Current Status and Resources of Alhagi Pseudoalhagi (Fabaceae) in Atyrau Region, Western Kazakhstan

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Article

Current Status and Resources of *Alhagi pseudoalhagi* (Fabaceae) in Atyrau Region, Western Kazakhstan

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Abstract: *Alhagi pseudalhagi* in the arid zone of the Atyrau region and an analysis of their current state with an assessment of raw material reserves were studied. Botanical characteristics, ontogenetic spectrum, morphological indicators, productivity, areas of thickets and reserves of raw materials of above-ground organs were assessed. The structural parameters of these coenopopulations in the Zhangyr and Coneu Rivers valleys, the vicinity of Imankara Mountain, and the Taisoigan sands were studied. It was established that the species composition of the populations includes 63 species from 54 genera and 30 families. The most common species include 49 taxa, category II – 17 taxa, category III – 7 species, category IV–V – 2 species. The maximum similarity in species composition was noted between populations in the Zhangyr and Coneu Rivers valleys. The maximum morphometric indicators were observed among the population of the river valley. Coneu and the minima are located on the Taisoigan sands. Analysis of the age spectrum made it possible to determine that the populations in the Zhangyr and Coneu Rivers valleys are characterized as young, in the area of Imankara Mountain and on the Taisoigan sands - as stable and middle-aged.

Keywords: medicinal plants; cenopopulation analysis; grass; stages of plant development

1. Introduction

The western part of Kazakhstan is a special territory with a relatively high concentration of biological diversity of various arid plant species, including those with medicinal properties. The arid Atyrau region is located in the extreme western part of Kazakhstan on the Caspian lowland, north and east of the Caspian Sea between the lower reaches of the Volga in the northwest and the Ustyurt plateau in the southeast within coordinates 47°05′- 56°45′ east longitude and 41°20′ - 49°15′ north latitude, extending from west to east to 720 km and 880 km from south to north. It is 118,637 km^2. The surface of the territory of the region is a plain, in the north of the region there are small mountains [1,2].

The climate is sharply continental, and extremely arid, with hot summers and moderately cold winters. The coldest month temperature ranges from -7 to -11°C. The coldest winters frosts reach from -36 to -42°C. Summers are hot and long in most of the territory. Everywhere, the average temperature in July (the hottest month) is not lower than 25°C. In some years, the air temperature rises from 41 to 46°C. This territory can be attributed to an arid zone with unfavorable conditions for most types of medicinal plants, which in turn increases interest in this territory and its natural plant sites [3–6].

Earlier, about 177 species of medicinal plants belonging to 118 genera and 46 families were found in this territory of the Atyrau region, the identified species are suitable for potential procurement of medicinal raw materials. Species such as *Althaea officinalis* L., *Nitraria schoberi* L. *Artemisia terrae-albae* Krasch., *Glycyrrhiza glabra* L., *Anabasis aphylla* L., *Anabasis salsa* (Ledeb.) Benth. ex Volkens and others. One of the promising medicinal species is *Alhagi pseudalhagi* (M.Bieb.) Desv. ex Wangerin [7–9].

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A. pseudoalhagi Wangerin camelthorns (Verblyuzh'ya kolyuchka) or manna trees (mannoe derevo) is one of four representatives of the genus *Alhagi* Tourn. ex Gagnebin of the family Fabaceae Lindl [10–12]. *A. pseudoalhagi* is used in official and folk medicine to treat diseases of the gastrointestinal tract, genitourinary system, liver, colds, and rheumatism, and is a choleretic, diuretic, and cleansing agent in the treatment of liver diseases and peptic ulcers. When applied externally, the decoction heals wounds [13–16].

The decoction and infusion have bacteriostatic, astringent, hemostatic, choleretic, and wound-healing effects [17–20]. They are used to treat inflammation of the colon and duodenum, gallbladder, gastritis, and peptic ulcer, sometimes prescribed for colds and excessive coughing, as well as for the prevention of dysentery. These medicinal properties make it possible to become the basis for the production of local domestic herbal medicines [21–24]. Based on the aboveground organs of *A.pseudalhagi*, a syrup has been developed for the treatment of colds [25,26].

The four members of this genus are widely distributed from North Africa and Greece, through Western and Central Asia to India and northern China. In Central Asia, including on the territory of Kazakhstan in the arid zone, *A. pseudalhagi* is widely found [27–29].

A. pseudalhagi grows in most arid territories of Kazakhstan and forms extensive thickets in semi-deserts, deserts, dry foothills, and river valleys, on clay, salt marsh, and sandy soils. Significant reserves have been formed in Almaty, Zhambyl, South Kazakhstan, Atyrau, and Aktobe regions [30].

This species has the particularly prickly characteristic of subshrubs, including a herbaceous perennial plant with a root system deeply penetrating arid soil. The main feature of the morphological difference is the high variation in plant height from 30 to 100 cm, which directly depends on the habitat.

The distribution environment differs mainly in dry steppes, clayey and gravelly semi-deserts, and deserts, along the banks of rivers and canals, in wastelands and fallow lands. Plant raw materials in the arid zone in Kazakhstan can be obtained both by growing on industrial plantations and by organizing collections in natural arid conditions [31,32]. However, similar work on the study of *A. pseudalhagi* in the Atyrau region and Kazakhstan has not previously been carried out.

Significant areas of thickets are noted for *A. pseudalhagi* and the range of this species is confined to steppe, semi-desert, and desert territories [33]. Preliminary field studies revealed the presence of thickets of *A. pseudalhagi* in the Mangystau region; large thickets were also identified in the Atyrau region: the vicinity of Mount Imankara, the floodplain of the Zhangir, Uter, Koneu, Krasny Yarik, and Aktolkyn rivers. , Aktailak, on the sands of Toysaigan and Naryn.

However, there is a need for additional research to assess the suitability of *A. pseudalhagi* populations for exploitation, as well as to identify potential volumes of raw material procurement. The aerial part contains phenolic compounds (phenolic carboxylic acids, flavonoids, proanthocyanidins, xanthones, coumarins, tannins, α-pyrones, diphenyl ethers and naphthoquinones), alkaloids, terpenoids (mono-, sesqui-, triterpenoids, polyterpenoids), fatty acids and their aldehydes, carbohydrates, organic acids [34].

However, raw material reserves and procurement possibilities in the arid region of Kazakhstan have not been sufficiently studied. There are studies on the study of various environmental factors affecting the biological mass of plants and their genetic characteristics.

The study of the current state of natural cenopopulations of economically valuable *A. pseudalhagi* with an assessment of the possibility of their practical application is determined by priorities. Strategies for preserving biological diversity in arid zones, as well as expanding the use of traditional herbal medicines [35–37].

