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

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Abstract: *Alhagi pseudalhagi*, which grows in the arid zone of the Atyrau region, and an assessment of the current state of its raw material reserves were studied. Botanical characteristics, ontogenetic spectra, morphological indicators, productivity, areas of thickets, and reserves of raw materials of above-ground organs were assessed. The structural parameters of these populations in the Zhangyr and Coneu Rivers valleys, in the vicinity of Imankara Mountain, and on 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 species, which, according to their occurrence in populations of *A. pseudalhagi*, are distributed in the following classes: 17 species—class II (0–20%); 7 species—class III (41–60%); and 2 species—classes IV (61–80%) and V (81–100%). The maximum similarity in species composition was noted between populations in the Zhangyr and Coneu Rivers valleys. The highest morphometric indicators were observed among the population of the Coneu river valley, and the lowest are located on the Taisoigan sands. Analysis of the age spectra made it possible to determine that the populations in the Zhangyr and Coneu River valleys are characterized as young and those in the area of Imankara Mountain and on the Taisoigan sands as stable and middle-aged.

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

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1. Introduction

Alhagi pseudalhagi (M. Bieb.) Desv. ex Wangerin (camel thorn or manna tree) is one of four representatives of the genus *Alhagi* Tourn. ex Gagnebin of the family Fabaceae Lindl. This herbaceous perennial has the particularly thorny characteristics of a subshrub, in addition to having a root system that penetrates deeply into arid soils. The main feature of its morphological difference is the high variation in plant height from 30 to 100 cm, which directly depends on the habitat [1,2].

A. pseudalhagi is used in clinical and folk medicine to treat diseases of the gastrointestinal tract, genito-urinary system, and liver, as well as colds and rheumatism, and is used as a choleretic, diuretic, and cleansing agent in the treatment of liver diseases and peptic ulcers. When applied externally, the decoction heals wounds [3,4]. The decoction and infusion of the leaves have bacteriostatic, astringent, hemostatic, choleretic, and wound-healing effects [5–9]. The decoction and tincture are used to treat inflammation of the colon and duodenum and the gall bladder, gastritis, and peptic ulcers, and are sometimes prescribed for colds and severe coughs, as well as for the prevention of dysentery. These medicinal properties make it possible for this plant to become the basis for the production of local domestic herbal medicines [10,11]. Based on the above-ground organs of *A. pseudalhagi*, a syrup has been developed for the treatment of colds and upper respiratory tract infections [12–14].

The four species of this genus are widely distributed from North Africa to 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 [15].

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, Aktobe, and Atyrau regions [16–21].

Earlier, about 177 species of medicinal plants belonging to 118 genera and 46 families were found in this territory of the Atyrau region. These identified species are suitable for potential procurement of medicinal raw materials and include such species 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 promising medicinal species is *Alhagi pseudalhagi* (M. Bieb.) Desv. ex Wangerin [22–25].

The environmental distribution of this species mainly includes dry steppes; clayey and gravelly semi-deserts and deserts; along the banks of rivers and canals; and in wastelands and fallow lands. Plant raw materials in the arid zone in Kazakhstan can be obtained both by growing industrial plantations and by organizing harvests from natural arid conditions [26,27]. However, similar work studying *A. pseudalhagi* in the Atyrau region and Kazakhstan has not previously been carried out [28–30].

Significant thicket areas are noted for *A. pseudalhagi*, and the range of this species is confined to steppe, semi-desert, and desert territories [31]. Preliminary field studies revealed the presence of thickets of *A. pseudalhagi* in the Mangystau region; large thickets were also identified in the Atyrau region in the vicinity of Mount Imankara; the floodplain of the Zhangir, Uter, Koneu, Krasny Yarik, and Aktolkyn rivers; in Aktailak; and on the sands of Toysaigan and Naryn [32].

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 procurable raw materials. The aerial part of the plant contains phenolic compounds (phenolic carboxylic acids, flavonoids, proanthocyanidins, xanthones, coumarins, tannins, α-pyrones, diphenyl ethers, and naphthoquinones), alkaloids, terpenoids (mono-, sesqui-, and triterpenoids and polyterpenoids), fatty acids and their aldehydes, carbohydrates, and organic acids [33]. However, raw material reserves and procurement possibilities in the arid region of Kazakhstan have not been sufficiently studied. There is research on various environmental factors affecting the biological mass of plants and their genetic characteristics [34].

