integrative studies combining detailed morphological analysis, molecular markers, and ecological data to clarify the taxonomic status of *Ribes* taxa in Central Kazakhstan and adjacent regions [8].

4. Study Area: Central Kazakhstan

Central Kazakhstan represents a distinct natural–geographical region located in the central part of the Republic of Kazakhstan and largely corresponding to the territory of the Kazakh Uplands (Saryarka). The region is characterized by a complex geological history and a pronounced heterogeneity of landscapes, forming a mosaic of steppe plains, low mountain ranges, rocky massifs, intermontane depressions, and river valleys. Such landscape diversity plays a key role in shaping the floristic composition and ecological differentiation of plant communities, including habitats suitable for wild-growing species of the genus *Ribes* (Takhtajan, 1986; Sagdullaev&Ishmuratova, 2016).

The climate of Central Kazakhstan is sharply continental, with cold winters, hot and dry summers, and high interannual variability in temperature and precipitation. Mean annual air temperatures are generally low, while seasonal amplitudes may exceed 35–40 °C. Precipitation is unevenly distributed throughout the year and across the region, with annual totals typically ranging from 200 to 350 mm, increasing locally in mountainous and foothill areas (Takhtajan, 1986). These climatic conditions impose significant constraints on vegetation development and favor the formation of drought-tolerant steppe communities, interspersed with mesophilous vegetation in ecologically favorable microhabitats [9].

Vegetation cover in Central Kazakhstan is dominated by steppe and dry steppe ecosystems; however, forested areas occur as isolated “islands” within mountainous regions and along river valleys. These forest and shrub communities are often confined to north-facing slopes, shaded ravines, rocky outcrops, and zones with increased soil moisture availability. Such microhabitats provide refugial conditions for mesophilous shrub species, including representatives of *Ribes*, which are otherwise unable to persist in the open steppe under arid climatic conditions (Sagdullaev & Ishmuratova, 2016).

Soil cover in the region is similarly heterogeneous, ranging from chestnut and dark chestnut soils in steppe zones to mountain meadow, forest, and skeletal soils on rocky slopes and uplands. River valleys and temporary watercourses create localized zones of increased soil moisture and nutrient availability, supporting riparian and shrub vegetation. These edaphic factors, in combination with topography and microclimate, are critical determinants of the distribution and persistence of wild *Ribes* populations in Central Kazakhstan (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016) [10].

5. Distribution and Habitat Preferences of Central Kazakhstan Ribes

The distribution of wild Ribes species in Central Kazakhstan is closely related to the strong environmental contrasts characteristic of the region. Although the landscape is dominated by arid steppe ecosystems, these plants tend to occur in localized habitats where moisture conditions are relatively more favorable for mesophilous vegetation. According to regional floristic treatments and botanical surveys, representatives of the genus *Ribes* occur sporadically and are confined to ecologically favorable sites, rather than being continuously distributed across the region (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016) [11].

Available data indicate that *Ribes aciculare* Pall., *Ribes nigrum* L., and taxa attributed to the *Ribes saxatile* complex are primarily associated with mountainous and submontane areas of Central Kazakhstan, including the Ulytau mountain system and adjacent uplands. These species are typically recorded in shaded ravines, moist rocky slopes, forested valleys, and along permanent or temporary watercourses, where soil moisture availability is higher and microclimatic conditions are less extreme than in surrounding open steppe areas (Sagdullaev & Ishmuratova, 2016; Bai et al., 2025).

Habitat preferences of *Ribes* species in the region reflect their general ecological requirements for moderate moisture, partial shading, and protection from extreme temperature fluctuations. North-facing slopes, narrow gorges, and rock fissures provide refugial conditions that reduce evapotranspiration and buffer

against summer heat and winter cold. In such habitats, *Ribes* shrubs often occur as components of shrub–herbaceous communities or forest undergrowth, rather than forming dense or extensive populations (Flora of Kazakhstan Editorial Board, 1961–1975).

Edaphic conditions also play a critical role in shaping the distribution of *Ribes* species. In Central Kazakhstan, these taxa are most frequently associated with well-drained but moisture-retentive soils, including mountain meadow soils, forest soils, and skeletal substrates enriched with organic matter in rock crevices and slope accumulations. In riparian habitats, *Ribes* may occur on alluvial soils with periodic moisture supply, particularly along small streams and seasonal watercourses (Sagdullaev & Ishmuratova, 2016) [12].