The purpose of this study is to analyze the current state of *A. pseudalhagi* cenopopulations in four locations according to various parameters on the territory of the Atyrau arid zone, and to estimate the amount of resources with the identification of the properties of the plant and the density of its distribution, as well as the species composition of related species for obtaining medicinal raw materials. In addition, the study of biomorphological features of *A. pseudalhagi* cenopopulations and distribution areas in the arid zone with the study of the age composition of vegetative and generative individuals located in various plant species associations.

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2. Materials and Methods

2.1. Floristic and cenopopulation analyses

The cenopopulations analysis of the biomorphological properties of plants in ontogenesis was studied using the methodology of O.V.Smirnova et al. [38]. At the same time, the name of the plant species was verified according to the "Flora of Kazakhstan"[39], the "Illustrated Determinant" [40], the "Determinant of Plants of Central Asia" [41] and the International Index of Names of Electronic Databases [42]. The classification of life forms of species included in cenopopulations was estimated according to the method of I.G. Serebriakov [43]. Traditional methods of geobotanical survey using ecological and morphological indicators were used to describe populations. *A. pseudalhagi* individuals were counted by age groups and floristic composition was described at 1 m recording sites [44]. Nomenclature names of plants are given according to POWO [45]. The similarity in floristic composition was estimated according to the Jaccard similarity index.

The frequency of occurrence of individual species in populations with *A. pseudalhagi* was estimated according to 5 classes: I - 0-20%; II - 21-40%; III- 41-60%; IV - 61- 80%; V -81-100%. When describing ontogenesis we used the method of Komarov et al. [46] the population type was determined according to S.V. Fedorova [47]. The following age groups were considered: juvenile plants (j), immature (im), adult vegetative (v), young generative (g1), middle-aged generative (g2) and old generative (g3). Sprouts and senile individuals were not identified in natural cenopopulations at the time of the study.

In the process of studying, four main comparative cenopopulations were selected in different geographical regions (mountain, coastal water, and sand) in the territory of the Atyrau region and are presented in Table 1. The study of the growth of *A. pseudalhagi* on the territory of the Atyrau region made it possible to identify four promising coenopopulations: the vicinity of Imankara Mountain (cenopopulations 1), the Zhangyr River valley (cenopopulations 2), and in the Coneu River valley (cenopopulations 3) and Taisoigan Sands (cenopopulations 4).

Table 1. Geographical locations of *A. pseudalhagi* cenopopulations in Atyrau region.

Name	Geographical location	Coordinates	Height above sea level	Administrative location
Cenopopulation 1	the vicinity of Imankara Mountain	47°19'49"N 54°22'12"E	370 m above sea level	Atyrau region, Zhylyoysky district
Cenopopulation 2	Zhangyr river valley	46°40'05"N 49°23'50"E	281 m below sea level	Atyrau region, Kurmangazinsky district
Cenopopulation 3	in the Coneu River valley	46°40'00"N 49°23'50"E	284 m below sea level	Atyrau region, Kurmangazinsky district
Cenopopulation 4	described in Taisoigan sands	48°49'23"N 53°44'36"E	225 m above sea level	Atyrau region, Kzylkoginsky district

2.2. Assessment of plant resources

Evaluation of aboveground organ resources was assessed according to the method of Elzinga et al. [48]. In the study area, 10-15 survey plots with an area of 1 m^2 were laid, from which above-ground

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organs of *A. pseudalhagi* were cut at a height of 5-8 cm from the soil level. The raw materials were dried to air-dry condition and weighed. The area of thickets was calculated by multiplying the length and width of the thickets. Average yield data from 1 survey plot were recalculated per hectare. The exploitable stock was calculated as the product of yield per total area, the volume of possible raw material collection as 40-50% of the exploitable stock.

2.3. Statistical processing

Statistical processing of the results was carried out using the Statistics 10 program (StatSoft STATISTICA 10.2011) and the capabilities of the Microsoft Excel 10.1 program. Statistical processing was carried out with the calculation of the non-parametric Mann-Whitney test to determine the reliability of differences in the indicators of the floristic composition between populations, as well as morphological indicators between the populations of the species under study.

Mathematical processing was performed according to the method of Kuziev R.K., Yuldashev G., et al. [49,50]. Statistical analysis of coenopopulation dynamics varies depending on the constraint, which varies by the standard deviation of the coefficient of variation, the mean value of the error, the degree of confidence and the degree of precision.

The dendrogram was constructed using the PAST program and unweighted pair group method with arithmetic mean (UPGMA) algorithm and Boot N:1,000 [51].

To compare the results, one-way analysis of variance (ANOVA) was used with a significant correlation between the soil type and the main plant parameters in the coenopopulations. When analyzing primary data, correlation coefficients were calculated using the statistics program R Studio (IDE) for Windows (R version 3.6.0, 2019). The average values of four cenopopulations of the main quantitative traits (Plant height, cm; plant diameter, cm; number of generative shoots; pieces number of individuals per 1 sq.m, pieces) were grouped according to PCoA (principal component analysis). PCoA was performed using the Numerical Taxonomy and Multivariate Analysis System (NTSYS-pc) program [52].

3. Results and discussion

3.1. Structure of coenopopulations of Alhagi pseudalhagi

The location of the studied cenopopulation of *A. pseudalhagi* and the conditions of its existence in the arid conditions of the Atyrau region are presented in Figure 1. For the first time, a comprehensive description of the structure of cenopopulations, species composition, and its resources depending on the position of the relief is given. Data on the distribution of species by ecological groups showed that in the cenopopulations of plants with *A. pseudalhagi*, xerophytes (53.9%), mesoxerophytes (15.8%), and mesophytes (14.3%) dominate. This fact is also confirmed by the ratio of ecological groups of plants according to humidification conditions. For example, the predominant number of species belongs to xerophytes, accounting for more than half of the species, while other ecological groups occupy a small proportion of the populations.