The study of the current state of a natural population of economically valuable *A. pseudalhagi* specimens with an assessment of the possibility of their practical application is motivated by priorities for preserving biological diversity in arid zones, thus expanding the use of traditional herbal medicines [35].

The purpose of this study is to analyze the current state of the *A. pseudalhagi* population in four locations on the territory of the Atyrau arid zone according to various parameters, to estimate the quantity of resources, identify the properties of the plant and the density of its distribution, and determine the composition of related species for obtaining medicinal raw materials. In addition, the morphological features of *A. pseudalhagi* population and distribution areas in the arid zone are studied, along with the age composition of vegetative and generative individuals located within various plant species communities.

2. Materials and Methods

2.1. Research Areas

The studied area belongs to the western part of Kazakhstan, which 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, northeast of the Caspian Sea. The surface of the region is flat; in the north of the region, there are small mountains. The

climate is sharply continental, and extremely dry, with hot summers and moderately cold winters. This territory can be classified as an arid zone with unfavorable conditions for most species of medicinal plants, which in turn increases interest in this territory and its natural plant species [36,37].

2.2. Floristic and Population Analyses

The population analysis of the morphological properties of plants in ontogenesis was studied using the methodology of O. V. Smirnova et al. [38]. At the same time, the names of the plant species were 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 the population 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 within 1 m recording sites [44]. Nomenclature of plants was determined according to POWO [45]. The similarity in floristic composition was estimated according to the Jaccard similarity index [46].

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%; and V—81–100%. When describing ontogenesis, we used the method of Komarov et al. [47]. The population type was determined according to the method of S.V. Fedorova [48]. The following age groups were considered: juvenile plants (j), immature plants (im), adult vegetative plants (v), young generative plants (g1), middle-aged generative plants (g2), and old generative plants (g3). Sprouts and senile individuals were not identified in the natural population at the time of the study.

During the study, four main comparative populations were selected from different geographical regions (mountains, coastal waters, and sands) in the Atyrau region: in the vicinity of Mount Imankara (population 1), in the valley of the Zhangyr River (population 2), in the valley of the Coneu River (population 3), and on the Taisoigan Sands (population 4). Details on these locations are presented in Table 1.

The locations of the studied population of *A. pseudalhagi* and the conditions of their existence in the arid conditions of the Atyrau region are presented in Figure 1.

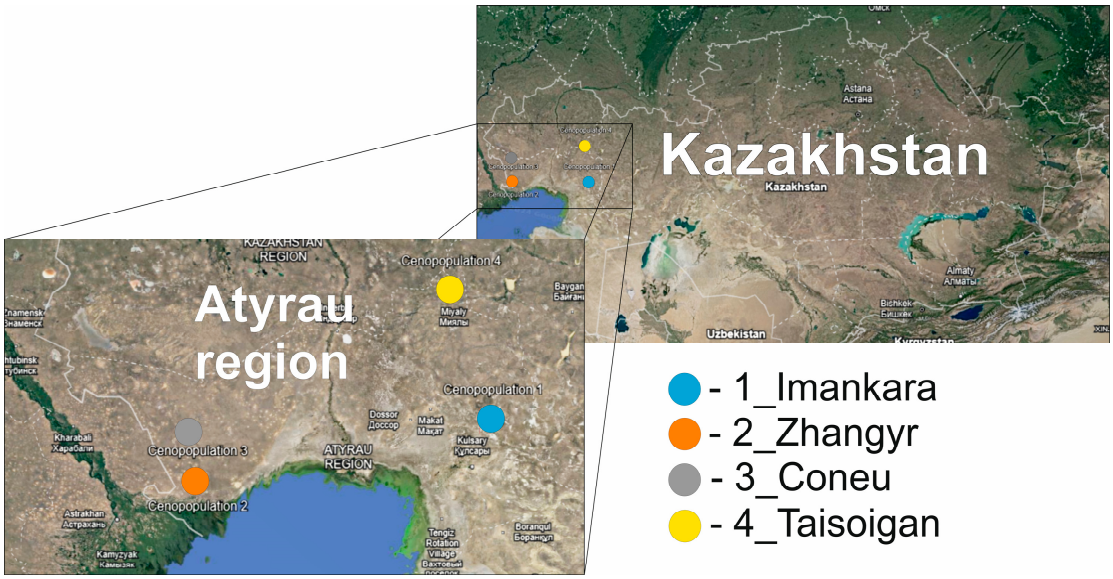


Figure 1. Locations of the populations of *A. pseudalhagi*.

