IRSTI 34.29.35 https://doi.org/10.26577/bb202510438

G. Kairanova[1*], A. Mamurova[1], G. Yeszhanova[1], A. Rakhymzhan[1], A. Beyatli[2]

[1]Al-Farabi Kazakh National University, Almaty, Kazakhstan
[2] University of Health Sciences, Istanbul, Turkey
*e-mail: gulzat-amanzholova@mail.ru

ENVIRONMENTAL AND BIOLOGICAL FEATURES AND ASSESSMENT OF THE CURRENT STATE OF *ZYGOPHYLLUM FABAGO* L. (*ZYGOPHYLLACEAE*) POPULATIONS IN THE ILE-BALKHASH REGION

The scientific article highlights the ecological and biological characteristics of populations of *Zygophyllum fabago* L. (*Zygophyllaceae*) growing in the Ile-Balkhash region of Almaty Region. The article analyzes the current state of *Zygophyllum fabago* L. cenopopulations, its morphological features, life forms, and ecological reactions in saline and semi-desert ecosystems of the Ile-Balkhash region. The flora of *Zygophyllum fabago* L. populations consists of 71 species from 47 genera and 20 families. The dominant ecological groups are xerophytes (42.25%), mesoxerophytes (28.17%), and mesophytes (14.08%). The leading families are *Chenopodiaceae* (21.13%), *Fabaceae* (16.90%), and *Asteraceae*, which together make up 60.56% of the total flora. The study revealed the high salt tolerance of *Zygophyllum fabago* L., which allows it to play an important role in soil stabilization and biodiversity conservation in the Ile-Balkhash region. In traditional medicine *Zygophyllum fabago* L. is widely used as an antiseptic, anti-inflammatory, and wound-healing agent. A taxonomic, ecological, and geographical analysis of the flora of *Zygophyllum fabago* L. populations emphasizes the uniqueness and biodiversity of the ecosystems in the Ile-Balkhash region. The data obtained emphasize the need to take measures to preserve this species and ensure the sustainable use of its resources.

Keywords: *Zygophyllum fabago* L.; *Zygophyllaceae*; coenopopulation; Ile-Balkhash region.

Г. Кайранова[1]*, А. Мамурова[1], Г. Есжанова[1],
А. Рахымжан[1], А. Бейатлы[2]

[1]Әл-Фараби атындағы Қазақ ұлттық университеті, әл-Фараби 71, Алматы, Қазақстан
[2] Медицина Ғылымдарының Университеті, Ыстамбұл, Түркия
*e-mail: gulzat-amanzholova@mail.ru

Іле-Балқаш өңіріндегі *Zygophyllum fabago* L. (*Zygophyllaceae*) популяцияларының экологиялық және биологиялық ерекшеліктері мен қазіргі жағдайын бағалау

Ғылыми мақалада Алматы облысының Іле-Балқаш өңірінде өсетін *Zygophyllum fabago* L. (*Zygophyllaceae*) популяцияларының экологиялық және биологиялық ерекшеліктері қарастырылған. Мақалада *Zygophyllum fabago* L. ценопопуляциясының қазіргі жағдайы, Іле-Балқаш өңірінің тұзды және шөлейтті экожүйелеріндегі морфологиялық ерекшеліктері, тіршілік формалары мен экологиялық реакциялары талданады. *Zygophyllum fabago* L. популяциясының флорасы 47 тұқымдас пен 20 тұқымдастың 71 түрінен тұрады. Басым экологиялық топтарға ксерофиттер (42,25%), мезоксерофиттер (28,17%) және мезофиттер (14,08%) жатады. Жетекші тұқымдастарға *Chenopodiaceae* (21,13%), *Fabaceae* (16,90%) және *Asteraceae* жатады, олар жалпы флораның 60,56% құрайды. Зерттеу нәтижелері *Zygophyllum fabago L.* өсімдігінің тұзды топыраққа жоғары төзімді екенін көрсетті. Бұл қасиет оған Іле-Балқаш аймағындағы топырақты тұрақтандыруға және биоалуантүрлілікті сақтауға елеулі үлес қосуға мүмкіндік береді. Халық медицинасында *Zygophyllum fabago* L. антисептикалық, қабынуға қарсы және жараларды емдейтін агент ретінде кеңінен қолданылады. *Zygophyllum fabago* L. популяцияларының флорасына таксономиялық, экологиялық және географиялық талдау Іле-Балқаш аймағының экожүйелерінің айрықшылығы мен биоалуантүрлілігін көрсетеді. Мақалада көрсетілген нәтижелер *Zygophyllum fabago* L. түрін сақтау және оның ресурстарын тұрақты пайдалануды қамтамасыз ету бойынша шаралардың қажеттілігін көрсетеді.