Altitude represents an additional factor influencing the occurrence of *Ribes* species in the region. Although precise altitudinal ranges are not consistently reported in the literature, available observations suggest that wild *Ribes* populations in Central Kazakhstan are mainly confined to low- and mid-mountain belts, where climatic conditions are comparatively milder and precipitation levels are slightly higher than in surrounding plains (Takhtajan, 1986; Bai et al., 2025). The absence or rarity of *Ribes* species in lowland steppe areas underscores their limited tolerance to prolonged drought and high summer temperatures.

Overall, the distribution pattern of *Ribes* species in Central Kazakhstan can be characterized as fragmented and habitat-dependent, shaped by the presence of localized mesic microhabitats within a broader arid matrix. This spatial fragmentation has important implications for population structure, regeneration dynamics, and genetic diversity, as well as for the conservation and sustainable use of wild *Ribes* resources in the region. The observed habitat specificity also suggests that environmental factors may significantly influence bioecological traits and phytochemical profiles of wild-growing *Ribes* populations, a topic that warrants further investigation in subsequent sections of this review (Table 1).

Table 1

Wild-growing *Ribes* species reported for Central Kazakhstan and their main habitat characteristics

Species	Accepted species / taxonomic note	Habitat type in Central Kazakhstan	Typical microhabitats	Altitudinal range (if reported)	Main sources
Ribes aciculare Pall.	Accepted species	Mountain slopes, forest edges, rocky ravines	Shaded rocky slopes, moist gullies, forest understory	Low–mid mountain belt (not consistently reported)	Flora of Kazakhstan (1961–1975); Sagdullaev & Ishmuratova (2016)
Ribes nigrum L.	Accepted species	Riparian forests, moist valleys, shrub communities	Riverbanks, stream valleys, moist forest margins	Low–midmountain belt	Flora of Kazakhstan (1961–1975); Sagdullaev & Ishmuratova (2016); Bai et al. (2025)
Ribes saxatile Pall. s.l.	Species complex (*incl. R. diacantha*, *R. petr aeum* auct. non Wulfen, *R. rubrum* var. *saxatile*)	Rocky slopes, mountains hrublands	Rock crevices, north-facing slopes, screes	Mainly mountainbelt	Rehder (1940); Flora of Kazakhstan (1961–1975); Pikunova et al. (2022); Bai et al. (2025)

Note.

1. Habitat descriptions are summarized from regional floristic sources; detailed quantitative ecological data are limited for Central Kazakhstan.

2. The *Ribes saxatile* group is treated here as a species complex (sensulato) due to taxonomic inconsistencies among sources.

3. Altitudinal ranges are reported only when explicitly mentioned in the literature.

6. Bioecological Characteristics of Wild-Growing Ribes Species

Wild-growing species of the genus *Ribes* in Central Kazakhstan exhibit a range of bioecological traits that reflect their adaptation to heterogeneous and often stressful environmental conditions. These traits include life form characteristics, phenological patterns, reproductive strategies, mechanisms of seed dispersal

and regeneration, as well as responses to limiting environmental and anthropogenic factors. Available information on these aspects is derived mainly from regional floristic accounts and general ecological studies, while species-specific quantitative data remain limited for the region (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016) [13].

6.1. Life Forms and Population Traits

All wild *Ribes* species reported from Central Kazakhstan are perennial deciduous shrubs. They typically form multi-stemmed bushes with well-developed root systems, allowing them to persist in rocky substrates, shallow soils, and periodically dry habitats. Plant height and crown architecture vary depending on species, habitat conditions, and moisture availability. In shaded and relatively moist microhabitats, individuals may attain greater height and biomass, whereas in exposed rocky sites plants often exhibit reduced stature and compact growth forms (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975).

Populations of wild *Ribes* in the region are generally sparse and spatially fragmented, reflecting the patchy distribution of suitable habitats. Dense, continuous stands are uncommon; instead, plants occur as isolated individuals or small groups within shrub–herbaceous or forest communities. Such population structure may limit gene flow and regeneration potential, particularly under increasing anthropogenic pressure (Sagdullaev & Ishmuratova, 2016) [14].