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

Name	Geographical Location	Coordinates	Height Above Sea Level	Administrative Location
Population 1	The vicinity of Imankara Mountain	47°19′49″ N 54°22′12″ E	370 m above sea level	Atyrau region, Zhylyoysky district
Population 2	Zhangyr River valley	46°40′05″ N 49°23′50″ E	281 m below sea level	Atyrau region, Kurmangazinsky district
Population 3	Coneu River valley	46°40′00″ N 49°23′50″ E	284 m below sea level	Atyrau region, Kurmangazinsky district
Population 4	Taisoigan sands	48°49′23″ N 53°44′36″ E	225 m above sea level	Atyrau region, Kzylkoginsky district

2.3. Assessment of Plant Resources

Evaluation of above-ground organ resources was performed according to the method of Elzinga et al. [49]. In the study area, 10–15 survey plots with an area of 1 m^2 were laid out, from which above-ground organs of *A. pseudalhagi* were cut at a height of 5–8 cm from the soil. The raw materials were air-dried and weighed. The areas of the thickets were calculated by multiplying the length and width of the thickets. Average yield data from 1 survey plot were recalculated per hectare (kg/ha). The exploitable stock was calculated as the product of yield per total area, and the volume of possible raw material collection was set as 40–50% of the exploitable stock.

2.4. 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 by calculating the non-parametric Mann–Whitney test to determine the reliability of differences between the indicators of the floristic composition between populations, as well as between morphological indicators of the populations of the species under study.

Mathematical processing was performed according to the methods of Kuziev R.K. and Yuldashev G. et al. [50,51]. Statistical analysis of population dynamics varies depending on the constraints, which vary according to the standard deviation of the coefficient of variation, the mean value of the error, the degree of confidence, and the degree of precision.

A dendrogram was constructed using the PAST 4.03 program and unweighted pair group method with arithmetic mean (UPGMA) algorithm and Boot N:1000 [52].

To compare the results, a one-way analysis of variance (ANOVA) was used with a significant correlation found between the soil type and the main plant parameters in the population. 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 the main quantitative traits (plant height, cm; plant diameter, cm; number of generative shoots, pieces; number of individuals per 1 m^2, pieces) of the four populations were grouped according to PCoA (principal component analysis). PCoA was performed using the Numerical Taxonomy and Multivariate Analysis System Version 2.1. (NTSYS-pc) program [53].

3. Results

3.1. Structure of the Populations of Alhagi pseudalhagi

For the first time, a comprehensive description is given of the structure of the population, species composition, and resources of *A. pseudalhagi* depending on the position of the relief. Data on the distribution of species according to ecological groups showed that in the population 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 largest number

of species belongs to xerophytes, accounting for more than half of the species found, while other ecological groups occupy smaller proportions of the studied populations.

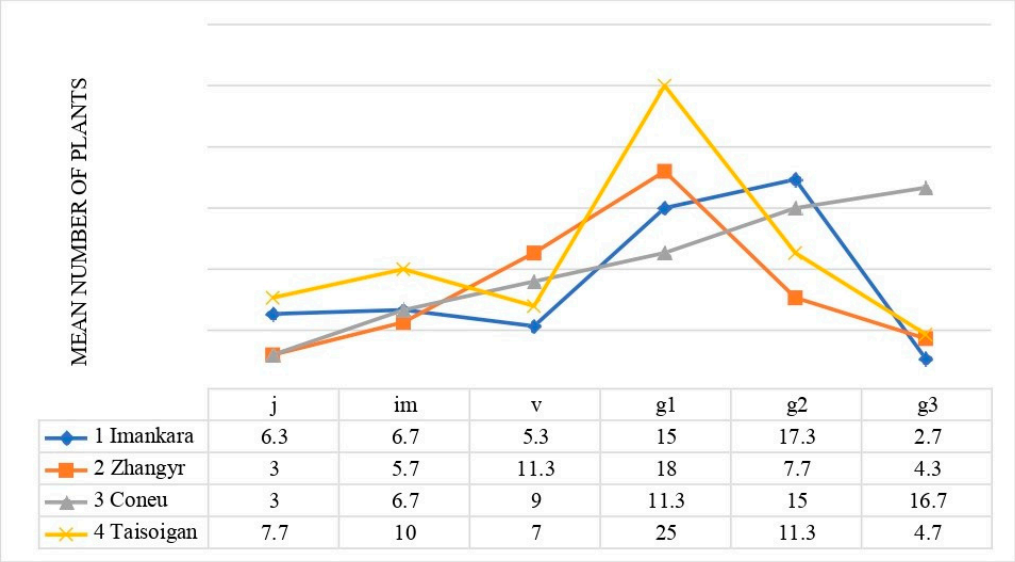
Population 1 (*Limonium suffruticosum* (L.) Kuntze—*Alhagi pseudalhagi* (M. Bieb.) Desv. ex Wangerin—Herbaxerophytica) is located in the vicinity of Imankara Mountain. The total projective cover (hereinafter referred to as the TCC) of vegetation is 40–50%. The relief is plain with slight differences in elevation, and soils are loamy and brown, with numerous outcrops of chalky rocks. The surveyed area is used for cattle grazing in spring. Vegetation consists of two tiers: shrub, 40–55 cm (*Atraphaxis spinosa* L.), and herbaceous, 15–35 cm. The basic summarized species in this 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* are present, with middle-aged generative plants being dominant. The status of population 1 can be characterized as stable and capable of self-renewal. Soil type: flat area in front of the chalk mountains of Imankara, with loamy, dry, grey-earth soils that are heavily gravelly and of a basic nature.