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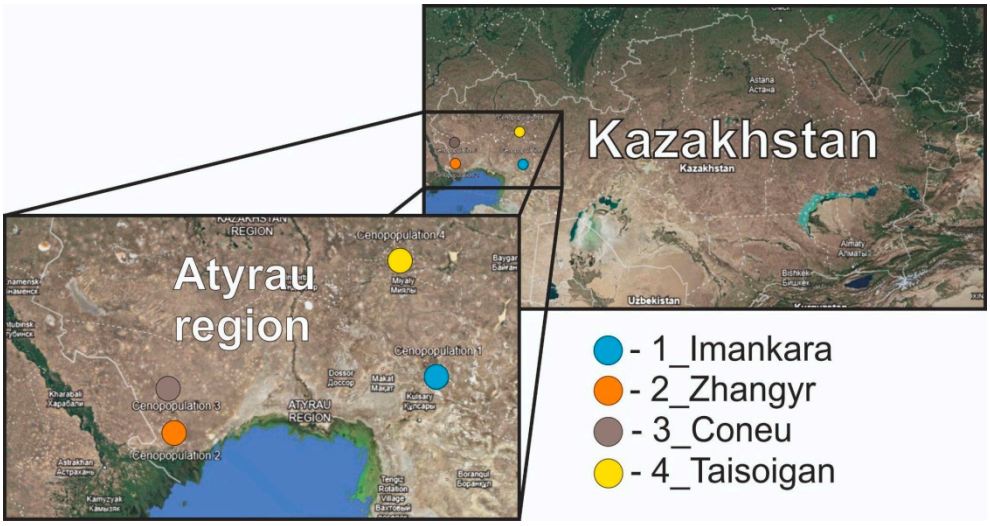

Figure 1. Locations of coenopopulations of *A. pseudalhagi.*

Cenopopulation 1 (*Limonium suffruticosum* (L.) Kuntze – *Alhagi pseudalhagi* (M.Bieb.) Desv. ex Wangerin – Herbaxerophytica) is located in the vicinity of Imankara Mountain. The total projective cover (hereinafter referred to as TCC) of vegetation was 40-50%. Relief plain with a slight elevation difference, soils - loamy, brown, with numerous outcrops of chalky rocks. The surveyed area is used for cattle grazing in spring. Vegetation consisted of two tiers: shrub, 40-55 cm (*Atraphaxis spinosa* L.), and herbaceous, 15-35 cm. The basic summarized species in a population are *Limonium suffruticosum*, *Alhagi pseudalhagi*, *Ephedra distachya* L., *Anabasis salsa* (C.A. Mey.) Benth. ex Volkens, *Atraphaxis spinosa* L., *Ferula nuda* Spreng., *Centaurea scabiosa* L., *Scabiosa isetensis* L., *Tanacetum santolina* C. Winkl., *Kochia prostrata* (L.) Schrad. and others. In the described population all age groups of *A.pseudalhagi* with dominance of middle-aged generative plants. The status of cenopopulation 1 can be characterized as stable, and capable of self-renewal.Soil type: flat area in front of the chalk mountains of Imankara, soils - loamy, dry, grey-earth, heavily gravelly, of a basic nature.

Cenopopulation 2 (*Alhagi pseudalhagi - Salsola foliosa* (L.) Schrad. - *Limonium gmelinii*(Willd.) Kuntze) is located in Zhangyr river valley. TCC was 75%. Soils are chestnut, and loamy. Vegetation forms 3 tiers: woody, 120-150 cm (*Elaeagnus angustifolia* L.), shrub, 70-90 cm (*Tamarix laxa* Willd.), and herbaceous, up to 50 cm high. The following species are part of the population: *Cynodon dactylon* (L.) Pers., *Salsola orientalis* S.G. Gmel., *Plantago major* L., *Trifolium fragiferum* L., *Polygonum aviculare* L., *Limonium gmelinii* (Willd.) Kuntze, *Echinochloa crus-galli* (L.) Beauv., *Xanthium strumarium*L., *Solanum dulcamara* L., *Potentilla spuria* A.Kern., etc. The area is actively exploited for livestock grazing, which leads to degradation of the vegetation cover; the degree of degradation is 50-55%. The population is normal, young, and dominated by pre-generative and young generative individuals.Soil type: soil is light chestnut, loamy, moist, without the presence of rocky elements. This area is flooded in the spring.

Cenopopulation 3 (*Alhagi pseudalhagi - Herba varia*) is located in the Coneu River valley. TCC was 75%. Soils are light- chestnut, loamy, in some places salty. Vegetation is degraded by 25-30% due to active cattle grazing. The vegetation is composed of 3 tiers (one shrub, 60-70 cm high, and 2 herbaceous, 30-50 and up to 20 cm high). The following species were found in the population: *Alhagi pseudalhagi*, *Tamarix laxa* Willd., *Salsola foliosa* (L.) Schrad., *S. orientalis* S.G. Gmel., *Persicaria amphibia* (L.) Delarbre, *Butomus umbellatus* L., *Plantago major* L., *Mentha arvensis* L., *Trifolium fragiferum* L., *Zygophyllum fabago* L., *Limonium gmelinii* (Willd.) Kuntze, etc. Cenopopulation 3 is *A.pseudalhagi* of the normal type, young with a predominance of young generative individuals. Soil type: soil is light chestnut, loamy, moist, without the presence of rocky elements. This area is flooded in the spring.

Cenopopulation 4 (*Alhagi pseudalhagi - Glycyrrhiza glabra* L. – Herbaxerophytica) is described in Taisoigan sands. TCC was 50-55%. The relief is flat; soils are sandy, with clay outcrops in places. There are traces of cattle grazing. Vegetation degradation by 10-15% is observed. The cover is composed of 2 tiers: high grass, 40-65 cm, and low grass, 15-25 cm. The species composition includes

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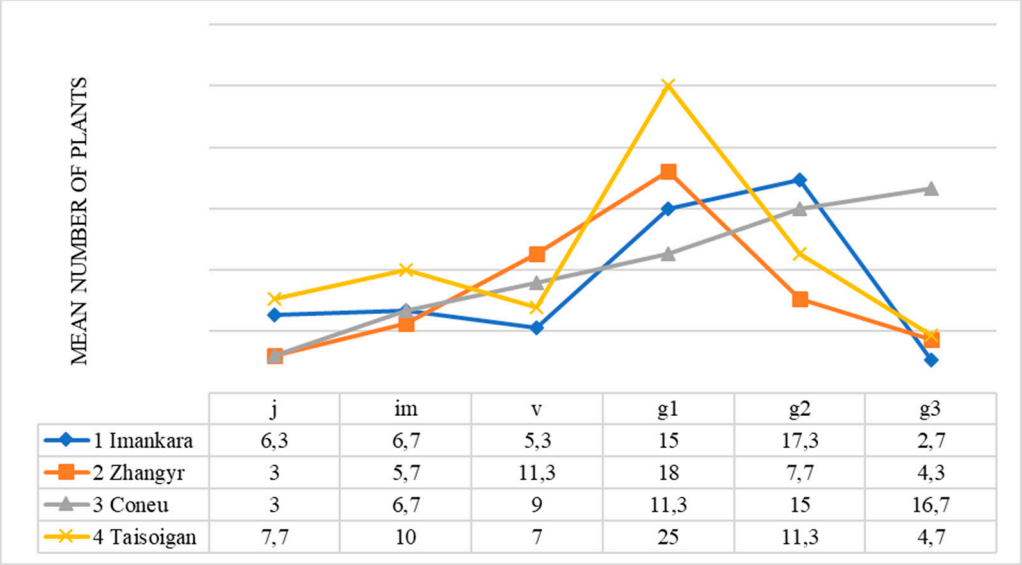
the following species: *Euphorbia seguieriana* Neck., *Melica taurica* K. Koch, *Agropyron fragile* (Roth) P. Candargy, *Achillea micrantha* Willd., *Kochia prostrata* (L.) Schrad., *Glycyrrhiza glabra* L., *Carex physodes* M.Bieb., *Arnebia decumbens* (Vent.) Coss. & Kralik, *Limonium suffruticosum* (L.) Kuntze, etc. Cenopopulation 4 is normal, stable, medium-aged, and dominated by medium-aged generative plants.Soil type: Typical sandy massifs, at a depth of 40cm - wet loans.