6.2. Phenology

Phenological development of *Ribes* species in Central Kazakhstan follows a pronounced seasonal pattern typical of continental climates. Flowering usually occurs in spring to early summer, shortly after leaf emergence, while fruit ripening takes place in mid to late summer. The exact timing of phenological phases varies depending on altitude, slope exposure, and local microclimatic conditions. North-facing slopes and shaded valleys often exhibit delayed flowering and fruiting compared to more exposed sites (Flora of Kazakhstan Editorial Board, 1961–1975). Interannual variability in temperature and precipitation may further influence phenological timing, potentially affecting reproductive success and fruit yield in wild populations.

6.3. Seed Dispersal and Regeneration

The fruits of Ribes species are fleshy berries, which indicate that their seeds are most likely dispersed by animals, mainly birds and mammals. This type of dispersal can help the plants spread to suitable microhabitats and may also support gene flow between populations that are otherwise spatially separated. In Central Kazakhstan, seedling establishment is likely constrained by moisture availability, soil depth, and competition with herbaceous vegetation, particularly in steppe-dominated landscapes (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975).

Regeneration of wild *Ribes* populations appears to be episodic and dependent on favorable climatic conditions. Periods of increased precipitation may enhance seed germination and seedling survival, whereas prolonged droughts can severely limit recruitment. Empirical data on regeneration dynamics in the region are scarce and largely qualitative [15].

6.4. Limiting Factors

The distribution and viability of wild Ribes populations in Central Kazakhstan may be constrained by a combination of environmental and human-related factors. Natural limitations include climatic aridity, high summer temperatures, and low or irregular precipitation. At the same time, anthropogenic pressures such as grazing, trampling, fire, and local habitat disturbance can further reduce population size and hinder natural regeneration, particularly in easily accessible mountain valleys and riparian habitats (Sagdullaev & Ishmuratova, 2016).

Because suitable habitats are often fragmented and spatially limited, even relatively small disturbances can have significant consequences for small and isolated populations. Under such conditions, maintaining stable habitats becomes particularly important. These circumstances underline the need for habitat protection and regular monitoring in order to conserve the genetic resources of wild Ribes species in the region (Table 2) [16].

Table 2

Bioecological traits of wild Ribes species recorded in Central Kazakhstan

Species	Life form	Typical plant height	Flowering period	Fruiting period	Reproduction	Main limiting factors	Main sources
Ribes aciculare Pall.	Perennial deciduous shrub	Up to 1–1.5 m	Spring–early summer	Midlate summer	Mainly sexual; possible vegetative shoots	Drought; habitat fragmentation	Flora of Kazakhstan (1961–1975); Sagdullaev & Ishmuratova (2016)
Ribes nigrum L.	Perennial deciduous shrub	Up to 1.5–2 m	Spring	Summer	Sexual; insect pollination; vegetative propagation	Moisture deficit; anthropogenic disturbance	Flora of Kazakhstan (1961–1975); Hummer & Barney (2002); Sagdullaev & Ishmuratova (2016)
Ribes saxatile complex (s.l.)	Perennial deciduous shrub	Usually ≤1 m	Late spring	Summer	Predominantly sexual; zoochorous dispersal	Rocky substrates; limited soil moisture	Rehder (1940); Flora of Kazakhstan (1961–1975); Pikunova et al. (2022)

Note.

1. Phenological periods are generalized based on available regional floristic data; precise timing may vary with altitude and microclimatic conditions.

2. Data on reproductive biology are largely inferred from studies conducted outside Central Kazakhstan or on cultivated material.

3. The *Ribes saxatile* group is treated as a species complex (sensulato**)** due to unresolved taxonomic boundaries.

7. Species Accounts

7.1. Ribesaciculare Pall.Taxonomic and Diagnostic Notes

Ribes aciculare Pall. is a well-recognized species within the genus *Ribes*, characterized by its spiny shoots, relatively small leaves with shallow lobation, and compact shrub habit. The species is morphologically adapted to continental and often xeric or semi-xeric environments, which is reflected in its reduced leaf surface area and the presence of spines that may contribute to protection against herbivory (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975). In contrast to some other members of the genus, *R. aciculare* exhibits comparatively low morphological plasticity, which facilitates its identification in the field and in herbarium material.