Population 2 (*Alhagi pseudalhagi—Salsola foliosa* (L.) Schrad.—*Limonium gmelinii* (Willd.) Kuntze) is located in the Zhangyr River valley. The TCC is 75%. The soils are chestnut and loamy. The vegetation forms three 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 the 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: the soil is light chestnut, loamy, and moist, without the presence of rocky elements. This area is flooded in the spring.

Population 3 (*Alhagi pseudalhagi—Herba varia*) is located in the Coneu River valley. The TCC is 75%. Soils are light chestnut, loamy, and, in some places, salty. The vegetation is degraded by 25–30% due to active cattle grazing. The vegetation is composed of three tiers (one shrub, 60–70 cm high, and two 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. Population 3 is composed of *A. pseudalhagi* of the young, normal type, with a predominance of young generative individuals. Soil type: the soil is light chestnut, loamy, and moist, without the presence of rocky elements. This area is flooded in the spring.

Population 4 (*Alhagi pseudalhagi—Glycyrrhiza glabra* L.—*Herbaxerophytica*) is described on the Taisoigan sands. The TCC is 50–55%. The relief is flat; the soils are sandy, with clay outcrops in some places. There are traces of cattle grazing. Vegetation degradation of 10–15% is observed. The cover is composed of two tiers: high grass, 40–65 cm, and low grass, 15–25 cm. The species composition includes 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. Population 4 is normal, stable, and medium-aged, dominated by medium-aged generative plants. Soil type: typical sandy massifs, with wet loams at a depth of 40 cm.

When describing the population structure, we also considered the age spectra of *A. pseudalhagi* individuals. In populations of perennial plants, all individuals are characterized by a set of biomorphic traits that determine their age differentiation (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 the populations of *A. pseudalhagi*.

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

Age structure is one of the most important traits of the population. 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 generational change. It shows the ability of the population to maintain itself and the degree of its resistance to the influence of negative environmental factors, including anthropogenic impacts.

3.2. Floristic Composition of A. pseudalhagi Populations

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*. Systematic 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 four leading families include 28 species and 23 genera, representing 44.4 and 42.6% of the total floral composition, respectively.

A comparison of the species composition of the populations showed that the greatest number of species was recorded for population 1 (25), the minimum for population 4 (21), while populations 2 and 3 have the same quantitative composition (24 species each).

Significant degradation of vegetation cover in the valleys of the Zhangyr and Coneu Rivers due to anthropogenic pressure is noted, which is confirmed by a significant number of weeds and 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 not typically eaten by domestic animals. The analysis of species according to occurrence showed that classes IV and V were noted only for *Alhagi kirghisorum* Schrenk and *Limonium suffruticosum* (L.) Kuntze (3.2% of the total number of species). Class III was assigned for 7 species or 11.1% (*Artemisia terrae-albae* Krasch., *Salsola foliosa* (L.) Schrad., *Carex physodes* M. Bieb., *Euphorbia seguieriana* Neck., etc.), and class II comprised 17 species or 26.9% (*Artemisia arenaria* D.C., *Peganum harmala* L., *Xanthium strumarium* L., *Tamarix laxa* Willd., etc.). The greatest number of species were in class 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%), with the second position occupied by minor shrubs (15 species or 23.8%) and the third by semi-shrubs (9 species or 14.3%). Shrubs account for five species (7.9%) and trees for one species (1.5%).