Түйін сөздер: *Zygophyllum fabago* L.; *Zygophyllaceae;* ценопопуляция; Іле-Балқаш өңірі.

Г. Кайранова[1]*, А. Мамурова[1], Г. Есжанова[1],
А. Рахымжан[1], А. Бейатлы[2]
[1]Казахский национальный университет имени аль-Фараби, Алматы, Казахстан
[2]Университет медицинских наук, Стамбул, Турция
*e-mail: gulzat-amanzholova@mail.ru

Экологические и биологические особенности и оценка текущего состояния популяций *Zygophyllum fabago* L. (*Zygophyllaceae*) в Иле-Балхашском регионе

В научной статье рассматриваются эколого-биологические особенности популяций парнолистника обыкновенного (*Zygophyllum fabago* L.) (*Zygophyllaceae*), произрастающего в Иле-Балхашском районе Алматинской области. Проведен анализ современного состояния ценопопуляций парнолистника бобового (*Zygophyllum fabago* L.), его морфологических особенностей, жизненных форм и экологических реакций в засоленных и полупустынных экосистемах Иле-Балхашского региона. Флора популяций парнолистника бобового (*Zygophyllum fabago* L.) представлена 71 видом из 47 родов и 20 семейств. Доминирующими экологическими группами являются ксерофиты (42,25%), мезоксерофиты (28,17%) и мезофиты (14,08%). Ведущими семействами являются *Chenopodiaceae* (21,13%), *Fabaceae* (16,90%) и *Asteraceae*, которые в совокупности составляют 60,56% от общей флоры. В результате исследования выявлена высокая солеустойчивость *Zygophyllum fabago* L., что позволяет ему играть важную роль в стабилизации почв и сохранении биоразнообразия в Иле-Балхашском регионе. В народной медицине *Zygophyllum fabago* L. широко используется как антисептическое, противовоспалительное и ранозаживляющее средство. Таксономический, эколого-географический анализ флоры популяций *Zygophyllum fabago* L. подчеркивает уникальность и биоразнообразие экосистем Иле-Балхашского региона. Полученные данные подчеркивают необходимость принятия мер по сохранению этого вида и обеспечению устойчивого использования его ресурсов.

Ключевые слова: *Zygophyllum fabago* L., *Zygophyllaceae*, ценопопуляция, Иле-Балхашский регион.

Introduction

The Ile-Balkhash region is located in the central part of Kazakhstan, covering an area of approximately 200,000 km². It includes the Ile River Basin and the northern shore of Lake Balkhash. The region encompasses semi-desert, steppe, and mountainous areas, highlighting its unique landscape. The climate in the Ile-Balkhash region is characterized by significant seasonal temperature variations. In summer, temperatures can rise to 40°C, while in winter, they drop below -30°C, with average annual temperatures ranging from 7°C to 12°C in some areas [1].

The Ile River is a vital water source for both humans and wildlife. Originating in the Tien Shan Mountains, it flows into Lake Balkhash. The region's topography is diverse: the northern part features flat terrain and gentle slopes near the Ile Basin, whereas the southern part is characterized by rising landscapes leading to the hills of the Alatau Mountains. Additionally, the Ile River delta contains wetland areas that serve as crucial stopover sites for migratory birds [2]. The region supports a wide range of biodiversity, including salt-tolerant plants and desert species. Many of the species inhabiting the area have developed adaptations to survive its harsh environmental conditions. Although agricultural activities are present, the region faces challenges such as water scarcity, desertification, and pollution [3].

To protect the ecosystem of region, including its endangered species, and to maintain biodiversity, the Ile-Balkhash State Reserve was established. It is situated between 45° N latitude and 75°–80° E longitude, extending from the Ile River in the west to the eastern shores of Lake Balkhash. To the north, it is bordered by the Chu-Ili Mountains, while its southern boundary is adjacent to the Gobi Desert. In addition to its ecological significance, the reserve holds economic value in agriculture, wildlife conservation, and sustainable tourism [4].