Distribution and Habitats in Central Kazakhstan

In Central Kazakhstan, *Ribes aciculare* is reported primarily from mountainous and upland areas, where it occurs sporadically in ecologically sheltered sites. According to regional floristic sources, the species is confined to shaded ravines, rocky slopes, and forest margins, often associated with north-facing exposures that provide reduced solar radiation and improved moisture retention (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016). The fragmented distribution of *R. aciculare* reflects the patchy availability of suitable microhabitats within the predominantly arid steppe matrix of the region [17].

The species is typically encountered in small populations or as isolated individuals rather than forming continuous stands. Such distribution patterns suggest limited dispersal opportunities and a strong dependence on local environmental conditions. Similar habitat preferences have been reported for *R. aciculare* populations in adjacent regions of Central Asia, supporting the view that the species is ecologically specialized and sensitive to habitat alteration (Takhtajan, 1986).

Ecological Role and Associated Plant Communities

In Central Kazakhstan, *Ribes aciculare* usually occurs as part of shrub–herbaceous or forest-edge communities and rarely forms dominant stands. It may co-occur with other shrubs and woody plants adapted to mesic microhabitats, contributing to structural diversity and providing food resources for wildlife through its fruits. Although detailed phytosociological studies focusing specifically on *R. aciculare* are lacking, its presence in forested ravines and rocky slopes suggests a role in stabilizing soils and supporting local biodiversity (Sagdullaev & Ishmuratova, 2016).

Conservation Notes

At present, *Ribes aciculare* is not widely recognized as a threatened species at the national level; however, its fragmented distribution and dependence on specific microhabitats may render local populations vulnerable to environmental change. Potential threats include habitat disturbance, overgrazing, and increased aridity associated with climate change. Given the limited data on population size, structure, and regeneration dynamics in Central Kazakhstan, targeted field surveys are required to assess the conservation status of the species more accurately [18].

7.2. Ribes nigrum L.

Taxonomic and Diagnostic Notes

Ribes nigrum L. (black currant) is one of the most widely recognized and economically important species of the genus *Ribes*. It is characterized by erect to spreading deciduous shrubs, palmately lobed leaves with glandular dots, racemose inflorescences, and black aromatic berries rich in phenolic compounds [19]. The species shows considerable morphological variability across its range, partly reflecting ecological plasticity and adaptation to different climatic conditions (Rehder, 1940; Hummer & Barney, 2002). Despite extensive research on cultivated forms, wild-growing populations remain less well documented in many regions, including Central Kazakhstan.

Ecological Role and Associated Plant Communities

In Central Kazakhstan, Ribes nigrum usually occurs as a minor component of riparian and forest-edge plant communities rather than forming dominant stands. It commonly grows together with other moisture-demanding shrubs and herbaceous plants. Within these communities, the species contributes to the understorey structure and may play an ecological role by helping stabilize soils and providing food resources for various wildlife species. The berries are consumed by birds and mammals, facilitating zoochorous seed dispersal and potentially enhancing gene flow among fragmented populations (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975) [20].

Although *R. nigrum* rarely forms dense stands in the region, its presence in ecologically sensitive habitats underscores its potential role as an indicator species for mesic microhabitats within arid landscapes. Disturbance of riparian zones and forest fragments may therefore disproportionately affect local populations.

Conservation Notes

At present, *Ribes nigrum* is not considered a threatened species in Central Kazakhstan; nevertheless, wild populations may be vulnerable to habitat degradation, hydrological changes, and increasing anthropogenic pressure in riparian zones. The fragmented nature of suitable habitats, combined with limited data on

population size and regeneration, complicates conservation assessment. Protection of moist habitats and forest fragments is therefore essential for maintaining wild *R. nigrum* populations and preserving their potential value as genetic resources for breeding and adaptation studies (Sagdullaev & Ishmuratova, 2016) [21].

7.3. Ribes saxatile Species Complex (sensulato)

Taxonomic Background and Rationale for the "Species Complex" Concept

The taxon traditionally referred to as *Ribes saxatile* Pall. represents one of the most taxonomically challenging groups within the genus *Ribes*. Across different floristic and systematic treatments, this group has been variously interpreted as a single polymorphic species, a set of closely related species, or a collection of intraspecific taxa adapted to rocky and montane habitats (Rehder, 1940; Flora of Kazakhstan Editorial Board, 1961–1975). Names such as *Ribes diacantha* Pall., *Ribes petraeum*auct. non Wulfen, and *Ribes rubrum* var. *saxatile* have frequently been applied to morphologically similar plants, often without consistent diagnostic criteria [22].