3.3. Morphological Differences between Populations and Resource Potential of A. pseudalhagi

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

The morphometric indicators of individuals from the four populations differed in the number of individuals per 1 m^2, the height of generative shoots, and the number of shoots per individual. Table 2 presents the morphometric parameters of *A. pseudalhagi* in the studied populations of the Atyrau region. According to the data obtained, the greatest number of individuals per 1 m^2 was noted for population 2 (2.6 pieces) and population 3 (2.2 pieces), and the lowest growth density was noted for population 4 (0.5 pieces).

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

Name	Generative Plant Height, cm	Number of Generative Individuals per 1 m^2, Pcs.	Number of Generative Shoots per Individual, Pcs.
Populations 1	24.4 ± 1.2	0.8 ± 0.02	3.2 ± 0.5
Populations 2	28.3 ± 1.3	2.6 ± 0.03	5.6 ± 0.8
Populations 3	30.5 ± 1.5	2.2 ± 0.01	6.1 ± 0.03
Populations 4	26.2 ± 1.4	0.5 ± 0.02	2.9 ± 0.4

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

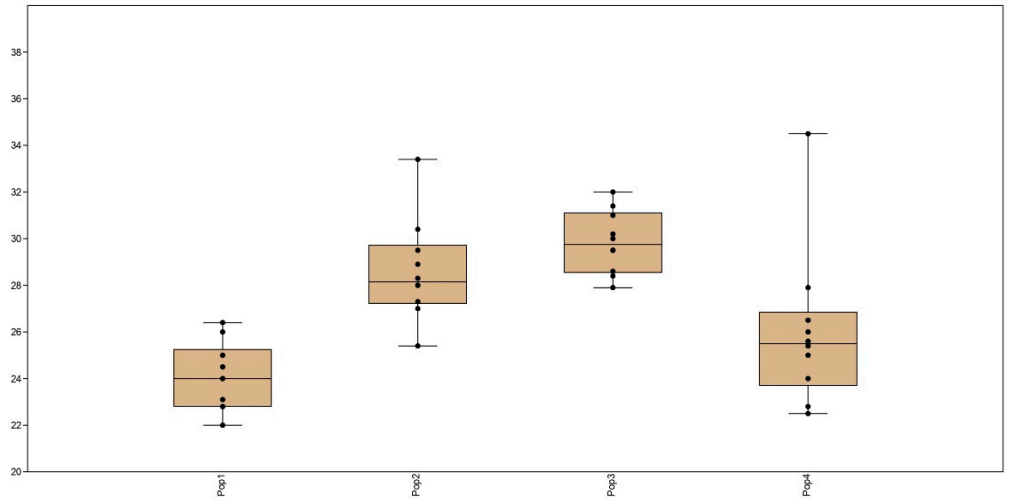


Figure 3. Column diagram of plant heights in populations of *A. pseudalhagi*.

Accordingly, individuals in population 3 which had the greatest generative shoot heights had the largest number of generative shoots per individual (6.1 pieces) by far, while population 4 had the largest number of generative shoots (2.9 pieces). Population 1 occupies an intermediate position between population 2 and population 4 in terms of morphometric parameters. Probably, the differences between the populations are 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 population parameters between populations 2 and 3 and between populations 1 and 4 (Figure 4). This group association is related to the geographical proximities of these two groups. The most significant difference in the morphological parameters of individuals between different populations was observed for population 1 and population 4, while population 2 and population 3 have similar parameters.