The Ile-Balkhash region in the southeastern part of Kazakhstan is a part of the lager Ile River Basin. It has various desert, semi-desert landscapes, saline wetlands and river valley [5]. The structure of this environment makes the region suitable to study *Zygophyllum fabago* L., salt-tolerant plant species belongs to the family of *Zygophyllaceae*. It has ability to survive in saline soil conditions of Central Asia [6]. *Zygophyllum fabago* L., a perennial herbaceous plant normally found in solonchaks of Ile-Balkhash region, has developed adaptations to extremely salt environment and possesses the ability to store moisture during dry periods because of drought-resistant leaves. The plant typically reaches a height of 30-75 cm and

displays a branching growth form. Its capsule is cylindrical in shape, short or long, drooping or deflected downwards with a length of 15-40 mm. Flowering occurs primarily between April and June months, with the species favoring desert steppe ecosystems, particularly in salty or sandy substrates [7-8].

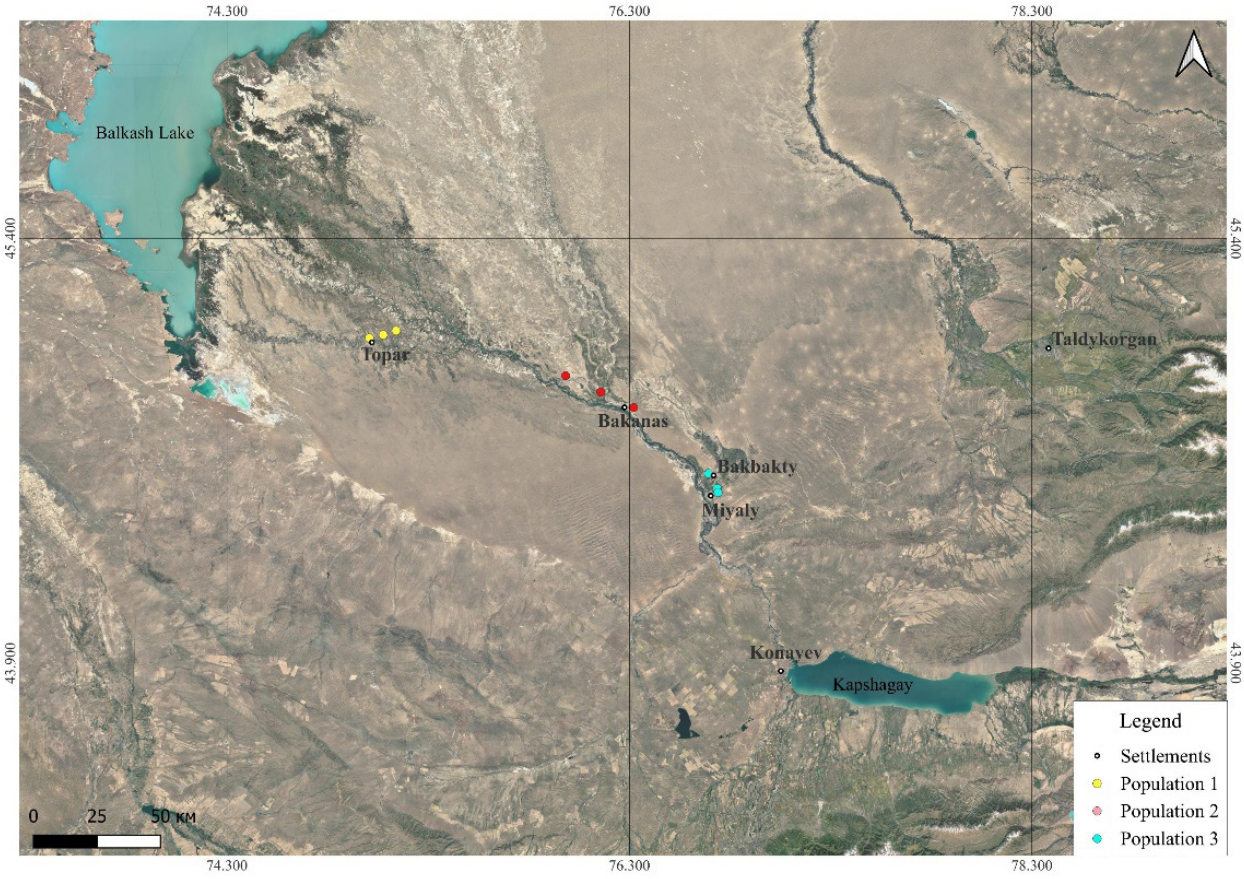

Figure 1 – Map of the Ile-Balkhash region, Almaty district

Zygophyllum fabago L. plays a crucial role in stabilizing erosive soils; this feature allows it to reduce the effects of wind and water degradation. It contributes to the long-term maintenance of soil structure and fertility. Additionally, this plant is an important component of the local food web, serving as a food resource for various desert-adapted herbivores and providing shelter for insects and other small animals. All these features make *Zygophyllum fabago* L. one of the major contributors to biodiversity conservation in the region's saline and semi-arid environments, further enhancing its ecological importance in this fragile habitat [9-10].

Studies on the distribution of *Zygophyllum fabago* L. within the Ile-Balkhash region demonstrate a strong correlation between its prevalence and the ecological conditions of solonchak habitats. The species exhibits exceptional adaptability to high-salinity soils and is one of the few dominant plant species capable of thriving in such environments. Therefore, it plays an essential role in shaping the structure and composition of local plant communities.

Additionally, *Zygophyllum fabago* L. has economic significance. Its seeds have been used in medicine, and chemical analyses have been conducted to study its biological properties. This highlights its potential applications in the pharmaceutical and agricultural sectors [11].