In many cases, the application of these names reflects regional taxonomic traditions rather than clear biological discontinuities. As a result, the same or closely similar populations may be treated under different names in different parts of Eurasia. This situation has led to considerable ambiguity in the interpretation of distributional and ecological data, particularly in regions where detailed taxonomic revisions are lacking.

Treatment of the Ribes saxatile Complex in Central Kazakhstan

In floristic accounts of Central Kazakhstan, including regional monographs and checklists, taxa attributable to the *Ribes saxatile* group are consistently reported; however, their exact taxonomic circumscription varies among sources (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016). Some authors recognize *R. saxatile* Pall. as a distinct species, while others refer to related forms under alternative names or treat them as variants within a broader species concept.

Given the absence of integrative taxonomic studies (combining morphology, genetics, and ecology) for Central Kazakhstan populations, a conservative approach is adopted in the present review [23]. All records corresponding to this group are therefore treated collectively as the *Ribes saxatile species complex (sensulato)*, encompassing plants referred to in the literature as *R. saxatile* Pall., *R. diacantha* Pall., *R. petraeum*auct. non Wulfen, and *R. rubrum* var. *saxatile*. This approach allows for the synthesis of available data without imposing potentially unsupported taxonomic decisions.

Distribution and Habitat Preferences

In Central Kazakhstan, representatives of the *Ribes saxatile* complex are primarily associated with mountainous and rocky habitats. They are most frequently recorded on rocky slopes, screes, cliff faces, and north-facing exposures, where shallow soils, reduced competition, and localized moisture retention create suitable conditions for shrub establishment (Flora of Kazakhstan Editorial Board, 1961–1975; Sagdullaev & Ishmuratova, 2016) [24].

Reproductive Biology and Regeneration

Information on the reproductive biology of *Ribes saxatile*s.l. in Central Kazakhstan is extremely limited. As with other members of the genus, reproduction is presumed to be predominantly sexual, with insect pollination and zoochorous seed dispersal via fleshy berries. However, direct observations of pollination biology, seed dispersal agents, and regeneration dynamics are lacking for regional populations (Flora of Kazakhstan Editorial Board, 1961–1975) [25].

The fragmented distribution of suitable rocky habitats suggests that populations may be small and isolated, potentially limiting gene flow and increasing vulnerability to environmental change. At the same time, the persistence of *R. saxatile*s.l. in extreme microhabitats indicates a degree of ecological resilience, which may be of interest for future studies on stress tolerance and adaptation.

Conservation Considerations

Although taxa of the *Ribes saxatile* complex are not currently recognized as threatened in Central Kazakhstan, their restriction to specialized rocky habitats may increase sensitivity to localized disturbances, such as mining activities, infrastructure development, and changes in hydrological regimes. The lack of detailed population-level data hampers accurate assessment of conservation status [26].

From a conservation and research perspective, the *Ribes saxatile* complex represents an important target for future integrative studies aimed at clarifying species boundaries, assessing genetic diversity, and evaluat-

ing adaptive traits under continental and montane conditions. Such studies would not only resolve long-standing taxonomic questions but also contribute to the sustainable management of wild *Ribes* genetic resources in Central Kazakhstan.

8. Major Compound Classes

Phenolic Compounds

Phenolic compounds represent the dominant class of secondary metabolites in *Ribes* species. These include flavonols, flavan-3-ols, proanthocyanidins, and phenolic acids, which contribute significantly to antioxidant capacity and other biological effects (Oszmiański & Wojdyło, 2009; Dobson et al., 2012). In *Ribes nigrum*, numerous phenolic constituents have been identified, including derivatives of quercetin, myricetin, and kaempferol, as demonstrated by chromatographic analyses of fruit and leaf extracts (Koponen et al., 2007; Izteleuova et al., 2025) [27].

Anthocyanins

Anthocyanins are particularly abundant in the fruits of *Ribes nigrum* and represent key phytochemical markers of the species. The major anthocyanins commonly reported include delphinidin-3-O-rutinoside, cyanidin-3-O-rutinoside, delphinidin-3-O-glucoside, and cyanidin-3-O-glucoside (Koponen et al., 2007; Krüger & Dietrich, 2018). These compounds are largely responsible for the intense coloration of black currant fruits and their strong antioxidant properties.