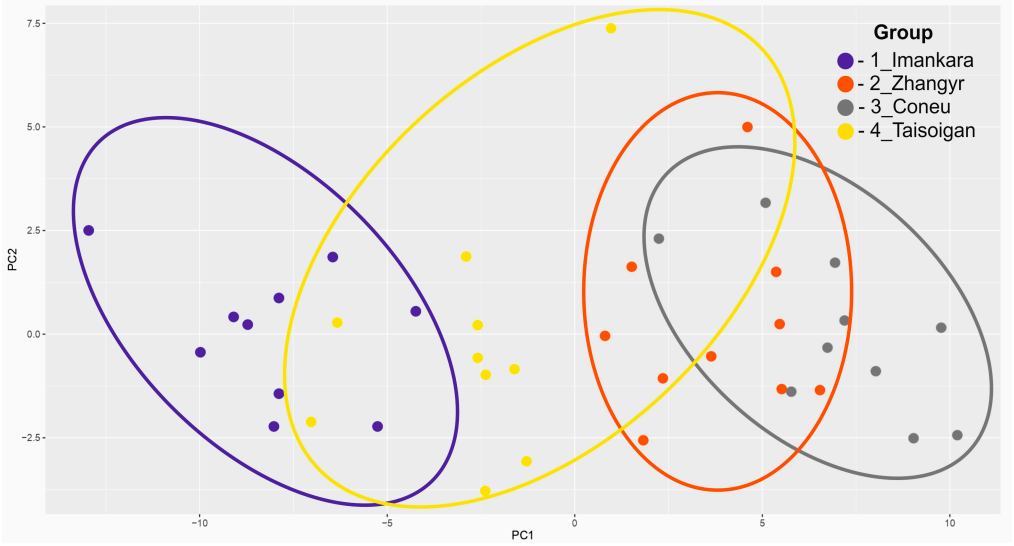


Figure 4. Principal coordinate analysis (PCoA) for populations of *A. pseudalhagi*.

The dendrogram shows that there is a small overlap of individuals between populations 2, 3, and 4, comprising a special group that does not climb up to the mountainous territory. A low degree of overlap characterizes the mountainous population. All populations differed significantly from each other in the number of individuals and in the growth of significant differences (Figure 5).

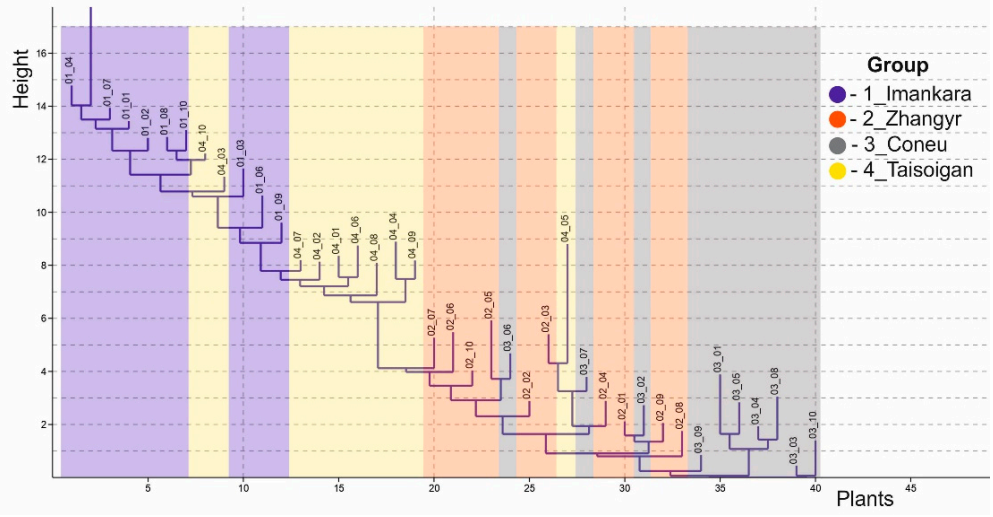


Figure 5. Unweighted pair group method with arithmetic mean (UPGMA) dendrogram populations of *A. pseudalhagi*.

Moreover, differences between populations 2 and 4 were pointed out. There were significant differences in the number of generative shoots between populations 1 and 4 and between populations 2 and 3. Probably, the differences between the populations were due to the difference in the climatic conditions of the arid zone and the various natural conditions influencing the growth of the species.

The following indicators were correlated: the plant height, in cm (PH); the plant diameter, in cm (PD); the number of generative shoots (GS), in pieces; the number of individuals per 1 m^2, in pieces (NI); the soil type (ST); the and population (CP). These correlations show the positive influence of the main factors for identifying and assessing the state of *A. pseudalhagi* populations (Figure 6).