When describing the population structure, we also took into account the age spectrum of *A. pseudalhagi* individuals. In populations of perennial plants, all individuals are characterized by a set of biomorphic traits that determine their age differentiation. Determining age states (biological age) is much more important for population studies (Figure 2).



	j	im	v	g1	g2	g3
1 Imankara	6,3	6,7	5,3	15	17,3	2,7
2 Zhangyr	3	5,7	11,3	18	7,7	4,3
3 Coneu	3	6,7	9	11,3	15	16,7
4 Taisoigan	7,7	10	7	25	11,3	4,7

Figure 2. Age composition of cenopopulation of *A. pseudalhagi.*

Thus, the analysis of age spectra showed that cenopopulation 1 and cenopopulation 4 have a middle-aged and stable status, cenopopulation 2 and cenopopulation 3 are normal, young. These characteristics make it possible to recommend all studied populations for organizing the procurement of raw above-ground organs.

Age structure is one of the most important traits of cenopopulation. It reflects the vital state of the species in the cenosis, as well as such important processes as the intensity of reproduction and the rate of generation change. It shows the ability of the population system to maintain itself and the degree of its resistance to the influence of negative environmental factors, including anthropogenic impact.

3.2. Floristic composition of A. pseudalhagi cenopopulations

As a result of the analysis of herbarium material collected during field studies, 63 species from 54 genera and 26 families were observed growing as part of populations with *A. pseudalhagi*. Systematical analysis showed that the leading families by species composition are Poaceae (12.7%), Asteraceae (12.7%), Chenopodiaceae (9.5%), and Fabaceae (9.5%) (Table S1). The leading 4 families include 28 species and 23 genera, representing 44.4 and 42.6%, respectively, of the total flora composition.

Comparison of the species composition of cenopopulation showed that the greatest number of species was recorded for cenopopulation 1 - 25, the minimum for cenopopulation 4 - 21, while cenopopulation 2 and cenopopulation 3 have the same quantitative composition - 24 taxa each.

Significant differences in the species composition of *A. pseudalhagi* cenopopulation were noted. Thus, the maximum index of similarity in floristic composition was found between cenopopulation

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2 and cenopopulation 3 - 0.122; the minimum index was between cenopopulation 1 and cenopopulation 2 - 0.042.

The obtained data can be explained by the fact that in the valley of the rivers Zhangyr and Coneu similar soil and climatic conditions and the degree of anthropogenic pressure are observed, while cenopopulation 1 and cenopopulation 4 are located in significantly different conditions. Thus, in the vicinity of Imankara Mountain 25 species grow, in the valley of the rivers Zhangyr and Coneu – 24 species each, on the sands of Taisoigan - 21 species. Significant degradation of vegetation cover in the valley of the Zhangyr and Coneu rivers due to anthropogenic pressure is noted, which is confirmed by a significant number of weed-ruderal elements (*Onopordum acanthium* L., *Xanthium strumarium* L., *Cynodon dactylon* (L.) Pers., *Polygonum aviculare* L., *Convolvulus arvensis* L., *Echinochloa crus-galli* (L.) P. Beauv., etc). However, grazing has no depressing effect on *A. pseudalhagi*, as this species is practically not eaten by domestic animals. The analysis of species by occurrence showed that points IV and V were noted only for *Alhagi kirghisorum* Schrenk and *Limonium suffruticosum* (L.) Kuntze (3.2% of the total number of species). Score III was recorded for 7 species or 11.1% (*Artemisia terrae-albae* Krasch., *Salsola foliosa* (L.) Schrad., *Carex physodes* M.Bieb., *Euphorbia seguieriana* Neck., etc.), and a score of II - 17 species or 26.9% (*Artemisia arenaria* DC., *Peganum harmala* L., *Xanthium strumarium* L., *Tamarix laxa* Willd., etc.). The main number of species had a score of I - 49 taxa or 77.8% (*Allium sabulosum* Steven ex Bunge, *Atriplex cana* C.A. Mey., *Salsola orientalis* S.G. Gmel., *Arnebia decumbens* (Vent.) Coss. & Kralik, *Onosma stamineum* Ledeb., *Alyssum lenense* Adams, *Trifolium fragiferum* L., etc.). The analysis of life forms showed the predominance of herbaceous perennials (33 species or 52.4%), the second position is occupied by minor shrubs (15 species or 23.8%), the third – by semi-shrubs (9 species or 14.3%). Shrubs account for 5 species (7.9%) and trees for 1 species (1.5%).

It should be noted that the steppe and semi-desert territories of Kazakhstan are characterized by the predominance in the floristic composition of populations of representatives of the families Poaceae, Polygonaceae, Asteraceae, Chenopodiaceae and Fabaceae. Thus, the Chenopodiaceae family is the most characteristic family for the steppes and deserts of the globe. The large number of species in this family indicates the presence of significant areas of saline or heavily saline areas. The species of this family mainly belong to the group of plants with summer-autumn vegetation. The Asteraceae family serves as a price-maker in the flora of arid areas such as steppes and deserts. The Poaceae family includes groups of species that play the role of edificators and subedificators of steppe and desert flora (genera Agropyron, Anisantha, Poa, Eremopyrym), as well as forming small areas of vegetation along water sources (*Cynodon dactylon* (L.) Pers.). The Turanian flora is characterized by the first place of the families Chenopodiaceae and Polygonaceae; a large number of species of the families Asteraceae and Fabaceae indicates the influence of the Mediterranean flora proper.

3.3. Morphological differences between cenopopulations and resource potential of A. pseudalhagi

Biomorphological studies of various cenopopulations made it possible to determine that the range of *A. pseudalhagi* in the Zhylyoysky, Kzylkoginsky, and Kurmangazinsky districts of the Atyrau region differ in a systematic structure, morphometric indicators and age spectrum. It is noted that previous studies of natural populations of *A. pseudalhagi* both in the Atyrau region and in Kazakhstan as a whole have not been carried out.