Vitamins, Organic Acids, and Sugars

In addition to phenolic compounds, *Ribes* fruits are known to contain considerable amounts of vitamins, particularly vitamin C, as well as various organic acids and sugars that influence nutritional value and sensory properties (Nour et al., 2011; Izteleuova et al., 2025). Citric and malic acids are frequently reported as dominant organic acids in the genus, although quantitative profiles may vary depending on species, environmental conditions, and developmental stage [28].

Seed Lipids and Fatty Acids

Seeds and pomace of *Ribes nigrum* have attracted attention as potential sources of biologically active lipids and fatty acids, particularly in the context of by-product utilization and sustainable processing. Studies employing green extraction technologies, such as supercritical CO_2 extraction, highlight the relevance of seed-derived fractions for functional food and nutraceutical applications (Krüger & Dietrich, 2018) (Table 3) [29].

Table 3

Key phytochemical marker groups and analytical methods reported for *Ribes* (with relevance to Central Kazakhstan review)

Taxon (Central Kazakhstan)	Major reported compound classes	Representative markers (examples)	Typical analytical methods	Evidence base in provided sources
Ribes aciculare	Phenolics expected at genus level	(Data insufficient for CK wild populations in provided set)	HPLC-DAD / LC–MS/MS (commonly used in *Ribes*)	Genus-level summary only
Ribes nigrum	Anthocyanins, flavonols, phenolic acids; also seed-related lipids in by-products	Delphinidin- and cyanidin-glycosides (rutinosides/glucosides); quercetin-/myricetin-/kaempferol-glycosides	HPLC-DAD-ESI-MS;UVC postharvest experiments with phenolic profiling; SFE-CO_2 for pomace fractions	Strong (multiple experimental review sources)
Ribes saxatile complex (s.l.)	Phenolics expected at genus level; species-level specificity unresolved	(Data insufficient for CK wild populations in provided set)	HPLC-DAD / LC–MS/MS (commonly used in *Ribes*)	Genus-level summary only

Note. "CK" = Central Kazakhstan. Where Central Kazakhstan–specific datasets are missing, the table explicitly indicates insufficient evidence rather than extrapolating.

9. Biological and Pharmacological Activities

Biological and pharmacological activities reported for species of the genus *Ribes* are largely attributed to their rich phytochemical composition, particularly phenolic compounds such as anthocyanins, flavonols, proanthocyanidins, and phenolic acids. Numerous experimental and review studies indicate that extracts and isolated fractions from *Ribes* species exhibit a broad spectrum of biological effects, including antioxidant, anti-inflammatory, antimicrobial, and other health-related activities (Brennan, 2008; Krüger & Dietrich, 2018; Izteleuova et al., 2025) [30, 31].

It should be emphasized that the majority of available evidence originates from cultivated material or wild populations outside Central Kazakhstan. Consequently, the activities summarized below reflect genus- and species-level knowledge, while data specifically obtained from wild-growing *Ribes* populations in Central Kazakhstan remain extremely limited.

10. Ethnobotany and Traditional Uses

Species of the genus *Ribes* have a long history of traditional use as food and medicinal plants across Eurasia and other temperate regions. Ethnobotanical records indicate that fruits, leaves, and, less frequently, buds of various *Ribes* species have been utilized in traditional diets, folk medicine, and household practices, primarily due to their perceived health-promoting properties and pleasant organoleptic characteristics (Moerman, 1998; Brennan, 2008; Izteleuova et al., 2025) [32].

Among the species occurring in Central Kazakhstan, *Ribes nigrum* L. is the most widely documented in ethnobotanical and traditional contexts. Its fruits have been traditionally consumed fresh or processed into juices, preserves, and fermented beverages, while leaves have been used in herbal infusions and decoctions. These practices are commonly associated with the treatment or prevention of colds, fever, inflammatory conditions, and general weakness, reflecting the high vitamin and polyphenol content reported for the species (Brennan, 2008; Krüger & Dietrich, 2018) [33].

In contrast, ethnobotanical information specifically referring to *Ribes aciculare* Pall. and taxa belonging to the *Ribes saxatile* species complex is scarce and largely anecdotal. In several regions of Eurasia, related taxa have been reported as minor food sources or as components of local herbal remedies; however, detailed descriptions of preparation methods, dosage, or therapeutic efficacy are generally lacking (Moerman, 1998). For Central Kazakhstan in particular, no systematic ethnobotanical surveys focusing on wild-growing *Ribes* species have been published to date, and available regional floristic works provide little or no information on traditional uses (Sagdullaev & Ishmuratova, 2016) [34].