Recent ecological surveys on *Zygophyllum fabago* L. populations in the Almaty region have revealed significant environmental pressures affecting the species. While the plant has developed a strong capacity for survival in saline and arid conditions, it

remains highly vulnerable to prolonged disturbances in the region's water balance. It also faces additional threats, such as overgrazing, agricultural expansion, and urban sprawl, which further endanger its habitat. Conservation initiatives have been undertaken to protect solonchak ecosystems, contributing to the persistence of this valuable species amid environmental changes [12–13].

Materials and methods

2.1. Research objects

Species Studied: *Zygophyllum fabago* L. from the family *Zygophyllaceae*. The studies were conducted in 2024 within the natural phytocenoses of the Ile-Balkhash region, Almaty region (Table 1).

Table 1 – Cenopopulations of the species *Zygophyllum fabago* L. were discovered during field studies

Species, P/CP number	Geographical distribution	GPS coordinates & elevation
Z.Fabago L. P1/CP1	Balkhash-Alakol Flora Reserve, Almaty Region, Balkhash District, Near the settlement of Topar. Delta of the Ili River.	N 45,05190519; E 75,00765995; h-362 m.
Z.Fabago L. P1/CP2	Balkhash-Alakol Flora Reserve, Almaty Region, Balkhash District, Near the settlement of Topar. Delta of the Ili River.	N 45,06234703; E 75,07622249; h-360 m.
Z.Fabago L. P1/CP3	Balkhash-Alakol Flora Reserve, Almaty Region, Balkhash District, Near the settlement of Topar. Delta of the Ili River.	N 45,07735082; E 75,14082324; h-355 m.
Z.Fabago L. P2/CP1	Balkhash-Alakol Flora Reserve, Almaty Region, Balkhash District, Near the settlement of Bakanas. Saryesik-Atyrau.	N 44,91989194; E 75,982814; h-389 m.
Z.Fabago L. P2/CP2	Balkhash-Alakol Flora Reserve, Almaty Region, Balkhash District, Near the settlement of Bakanas. Saryesik-Atyrau.	N 44,8617504; E 76,15751952; h-396 m.
Z.Fabago L. P2/CP3	Balkhash-Alakol Flora Reserve, Almaty Region, Balkhash District, Near the settlement of Bakanas. Saryesik-Atyrau.	N 44,8071172; E 76,32089236; h-400 m.
Z.Fabago L. P3/CP1	Balkhash-Alakol Flora Reserve, Almaty Region, Balkhash District, Near the settlement of Bakbakty. Saryesik-Atyrau.	N 44,57463061; E 76,69245509; h-415 m.
Z.Fabago L. P3/CP2	Balkhash-Alakol Flora Reserve, Almaty Region, Balkhash District, Near the settlement of Bakbakty. Saryesik-Atyrau.	N 44,52143244; E 76,73579867; h-415 m.
Z.Fabago L. P3/CP3	Balkhash-Alakol Flora Reserve, Almaty Region, Balkhash District, Near the settlement of Miyaly. Along the canal. Saryesik-Atyrau.	N 44.507513; E 76.740675; h-420 m.