Morphometric indicators of individuals from 4 cenopopulations differed in the number of individuals per 1 m^2, the height of generative shoots, and their number per 1 individual. Table 2 presents the morphometric parameters of *A. pseudalhagi* in the studied populations of the Atyrau region. By the data obtained, the maximum number of individuals per 1 m^2 was noted for cenopopulations 2 (2.6 pieces) and cenopopulation 3 (2.2 pieces), and the minimum growth density was for cenopopulations 4 (0.5 pieces).

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Table 2. Quantitative and morphological indicators of generative individuals of *Alhagi pseudalhagi* in the studied cenopopulations (M±m).

Name	Generative plant height, cm	Number of generative individuals per 1 m², pcs.	Number of generative shoots per individual, pcs.
Cenopopulation 1	24.4±1.2	0.8±0.02	3.2±0.5
Cenopopulation 2	28.3±1.3	2.6±0.03	5.6±0.8
Cenopopulation 3	30.5±1.5	2.2±0.01	6.1±0.03
Cenopopulation 4	26.2±1.4	0.5±0.02	2.9±0.4

* Different letters show statistically significant differences at P< 0.05.

The main morphological difference between individuals of the four cenopopulations of *A. pseudalhagi* is the height of the plants. In terms of growth indicators, the maximum values were noted in cenopopulations 3 – 30.5 cm, and the minimum in cenopopulations 1 – 24.4 cm (Figure 3).

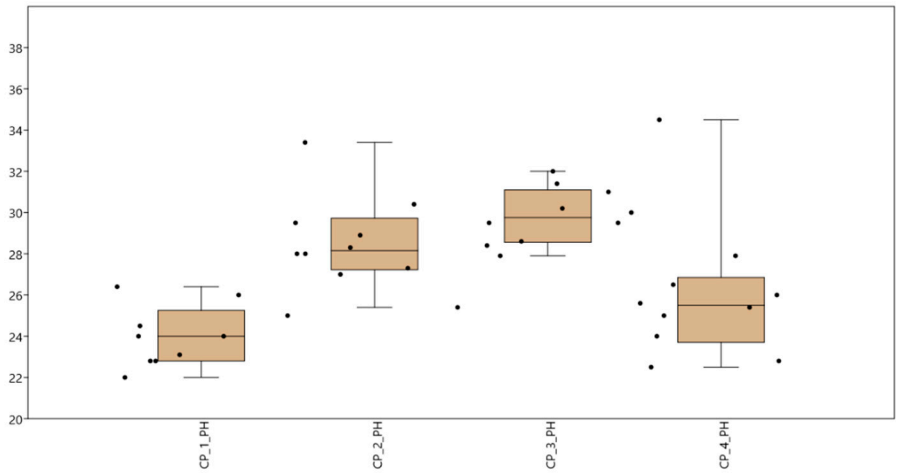

Figure 3. Column diagram of plant heights in cenopopulation *A. pseudalhagi.*

Accordingly, individuals in cenopopulation 3 with the maximum height of generative shoots had significantly the largest number of generative shoots per individual (6.1 pieces), and in cenopopulation 4 - the largest number of generative shoots (2.9 pieces). Cenopopulation 1 occupies an intermediate position in morphometric parameters between cenopopulation 2 and cenopopulation 4. Probably, the difference between the cenopopulations is due to differences in climatic conditions and the degree of anthropogenic load at the growing points.

The principle of basic coordinates showed the presence of similar basic parameters of coenopopulations between coenopopulations 2 and 3, and between 1 and 4 (Figure 4). This group association is associated with the geographical proximity of these two groups. The most significant significant difference in the morphological parameters of individuals between different populations was observed for cenopopulations 1 and cenopopulations 4, while cenopopulations 2 and cenopopulations 3 have similar parameters.

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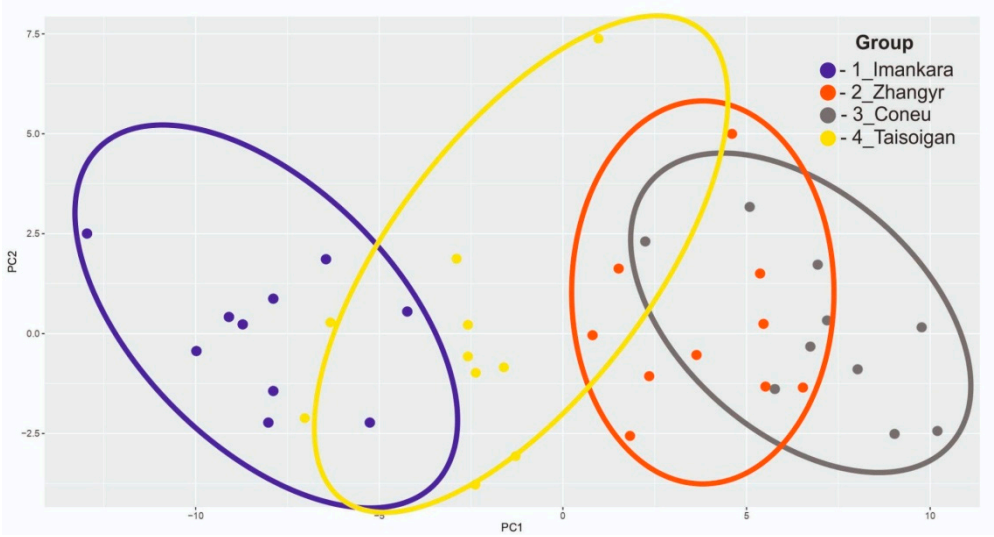

Figure 4. Principal coordinate analysis (PCoA) for cenopopulations of *A. pseudalhagi.*

The following indicators were correlated: Plant height, cm (PH); plant diameter, cm (PD) number of generative shoots (GS), pieces number of individuals per 1 sq.m, pieces (NI); Soil type (ST); Cenopopulation (CP). The correlation showed the positive influence of factors as the main ones for identifying and assessing the state of *A. pseudalhagi* coenopopulations (Figure 5).