It is important to emphasize that much of the ethnobotanical knowledge reported for *Ribes* species originates from cultivated material or from regions with long-standing horticultural traditions, such as Europe and East Asia. Extrapolation of these uses to wild-growing populations in Central Kazakhstan should therefore be approached with caution. Environmental conditions, genetic differentiation, and phytochemical variability may all influence the suitability and efficacy of plant material used for food or medicinal purposes.

Despite these limitations, the presence of well-documented traditional uses for *Ribes nigrum* and related taxa suggests a potential cultural and practical relevance of wild *Ribes* species in Central Kazakhstan. However, this aspect remains poorly explored and represents a promising direction for future interdisciplinary research integrating ethnobotany, phytochemistry, and conservation biology. Systematic documentation of local knowledge, where available, could help broaden our understanding of the role of *Ribes* species in regional human–plant relationships and may also support the development of sustainable use strategies [35].

Conclusion

1. Wild-growing species of the genus *Ribes* occurring in Central Kazakhstan (*Ribes aciculare*, *Ribes nigrum*, and the *Ribes saxatile* species complex) represent ecologically specialized taxa adapted to fragmented and heterogeneous habitats within a predominantly arid continental landscape.

2. The distribution of *Ribes* species in the region is strongly associated with localized mesophilous microhabitats, including moist ravines, riparian zones, forest edges, and rocky slopes, resulting in small, spatially isolated populations with limited connectivity.

3. At present, bioecological information on Ribes species in Central Kazakhstan is based mainly on qualitative floristic observations, while quantitative data on population structure, regeneration dynamics, and reproductive success are still largely lacking.

4. Although the antioxidant, anti-inflammatory, and antimicrobial properties of Ribes species are well documented in the international literature, direct evidence from wild populations in Central Kazakhstan remains very limited and should not be generalized without empirical verification.

5. The taxonomic complexity of the Ribes saxatile species complex represents a significant challenge for ecological interpretation and conservation planning in the region. This situation highlights the need for integrative studies that combine taxonomic and genetic approaches.

6. Future interdisciplinary research integrating field ecology, phytochemistry, molecular taxonomy, and bioactivity assessment is essential to advance understanding of *Ribes* species in Central Kazakhstan and to support evidence-based conservation and utilization strategies.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CRediT: **Zhanayeva M.B. —** investigation, visualization, manuscript writing; **Shmakov A.I. —** checking manuscripts, correcting comments, data curation.

Conflict of Interest

The authors declare no conflict of interest.

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М.Б. Жанаева, А.И. Шмаков

Орталық Қазақстанда *Ribes* L. тұқымдасының жабайы өсетін түрлері: биоэкологиялық сипаттамасы

Ribes L. (Grossulariaceae) туысы экологиялық, тағамдық және дәрілік маңызы бар, Солтүстік жарты шардың қоңыржай аймақтарында кең таралған көптеген түрлерді қамтиды. Орталық Қазақстан — ландшафтарының алуан түрлілігімен және табиғи климаттық жағдайларының гетерогендігімен сипатталатын биогеографиялық тұрғыдан күрделі өңір. Алайда осы аймақта өсетін *Ribes* туысының жабайы түрлері туралы мәліметтер әлі де бытыраңқы әрі жеткілікті деңгейде жүйеленбеген. Шолудың мақсаты — Орталық Қазақстан аумағында таралған *Ribes* туысының жабайы түрлеріне, атап айтқанда *Ribes aciculare Pall.*, *Ribes nigrum L.* және *Ribes saxatile* түрлік кешенінің өкілдеріне қатысты биоэкологиялық ерекшеліктерді, фитохимиялық құрамды және зерттеу перспективаларын сипаттайтын әдеби деректерді жинақтау және сыни тұрғыдан талдау. Шолу халықаралық және аймақтық ғылыми журналдарда жарияланған флористикалық деректерге, экологиялық зерттеулерге және фитохимиялық еңбектерге негізделген. Түрлердің таралуы, мекен ету ортасы, фенологиясы және экологиялық бейімделу ерекшеліктері туралы мәліметтер, сондай-ақ антоциандар, флавоноидтер, проантоцианидиндер, органикалық қышқылдар мен витаминдер сияқты биологиялық белсенді қосылыстардың негізгі топтары жөніндегі ақпарат жүйелендірілді. *R. nigrum* туысының ең жақсы зерттелген түрі ретінде фитохимиялық тұрғыдан кеңірек қарастырылып, басқа жабайы таксондар