Notes: P-populations; CP – coenopopulations; N – north, E – east; h – above sea level.

Research methods

The main methods used to study the morphological and biological characteristics of *Zygophyllum fabago* L. included observations of its morphological signs, biological characteristics, taxonomy, and floristics. Traditional geobotanical research methods were applied, focusing on the coenopopulations of *Zygophyllum fabago* L. and their interactions with the environment. The geobotanical characterization of the coenopopulations was conducted as extensively as possible, and their locations were recorded using GPS (Garmin eTrex 22x).

Fieldwork employed a route reconnaissance method, in which plants were identified and sampled while moving along predetermined routes. This approach allowed for the survey of large areas and the assessment of species diversity. Population studies were conducted using standard methods in modern plant population biology [14–19].

Herbarium samples were collected and processed following established procedures. *Zygophyllum fabago* L. specimens were placed in herbarium folders with detailed information on the collection locality, date, and collector. The material was dried and examined under binocular magnifying glasses after fieldwork. Herbarium sample collection and preparation adhered to traditional procedures [20].

Species identification and taxonomy were carried out in the laboratory using multi-volume reference books [21–23]. The species and generic classification of *Zygophyllum fabago* L. in the Ile-Balkhash

region was based on the classifications of Abdulina and Cherepanov [24, 25]. The analysis of life forms followed the classification system of Serebryakov [26]. To confirm species identification, a portion of the collected material was preserved and shipped to the Institute of Botany and Phytointroduction, Almaty, Kazakhstan, for herbarium storage (voucher no: 05/337).

During the field survey, three populations of *Zygophyllum fabago* L. were identified, each consisting of three coenopopulations, totaling nine coenopopulations. The morphological characteristics of the species were examined in both living plants and herbarium specimens.

Statistical review of measurement data in Microsoft Excel 2019. The methods of the described statistics were compared, including the calculation of mean values, standard deviations (SD). Statistical significance was assessed at a mean innovation level of $p < 0.05$.

Results and discussion

Plants population identification

To determine the natural habitats of *Zygophyllum fabago* L. around the Bakanas settlement area in the Ile-Balkhash and Almaty regions, expedition routes were mapped, flowering periods were recorded, and ecological niches were studied. This research was conducted through the examination of herbarium specimens from the central collection of the Institute of Botany and Phytointroduction.

The natural habitats of *Zygophyllum fabago* L. in these regions are characterized by yellowish, low-humus soils (Figure 2).

As a result, to the survey of expeditions, there were three large populations (each population has three coenopopulations) of *Zygophyllum fabago* L. recorded in varied phytocenotic and ecological habitats. They were found on parent rocks outcrops, low-humus sands, and loamy sandy soils *(Fig. 2)*.

Figure 2 – Population of *Zygophyllum fabago* L. identified in the Ile-Balkhash, Almaty district

Ecological groups of populations

The flora of the studied populations of *Zygophyllum fabago* L. in the Ile-Balkhash region of the Almaty region comprises 71 species from 47 genera and 20 families. Key indicator species include *Sophora alopecuroides, Petrosimonia brachiata, Ceratocarpus arenarius, Kraschenninnikovia ceratoides, Climacoptera lanata, Ceratocarpus utriculosus, Acroptilon repens, Descurainia sophia,* and *Lepidium perfoliatum.* The primary factors limiting the distribution of these species are intense competition within phytocenoses, anthropogenic impact, and specific ecological requirements. The main ecological groups of plants in the populations of *Zygo-*

phyllum fabago L. are as follows: Mesophytes – 10 species (14.08%), Mesoxerophytes – 20 species (28.17%), Mesohygrophytes – 5 species (7.04%), Xerophytes – 30 species (42.25%), Hemixerophytes – 2 species (2.82%), Hygrophytes – 2 species (2.82%), Euryhaline plants – 1 species (1.41%)