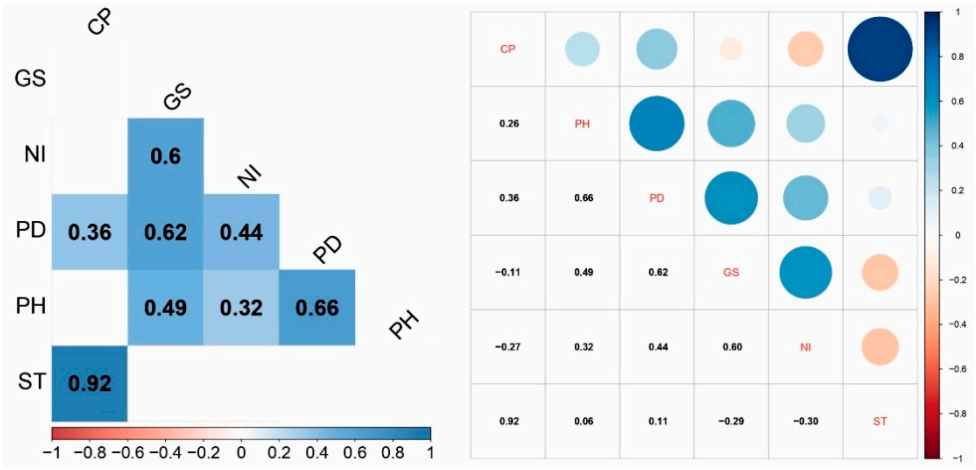

Figure 5. Correlation of the main significant parameters of coenopopulations: Plant height, cm (PH); cenopopulation (CP); plant diameter, cm (PD) number of generative shoots (GS), pieces number of individuals per 1 sq.m, pieces (NI), soil type (ST).

The one-way factor analysis (ANOVA) showed the significance ($P < 0.05$) of the influence of the soil type (ST) factor on the plant indicator in different coenopopulations: plant height (PH) with a value of 4.16e-06; plant diameter (PD) with a value of 6.55e-13; number of generative shoots (GS) with a value of 3.79e-10; pieces number of individuals per 1 sq.m, pieces (NI) with the value 3.59e-06.

The dendrogram showed that there is a small mixture of individuals of coenopopulations 2, 3, and 4, as a special group that does not climb from the mountainous territory. The mountain's first coenopopulation is characterized by a low mixture. All populations differed significantly from each other in the number of individuals and in the growth of significant differences (Figure 6).

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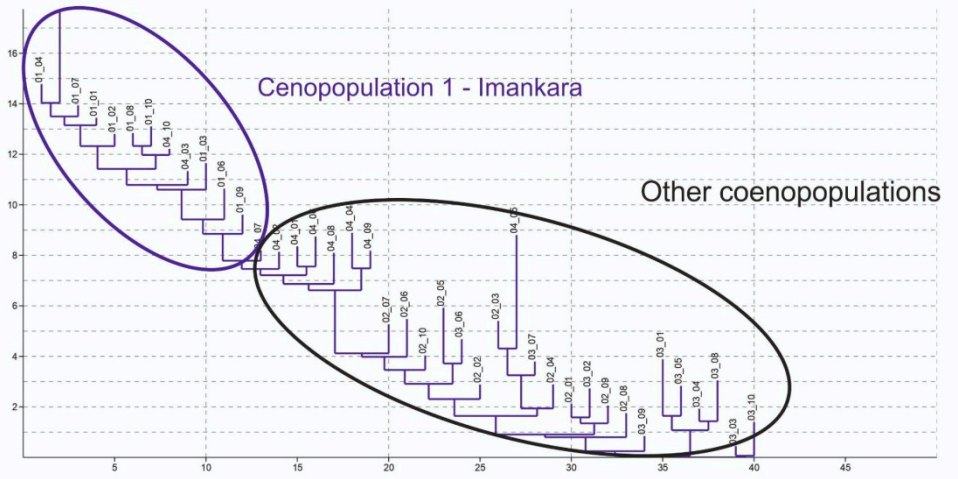

Figure 6. Unweighted pair group method with arithmetic mean (UPGMA) dendrogram cenopopulation of *A. pseudalhagi.*

And between cenopopulations 2 and 4, she pointed out differences from each other. There were significant differences in the number of generative shoots between cenopopulations 1 and 4 and cenopopulations 2 and 3. Probably, the difference between the cenopopulations was due to the difference in climatic conditions of the arid zone and various natural conditions for the growth of the species.

3.4. Resource potential of the cenopopulation A. pseudalhagi

A study of the resources of *A. pseudalhagi* made it possible to determine that the yield of raw materials varied from 850 to 2847 c/ha (Table 3). The maximum harvest was found in the area of Imankara Mountain, and the minimum - was in the Zhangyr River valley.

Table 3. Areas of thickets and raw materials of aboveground organs of *A. pseudalhagi* in the studied populations in the Atyrau region (in air-dry weight).

Number of cenopopulations	Area, ha	Yield, kg/ha	Operational reserve, tons	The volume of possible raw material collecting, tons
Cenopopulation 1	96.0	2847 ± 180	273.30	136.65
Cenopopulation 2	52.0	976 ± 42	50.76	25.38
Cenopopulation 3	80.0	850 ± 94	68.04	34.02
Cenopopulation 4	12.3	2148 ± 122	26.42	13.21
Total	240.3	-	418.52	209.26

The total area of thickets is estimated at 240.3 ha. The operational reserve amounted to 418.52 tons, while the annual possible collection of above-ground organs was estimated at 209.26 tons. Sufficient areas of thickets and the volume of potential plant raw materials of *A. pseudalhagi* on the territory of the Atyrau region make it possible to recommend this species for the industrial procurement of above-ground organs.

4. Conclusions

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In general, the study of four cenopopulations of the medicinal plant *A. pseudalhagi* (in the arid zone of Zhangyr and Coneu Rivers, the vicinity of Imankara Mountain and Taisoigan sands) showed that they are in satisfactory condition and can be used for organizing the procurement of medicinal herbs in compliance with the correct regime and frequency of harvesting raw materials. All cenopopulations of *A. pseudalhagi* differ from each other in floristic composition and main significant morphological indicators. Analysis of the age spectrum made it possible to determine that the population in the valley of the Zhangyr and Coneu Rivers is characterized as young, in the area of Imankara Mountain and on the Taisoigan sands - as stable and middle-aged. The annual volume of harvesting of above-ground organs is estimated at 209.26 tons in the catches of the arid zone of the Atyrau region. To preserve natural populations of this medicinal species, it is necessary to regularly monitor the state of populations and develop recommendations for the procurement of herbal medicinal raw materials.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org. Table S1: Floristic composition of populations with *Alhagi pseudoalhagi.*