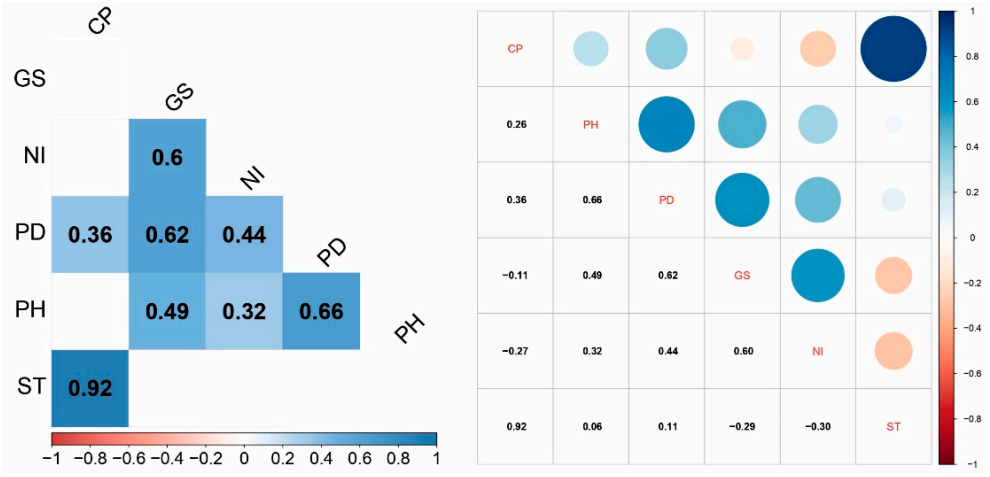


Figure 6. Correlation of the main significant parameters of populations of *A. pseudalhagi*: plant height, cm (PH); population (CP); plant diameter, cm (PD); number of generative shoots (GS), pieces; number of individuals per 1 m^2, pieces (NI); soil type (ST).

The one-way factor analysis (ANOVA) showed the significance ($p < 0.05$) of the influence of the soil type (ST) on the following plant indicators in the different populations: plant height (PH), with a value of 4.16×10^{-6}; plant diameter (PD), with a value of 6.55×10^{-13}; number of generative shoots (GS), in pieces, with a value of 3.79×10^{-10}; and number of individuals per 1 m^2, in pieces (NI), with a value of 3.59×10^{-6}.

A canonical correspondence analysis (CCA) was also performed for the four populations to determine correspondence between the parameters of height above sea level (altitude) and type of land and the following parameters: plant height, cm (PH), plant diameter, cm (PD); number of generative shoots, pieces (GS); number of individuals per 1 m^2, pieces (NI). Also, the presence and absence of such geographical factors as mountainous terrain, riverbanks, and empty sands were considered. The results are presented graphically in Figure 7.

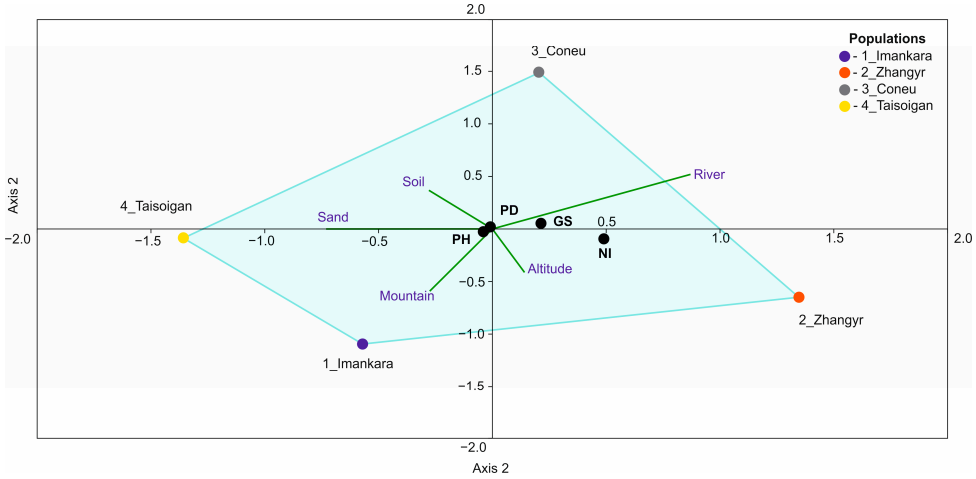


Figure 7. Canonical correspondence analysis (CCA) of populations of *A. pseudalhagi* (The black dot indicates: plant height, cm (PH); plant diameter, cm (PD); number of generative shoots, pieces (GS); number of individuals per 1 m^2, pieces (NI).