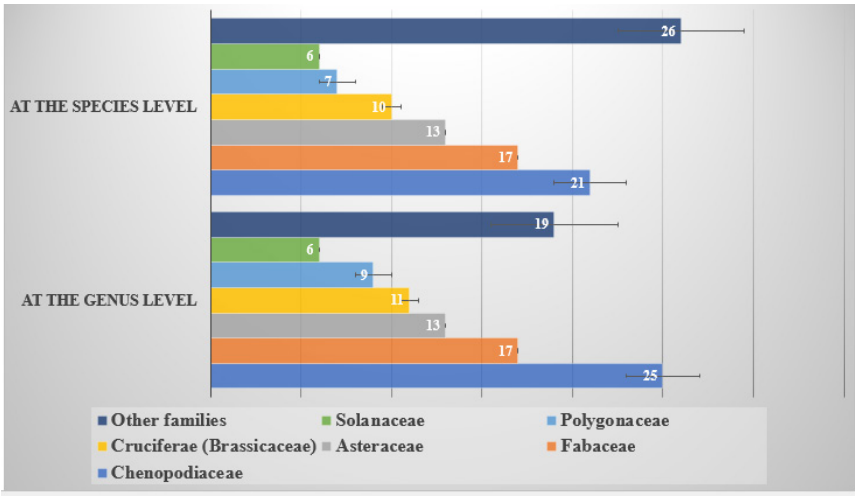

Figure 3 – Leading flora families of *Zygophyllum fabago* L. populations
a) At the Genus Level; b) At the Species Level

The results indicate that the dominant families in the flora of *Zygophyllum fabago* L. in the Ile-Balkhash area are *Chenopodiaceae* and *Fabaceae*, comprising 15 species (21.13%) and 12 species (16.90%), respectively. Along with *Asteraceae, Cruciferae,* and *Polygonaceae*, these families account for 43 species (60.56%) of the vegetation in these populations. In comparison, the remaining 15 families collectively represent 28 species (39.44%).

Floristic diversity typically depends on the ecological conditions such as soil salinity, low humus content, and periodic water scarcity. Regional heterogeneity and climate are also significant factors that affect the flora of *Zygophyllum fabago* L. populations in the Ile-Balkhash region. The life form analysis indicated that herbaceous plants, predominantly xerophytes, were the most frequent. These species are best adapted to the specific conditions of salt marshes and sandy soils, where high salt levels and low soil fertility set the terms for plant existence. Shrubs and semi-shrubs (hemicryptophytes and microphyllophytes) account for a smaller proportion of the flora (*Table 2*). This is due to the harsh conditions of salt marsh and sandy landscapes, where shrub growth is limited by high salinity and poor nutrients. Overall, the flora mainly consists of species typical for salt marshes and poor sandy habitats. As already stated, the most conspicuous life forms of this area are annuals and herbaceous perennials, which have a wide ecological range and are salt-tolerant to thrive in salt soils. Shrubs, however, are least characterized by a life form since their growth is limited by salt marsh and sandy soil environments. Semi-shrubs are also not abundant and are mostly encountered in relatively more humid and less saline areas. This life pattern develops in the flora of *Zygophyllum fabago* L. and is a reflection of the climatic regime of the region, emphasizing its mesophytic and mesoxerophytic character, typical of arid and saline habitats where vegetation is adapted to conditions of extreme salinity and nutrient deficiency.

Table 2 – Spectrum of dominant life forms found in *Zygophyllum fabago* L. populations

Life forms	Species	%
Mesophytes	10	14.08%
Mesoxerophytes	20	28.17%
Mesohygrophytes	5	7.04%
Xerophytes	30	42.25%
Hemixerophytes	2	2.82%
Hygrophytes	2	2.82%
Euryhaline plants	1	1.41%
Total	71	100 %

Plants with economical or industrial importance.

The significance of plants growing in salt marshes and low-humus sand as a resource extends across multiple fields, such as animal husbandry, agriculture, and medicine. Species known as halophytes and xerophytes, which are adapted to the extreme characteristics of saline soils that are deficient in organic matter, hold great importance.

The Ile-Balkhash region of Almaty province contains a diverse plant collection of flora *Zygophyllum fabago* L., valued for their medical, ornamental, forage, honey-bearing, and technical properties. These species include: *Kraschenninnikovia ceratoides* – a forage plant that is used as an effective tool for stabilizing sands and maintaining soil integrity; *Climacoptera lanata* – serves as a crucial part of the forage base for livestock; *Petrosimonia brachiata* – valued for its medical benefits and potential applications in herbal medicine; *Ceratocarpus arenarius* – utilized as animal feed for camels and small herds, predominantly in xeric ecosystems; *Suaeda salsa* – a salt-tolerant plant employed in tannin production and optimizing soil health.

Research on the advantageous characteristics of salt marsh flora underscores their economic and ecological significance while emphasizing the importance of their sustainable usage.