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References

1. Chen,X.; Jiang, F.Q., Wang, Y.J.; Li, Y.M., Hu, R.J. Characteristics of the Eco-geographical pattern in arid land of central Asia.*Arid Zone Res.*, **2013**, *30,* 385–390.
2. Sagyndykova, M.S.; Imanbayeva, A.A.; Ishmuratova, M.Yu.; Gassanova, G.G. Analysis of flora of the medicinal plants of the Atyrau region. *Bulletin of the Karaganda University, series biology, medicine, geography,***2021**, *1 (101),* 67-73. https://doi.org/10.31489/2021BMG1/67-73
3. Grudzinskaya, L.M.; Gemedjieva, N.G.; Nelina, N.V.; Karzhaubekova, Zh. Annotated list of medicinal plants of Kazakhstan: a reference edition. Almaty, **2010**, 200 p. (In Russian)
4. Myrzagalieva A.B. Comparative analysis of the species composition and resources of medicinal plants of the Kazakhstan Altai. *Bulletin of KazNU, biological series*, **2013**, *2 (58)*, 3-9.
5. Galaktionova, E.V. Medicinal plants included in the flora of the North Kazakhstan region. Studies in the natural sciences, **2012**, 5. (In Russian)
6. Nature's pharmacy, our treasure chest: why we must conserve our natural heritage. A native plant conservation campaign report. New-York, **2008**. 19 p.
7. Aidarkhanova, G.S.; Novak, A.P.; Imasheva, B.S.; Tashev, A. Evaluation of resources of medicinal plants in the forests of the Kazakhstan part of the Altai and their ecological state. *Bulletin of Karaganda University, series Biology, Medicine, Geography,***2019**, *3 (95),* 73-79.
8. Kotukhov, Yu.A.; Danilova, A.N.; Kubentaev, S.A. List of medicinal plants Kazakhstan Altai. Ridder, **2015**, 70 p. (In Russian)
9. Kubentayev, S.A.; Suleimenov, A.N.; Kotukhov, J.A.; Danilova, A.N.; Sumbembayev, A.A. Phytocenotic characteristics and stock of the main medicinal plants of the South-Western Altai (East Kazakhstan). *Eurasian Journal of BioScience*, **2018**, *12,* 355-368.

10. Patsaev, A.K.; Makhatov, B.K.; Kucherbaev, K.D.; Bukharbaeva, A.E.; Anes, A.T. The study of medicinal plants of southern Kazakhstan. *Bulletin of the Kyrgyz State Medical Academy named after I.K. Akhunbaev*, **2017**, *5*, 96-97.
11. Yerekeyeva, S.Zh.; Gemejiyeva, N.G.; Balan, I.M. Northern Tien Shan medicinal herbs. *Journal LucrăriȘtiințifice Management Agricol.*,**2019**, *20/3*, 399.
12. Ishmuratova, M.Y.; Murzalieva, G.T.; Kraschanovskaya, T.R.; Sivolobova, O.A.; Kaldybaeva, A.K.; Temireeva, K.S.; Tukubaeva, G.N.; Isina, J.A.; Amanzhan, A. Wild medicinal plants of Karaganda region. Monograph. Karaganda: Bolashak-Baspa, **2016**, 205 p. (In Russian)
13. Ishmuratova, M.Yu.; Zhunussova, M.A.; Tyrzhanova, S.S.; Silant'eva, M.M. Study of spreading and plant resources of herbs Scabiosa ochroleuca L. and Scabiosa isetensis L. on the territory of Karaganda region. *Bulletin of the Karaganda University, series biology, medicine, geography*, **2020**, *1 (97)*, 47-53. https://doi.org/10.31489/2020BMG1/47-53
14. Arezoo, A.; Younes, A.; Assadi, M.; Mehregan, I. Systematics of Alhagi: molecular phylogeny and morphology revisited. *Rostaniha*,**2020**, *21(2)*, 174-184. https://doi.org/10.22092/BOTANY.2020.343028.1200
15. Imanbayeva, A.A.; Duysenova, N.I.; Tuyakova, A.T. Resources of Mentha longifolia (L.) Huds. and Alhagi pseudoalhagi (M. Bieb.) Desv. in the territory of Mangystau region. *Proceedings of National Academy of Science. Series Biol. & Med*., **2013**, *4(298)*, 110-115.
16. Sagyndykova, M.S.; Imanbayeva, A.A.; Ishmuratova, M.Y.; Gassanova, G.G. Analysis of medicinal flora of Atyrau region (preliminary study). Actual problems of biology and ecology: abstract of Republic Scientific Practical Conf. Karaganda: KarU, **2020**, 38-39.
17. Amini, M.H.; Ahmady, A.; Zhakfar, A.M.; Sediqi, M.N.; Babak, G. Preliminary Phytochemical Profile, in vitro Antioxidant and Sun Protective Activities of Alhagi pseudalhagiand Elaeagnus angustifolia L. *Journal of Pharmaceutical Research International*, **2019**, *12*, 1-13. https://doi.org/10.9734/jpri/2019/v31i430308
18. State Pharmacopoeia of the Republic of Kazakhstan. Vol. 2. Almaty, 2009. 803 p. (In Russian)
19. State Pharmacopoeia of the USSR. Issue XI. Moscow: Medicine, 1989. Vol. 2. 398 p.(In Russian)
20. Srivastava, B.; Sharma, H.; Dey, H.S.; Wanjari, M.M.; Jadhav, A.D. Alhagi pseudoalhagi: a review of its phytochemistry, pharmacology, folklore claims and Ayurvedic studies. *International Journal of Herbal Medicine*,**2014**, *2(2)*, P. 47-51.
21. Nishanbaev, S.Z.; Shamyanov, I.J.; Bobakulov, K.M.; Sagidullaev, Sh. Chemical composition and biological activity of metabolites of the genus Alhagi (review). *Chemistry of plant raw materials*,**2019**, *4*, 5-28. https://doi.org/10.14256/jcprm.2019045117
22. Xu, X.; Zhang, J.; Chen, L.; Sun, Yu.; Qing, D.; Xin, X.; Yan, Ch. Alhagi pseudalhagiExtract Exerts Protective Effects Against Intestinal Inflammation in Ulcerative Colitis by Affecting TLR4-Dependent NF-κB Signaling Pathways. *Front. Pharmacol.*,**2021**, 764602 https://doi.org/10.3389/fphar.2021.764602
23. Paiheerding, M.; Rehebati, N.; Lu, Ch.; Hibaier, H.; Aytursun, A.; Abulimiti, Y. Extraction, purification, and characterization of polysaccharides from Alhagy pseudoalhagi with antioxidant and hypoglycemic activities. *Process Biochemistry*,**2022**, *121*, 339-348. https://doi.org/10.1016/j.procbio.2022.06.026
24. Tavassoli, A.P.; Anushiravani, M.; Hoseine, S.M.; Nikakhtar, Z.; Baghdar, H.N.; Ramezani, M.; Ayati, Z.; Amiri, M.S.; Sahebkar, A.; Emami, S.A.; Sendmailto, E.S.A. Phytochemistry abd therapeutic effects of Alhagi spp. and Taganda bin in traditional and modern medicine: a review. *Journal of herb Med Pharm.*,**2020**, *9(2)*, 86-104. https://doi.org/10.34172/jhp.2020.13
25. Wei, F.; Yang, X.; Pang, K.; Tanh, H. Traditional uses, chemistry, pharmacology, toxicology and quality control of Alhagi sparsifoliaShap.: a review. *Frontiers in Pharmacology*, **2021**, *1214*, 761811. https://doi.org/10.3389/fphar.2021.761811
26. Janalieva, K.M.; Budnikova, T.I.; Veselov, E.N. Physical Geography of the Republic of Kazakhstan. Almaty: Kazak University, **1998**, 266 p. (In Russian)
27. Karshibaev, H. K. Reproduction characteristics of some species Alhagi Gagnev. in the arid zones of Uzbekistan. *Arid ecosystems*,**2014**, *20, 2 (59)*, 97-104.
28. Kubentayev, S.A.; Zhumagul, M.Zh.; Kurmanbayeva, M.S.; Alibekov, D.T.; Kotukhov, Yu.A.; Sitpayeva, G.T.; Mukhtubayeva, S.K.; Izbastina, K.S. Current state of population of Rhodiola rosea L. (Crassulaceae) in East Kazakhstan. *Botanical Studies*, **2021**, *62 (19)*, 20 p. https://doi. org/10.1186/s40529-021-00327-4
29. Zhivotovsky, L.A. Typification of plant population on the basis of their ontogenetic spectra. *Contemporary Problems of Ecology*, **2023**, *16*, 265-273. https://doi.org/10.1134/S1995425523030137