бойынша деректердің шектеулі әрі үзінді сипатта екендігі атап өтілді. Сонымен қатар *R. saxatile* түрлік кешеніне байланысты таксономиялық белгісіздіктер талданып, аймақтық зерттеулерде түрлерді нақты ажыратудың маңыздылығы көрсетілді. Жүргізілген талдау қазіргі білімдегі елеулі олқылықтарды, әсіресе аймаққа тән фитохимиялық профильдер, популяциялық деңгейдегі экологиялық өзгергіштік және қоршаған орта факторлары мен екінші реттік метаболиттердің жиналуы арасындағы байланыстар жөніндегі мәліметтердің жеткіліксіздігін анықтады. Болашақ зерттеулердің негізгі бағыттары ретінде биоэкологиялық және фитохимиялық тәсілдерді кешенді қолдану, жабайы генетикалық ресурстарды сақтау және Орталық Қазақстандағы *Ribes* туысы түрлерін тұрақты пайдалану ұсынылады.

Кілт сөздер: Ribes L., Орталық Қазақстан, биоэкология, фитохимиялық құрам, қарақат, дәрілік өсімдіктер, жабайы өсетін түрлер.

М.Б. Жанаева, А.И. Шмаков

Дикорастущие виды рода *Ribes L.* в Центральном Казахстане: биоэкологические характеристики

Род Ribes L. (Grossulariaceae) включает многочисленные виды, обладающие экологической, пищевой и лекарственной ценностью и широко распространённые в умеренных регионах Северного полушария. Центральный Казахстан представляет собой биогеографически сложную территорию, характеризующуюся разнообразием ландшафтов и гетерогенностью природно-климататических условий; вместе с тем сведения о дикорастущих видах рода *Ribes* в данном регионе остаются фрагментарными и недостаточно систематизированными. Цель настоящего обзора — обобщение и критическая оценка литературных данных, посвящённых биоэкологическим особенностям, фитохимическому составу и перспективам изучения дикорастущих видов *Ribes*, произрастающих в Центральном Казахстане, с акцентом на *Ribes aciculare Pall., Ribes nigrum L.* и представителей видового комплекса *Ribes saxatile.* Обзор основан на анализе региональных флористических источников, экологических исследований и фитохимических работ, опубликованных в международных и региональных научных журналах. Систематизированы данные о распространении видов, их местообитаниях, фенологии и экологических адаптациях, а также сведения об основных группах биологически активных соединений, включая антоцианы, флавоноиды, проантоцианидины, органические кислоты и витамины. Особое внимание уделено фитохимическим исследованиям *R. nigrum* как наиболее изученного вида рода, при одновременном подчёркивании ограниченного и фрагментарного характера данных по другим дикорастущим таксонам. Кроме того, рассматриваются таксономические неопределённости, связанные с видовым комплексом *R. saxatile*, что указывает на необходимость более точной делимитации видов в региональных исследованиях. Проведённый анализ выявил существенные пробелы в современных знаниях, прежде всего в отношении регионально-специфических фитохимических профилей, популяционной экологической изменчивости и взаимосвязи факторов среды с накоплением вторичных метаболитов. В заключение обозначены перспективные направления дальнейших исследований, ориентированные на интеграцию биоэкологических и фитохимических подходов, сохранение диких генетических ресурсов и устойчивое использование видов рода *Ribes* в Центральном Казахстане.

Ключевые слова: Ribes L, Центральный Казахстан, биоэкология, фитохимический состав, смородина, лекарственные растения, дикорастущие виды.

Information about the authors

Zhanayeva Merey Baibolovna — PhD-student, Karaganda National Research University / named after Academician E.A. Buketov, Karaganda, Kazakhstan; e-mail: merey.baibolovna@mail.ru: ORCID: https://orcid.org/0009-0002-2841-3897

Shmakov Alexander Ivanovich — Doctor of Biological Sciences, Professor, Altai State University: Barnaul, Russia; e-mail: alex_shmakov@mail.ru ORCID: https://orcid.org/0000-0002-1052-4575