Table 3 – Plant groups with economic & industrial importance within the *Zygophyllum fabago* L. populations

Plant Group	Number of Species	% Contribution
Weed	25	10.96
Forage	80	35.09
Medicinal	25	10.96
Poisonous	5	2.19
Melliferous	35	15.35
Food (Edible)	18	7.89
Essential Oils	7	3.07
Ornamental	18	7.89
Dye	7	3.07
Industrial	8	3.51
Vitamin-bearing	3	1.32
Total	228	100.0

Flora of *Zygophyllum fabago* L. populations in Ile-Balkhash district of Almaty region:
Economic potential and environmental considerations.

The flora of the Ile-Balkhash region, particularly with *Zygophyllum fabago* L. ecological clusters, consists of diverse vegetation types that hold commercial and industrial value. These plants are crucial for various sectors, such as medicine, agriculture, and industry. Below is a categorized summary of plant groups based on their uses, along with the number of species and their percentage contribution to the total flora.

The plant diversity within *Zygophyllum fabago* L. populations in the Ile-Balkhash district of the Almaty region holds valuable prospects for the enhancement of key fields, including pharmaceuticals, forage plants, honey production, and economically valuable crops, with special attention given to the prominence of salt marshes and saline soils.

The region possesses a wide range of economically valuable species, many of which thrive in the saline conditions of the salt marshes that dominate the area and play a special role in shaping the regional flora. An important portion of this flora is salt-tolerant. *Zygophyllum fabago* L., along with species such as *Kraschenninnikovia ceratoides, Alhagi pseudalhagi,* and *Artemisia terrae-albae* Krasch., are well adapted to the challenging conditions of saline soils. This adaptation highlights the potential use of these species in salt-tolerant agriculture, signifying their promise for future economic development in the region. In fact, the unique conditions of the Ile-Balkhash region highlight substantial capacity for sustainable progress in the healthcare, farming, and industrial sectors.

Based on Ilyin [27] and Pavlov [28, 29] classifications, the plant resources and floral heterogeneity in the area allow for the identification of 11 economically valuable plant groups (*Table 3*). *Forage plants*: 80 species (35.09%) – These are highly important financially, as they support pastoral activities. Species such as *Medicago falcata* [30], *Trifolium pratense* [31], and *Zygophyllum fabago* L., as well as grasses like *Elytrigia repens* [32], form an essential part of local livestock production and sustain forage for cattle and sheep. *Melliferous plants*: 35 species (15.35%) – The floral variety in the region supports the production of high-quality honey, which has medicinal and nutritional properties, increasing its value for both local and regional producers. *Medicinal plants*: 25 species (10.96%) – The region is home to plants with medicinal properties, such as *Zygophyllum fabago* L., *Descurainia sophia*, and *Peganum harmala* [33], which form a fertile field for the pharmaceutical industry. *Industrial plants*: 8 species (3.51%) – Industrial plants such as *Cera-*

tocarpus arenarius [34], *Petrosimonia brachiata*, and *Alhagi pseudalhagi* provide raw materials for the production of natural dyes, fibers, and medicinal compounds. Weeds: 25 species (10.96%) – Some weeds thrive in the region's disturbed soil, such as *Convolvulus arvensis* and *Chenopodium glaucum*. *Food plants*: 18 species (7.89%) – This group includes plants such as *Rosa alberti*, whose fruits are rich in vitamin C, as well as other berry plants utilized in the food and cosmetic industries. *Dye plants*: 7 species (3.07%) – Plants such as *Arnebia decumbens* [35] are valuable for their dyeing properties. *Essential oil plants*: 7 species (3.07%) – Includes species of the *Umbelliferae* family [36], such as *Daucus carota* and *Carum carvi*, used to produce essential oils. *Ornamental plants*: 18 species (7.89%) – Plants used for ornamental purposes in landscaping and floriculture. *Vitamin plants*: 3 species (1.32%) – This group encompasses species like *Rosa alberti*, which are high in vitamins and can be applied in nutrition-related aspects. *Poisonous plants*: 5 species (2.19%) – Some plants, such as *Peganum harmala*, depending on their usage, exhibit both toxic and therapeutic properties [37].