30. Kuanbay, Zh.I.; Abiyev, S.A.; Ishmuratova, M.Yu.; Admanova, G.B.; Kukenov, Zh.Zh.; Maksutbekova, G.T. The analysis of the Dongyztau chink flora (Aktobe region). *EurAsian Journal of BioSciences*, **2020**, *14(1),* 249-254
31. Zhang, M. A review on the floristic phytogeography in arid northwestern China and Central Asia. *Biodiversity Science*,**2017**, *25(2)*, 147-155. https://doi.org/10/17520/biods.2016192
32. Abduraimov, O.S.; Li, W.; Shomurodov, H.F.; Feng, Y. the main medicinal plants in arid regions of Uzbekistan and their traditional use in folk medicine. *Plants*, **2023**, *12,* 2950. https://doi.org/10.3390/plants12162950
33. Orazov A, Myrzagaliyeva A, Mukhitdinov N, Tustubayeva S. Callus induction with 6-BAP and IBA as a way to preserve Prunus ledebouriana (Rosaceae), and endemic plant of Altai and Tarbagatai, East Kazakhstan. Biodiversitas *Journal of Biological Diversity,* **2022**. *23(6):* 3178–3184. DOI: 10.13057/biodiv/d230645
34. Orazov A, Yermagambetova M, Myrzagaliyeva A, Mukhitdinov N, Tustubayeva S, Turuspekov Y, Almerekova S. Plant height variation and genetic diversity between Prunus ledebouriana (Schlecht.) YY Yao and Prunus tenella Batsch based on using SSR markers in East Kazakhstan. *PeerJ*. **2024.** 12:e16735 https://doi.org/10.7717/peerj.16735
35. Convention on Biological Diversity and the Nagoya Protocol: Intellectual Property Implications. United Nations: UNCTAD, **2014**. 215 p.
36. WHO Strategy for Traditional Medicine. **2014-2023**.
37. Myrzagaliyeva A, Seilkhan A, Takirova M, Mukhtubayeva S, Zhumagul M, Nursafina A, Bolgibayeva A, Makhambetov M. Morphological variability of the rare species Linaria cretacea in the conditions of the chalk hills in North-Western Kazakhstan. *Caspian Journal of Environmental Sciences*, **2023**. *21 (5):* 1273-1278. DOI: 10.22124/CJES.2023.7429
38. Smirnova, O.V.; Zaugolnova, L.B.; Ermakova, I.M. Cenopopulation of Plants; Science Publishing House: Moscow, Russia, **1976**; p. 217.
39. Pavlov N.B. Flora Kazahstana [Flora of Kazakhstan]. **1956**. Vol 1. Alma-Ata: AS Kazakh SSR, 347 p.
40. Illiustrirovannyi opredelitel rastenii Kazakhstana [Illustrated determinant of plants of Kazakhstan]. AlmaAta: Nauka. **1972**. Vol. 2. [in Russian]
41. Kamelin, R.V. Key to Plants of Central Asia. A Critical Abstract of Flora; Science Publishing House: Leningrad, Russia, **2015**; Volume 11.
42. International Plant Names Index. Available online: www.ipni.org (accessed on 30 January 2024).
43. Serebryakov, I.G. Ecological morphology of plants. Life forms of the overgrowths and conifers. Moscow: High School, **1982**, 380 p. (In Russian)
44. Shay, J.E.; Pennington, L.K.; Mandussi Montiel-Molina, J.A.; Toews, D.J.; Hendrickson, B.T.; Sextov, J.P. Rules of plants species ranges: application for conservation strategies. *Frontiers in Ecology and Evolution*, **2021**, *9,* 700962. https://doi.org/10.3389/fevo.2021.700962
45. Kew Royal Botanical Garden. Plants of the World Online. Available online: www.powo.science.kew.org (accessed on 30 January 2024).
46. Komarov, A.S.; Palenova, M.M.; Smirnova, O.V. The concept of discrete description of plant ontogenesis and cellular automata models of plant populations. *Ecological Modeling*,**2003,***170,* 427-439. https://doi.org/10.1016/S0304-3800(03)00243-6
47. Fedorova, S.V. Methodological approaches in population botany and plant ecology. *American Journal of BioScience*, **2020**, *8(3),* 73-90. https://doi.org/10.11648/j.ajbio.20200803.14
48. Elzinga, C.L.; Salzer, D.W.; Willoughby, J.W. Measuring & Monitoring plant populations. U.S. Nebraska, **2019**, 497 p.
49. Kuziev, R.K.; Sektimenko, V.E. Soils of Uzbekistan; Extremum Press Publishing House: Tashkent, Uzbekistan, **2009**; p. 351. (In Russian)
50. Kuziev, R.K.; Yuldashev, G.Y.U.; Akramov, I.A. Bonitization of Soils; The Way of Science Publishing House: Tashkent, Uzbekistan, **2004**; p. 127
51. Joshi SP, Gupta VS, Aggarwal RK, Ranjekar PK, Brar DS. 2000. Genetic diversity and phylogenetic relationship revealed by inter simple sequence repeat (ISSR) polymorphism in the genus Oryza. Theoretical and Applied Genetics 100(8):1311–1320 DOI 10.1007/s001220051440.
52. Rohlf F. 1998. NTSYSpc: numerical taxonomy and multivariate analysis system, Version 2.02. Setauket, New York: Exeter Software.

 doi:10.20944/preprints202402.1257.v1