Conclusion

This study examines the eco-biological characteristics and present status of *Zygophyllum fabago* L. in the Ile-Balkhash region, emphasizing its contribution to the semi-desert and saline ecosystems of Kazakhstan. The field survey conducted in 2024 identified nine coenopopulations, assessing the plant's morphological and ecological adaptations, such as aridity resistance and salt tolerance. The associated flora, comprising 71 species from 47 genera, reflects the ecological specificity of the region, with dominant families such as *Chenopodiaceae* and *Fabaceae*. *Zygophyllum fabago* L. demonstrates high adaptability to the arid regions of southern Kazakhstan, allowing it to maintain stable populations in extreme environmental conditions and contribute to the stabilization of degraded soils. Its presence plays a crucial role in preserving local biodiversity and serves as a biological indicator of soil salinization. The findings highlight the importance of conserving this species and developing sustainable management strategies for the fragile ecosystems of the Ile-Balkhash region.

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Information about authors:

Gulzat Kairanova (corresponding author), PhD student, Al-Farabi Kazakh National University, Almaty, Kazakhstan (e-mail: gulzat-amanzholova@mail.ru; ORCID: 0009-0002-8063-5403).

Mamurova Asem, Associate Professor in the Department of Biodiversity and Bioresources at al-Farabi Kazakh National University, Almaty, Kazakhstan (e-mail: amamurova81@mail.ru ; ORCID: 0000-0002-4676-9443).

Ahmet Beyatli, PhD, Professor in the Department of Medicinal and Aromatic Plants at the University of Health Science, Istanbul, Turkey (ORCID: 0000-0001-5225-6217).

Gaukhar Yeszhanova, Senior teacher of the Department of Fundamental Medicine, Faculty of Medicine and Health Care, al Farabi Kazakh National University, Almaty, Kazakhstan (e-mail: g.yeszhanova@mail.ru ; ORCID: 0009-0002-1597-6092).

Asylkhan Rakhymzhan – Ph.D., Associate Professor, Department of Fundamental Medicine, Faculty of Medicine and Health Care, al Farabi Kazakh National University, Almaty, Kazakhstan (ORCID: 0000-0003-3152-1557).

Авторлар туралы мәлімет:

Гүлзат Қайранова (жауапты автор) – әл-Фараби атындағы Қазақ ұлттық университетінің PhD докторанты (эл. пошта: gulzat-amanzholova@mail.ru ; ORCID: 0009-0002-8063-5403).

Асем Мамурова – әл-Фараби атындағы Қазақ Ұлттық Университетінің биоалуантүрлілік және биоресурстар кафедрасының қауымдастырылған профессоры (e-mail: amamurova81@mail.ru ; ORCID: 0000-0002-4676-9443).

Ахмет Бейатлы – Стамбул, Түркия, Медицина ғылымдарының университеті, дәрілік және хош иісті өсімдіктер кафедрасының PhD профессоры (ORCID: 0000-0001-5225-6217).

Гаухар Есжанова – Іргелі медицина кафедрасының аға оқытушысы, Медицина және денсаулық сақтау факультеті, әл Фараби атындағы Қазақ Ұлттық Университеті, Алматы, Қазақстан (e-mail: g.yeszhanova@mail.ru; ORCID: 0009-0002-1597-6092).

Асылхан Рахымжан – Іргелі медицина кафедрасының доцент м.а., Медицина және денсаулық сақтау факультеті, әл Фараби атындағы Қазақ Ұлттық Университеті, Алматы, Қазақстан (ORCID: 0000-0003-3152-1557).

Сведения об авторах:

Гүлзат Қайранова (автор-корреспондент) – PhD-докторант, Казахский национальный университет имени аль-Фараби (Алматы, Казахстан, e-mail: gulzat-amanzholova@mail.ru).

Асем Мамурова – ассоциированный профессор кафедры биоразнообразия и биоресурсов Казахского национального университета имени аль-Фараби (Алматы, Казахстан e-mail: amamurova81@mail.ru);

Ахмет Бейатли – PhD, профессор кафедры лекарственных и ароматических растений Университета медицинских наук (Стамбул, Турция);

Гаухар Есжанова – старший преподаватель кафедры фундаментальной медицины, факультет медицины и здравоохранения, Казахский национальный университет имени аль-Фараби (Алматы, Казахстан, e-mail: g.yeszhanova@mail.ru);

Асылхан Рахымжан – PhD, ассоциированный профессор кафедры фундаментальной медицины медицинского факультета Казахского национального университета имени аль-Фараби (Алматы, Казахстан).

Received January 20, 2025
Accepted August 20, 2025