3.4. Resource Potential of the Populations 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 kg/ha (Table 3). The maximum harvest was found in the vicinity of Imankara Mountain, and the minimum harvest was in the Zhangyr River valley.

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

Populations	Area, ha	Yield, kg/ha	Operational Reserve, tons	The Volume of Possible Harvested Raw Materials, tons
Population 1	96.0	2847 ± 180	273.30	136.65
Population 2	52.0	976 ± 42	50.76	25.38
Population 3	80.0	850 ± 94	68.04	34.02
Population 4	12.3	2148 ± 122	26.42	13.21
Total	240.3	-	418.52	209.26

The total area of the thickets is estimated to be 240.3 ha. The operational reserve amounts to 418.52 tons, while the annual possible collection of above-ground organs was estimated at 209.26 tons. Sufficient thicket areas 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 industrial procurement.

4. Discussion

Research studying the state of wild populations of *A. pseudalhagi* in the Atyrau region is scarce, and there is practically no scientific research on the study of the resource reserves of *A. pseudalhagi*. To conduct a comparative analysis, results from studies of closely related species were reviewed.

Significant differences in the species composition of *A. pseudalhagi* populations were noted. Thus, the maximum index of similarity in floristic composition was found between populations 2 and 3—0.122; the minimum index was between populations 1 and 2—0.042.

The obtained data can be explained by the fact that in the Zhangyr and Coneu River valleys, similar soil and climatic conditions and degrees of anthropogenic pressure are observed, while populations 1 and populations 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 grow each; and on the Taisoigan sands, 21 species grow. This statement about the complex relationships of *A. pseudalhagi* populations with various plant and animal species is confirmed in other studies [54].

One of the main indicators of a plant's resource reserves is the average height of the plants in the population. The tallest plants were recorded in populations 2 (Zhangyr) and 3 (Coneu) at 28.3 ± 1.3 and 30.5 ± 1.5 cm; in addition, the dry mass indicators are 976 ± 42 and 850 ± 94 kg/ha, which are among the lowest figures. Comparing the recorded dry weights of plants in this study, it can be seen that the same positive trends are shown in other parameters. This indicator is associated with the presence of the coastal–aquatic location factor, which is confirmed in Figure 7 (canonical correspondence analysis CCA). The same pattern has been scientifically confirmed in studies of *A. sparsifolia* populations in China [55]. The complex morphological structure of individual organs is also preserved for the root system of *A. pseudalhagi* [56]. A CCA of *A. pseudalhagi* populations showed a direct impact on the environment, namely rocky and soil characteristics showed differences between populations. This judgment is also confirmed in populations of *A. maurorum*, which may also be a growth strategy in arid and semi-arid conditions [57].

The one-way factor analysis (ANOVA) showed the significance ($p < 0.05$) of the influence of the soil type (ST) factor on the plant indicators in different populations: plant height (PH), with a value of 4.16×10^{-6}; plant diameter (PD), with a value of 6.55×10^{-13};

the number of generative shoots (GS), in pieces, with a value of 3.79×10^{-10}; and the number of individuals per 1 m^2, in pieces (NI), with the value 3.59×10^{-6}. These results show the great importance of soil type. The populations growing in non-mountainous zones are depleted into one diseased group, which is presented in the dendrogram in Figure 5 (UPGMA). Similar results were obtained in some populations of *A. graecorum* and confirmed by genetic studies. It can be noted that the main morphological characteristics correlate positively with each other, as well as with such indicators as plant height and shoot diameter, which, in turn, are observed in populations of *A. maurorum* [58].

These results highlight the need for further investigation into the specific drivers of unexplained variations and the role of *A. pseudalhagi* in shaping plant community relationships under arid conditions. This study not only expands our understanding of the structure and community composition of *A. pseudalhagi* populations but also highlights the significant biodiversity and abundance of plant species in this arid habitat. These studies may also be of interest in environmental assessment and population management [59].

5. Conclusions

In general, the study of four populations of the medicinal plant *A. pseudalhagi* (in the arid zone of the Zhangyr and Coneu Rivers, the vicinity of Imankara Mountain, and on the Taisoigan sands) showed that they are in satisfactory conditions and can be used for organizing the procurement of medicinal herbs in compliance with the correct regime and frequency of harvesting. All populations of *A. pseudalhagi* differ from each other in terms of their floristic compositions and main significant morphological indicators. Analysis of the age spectra made it possible to determine that the populations in the valleys of the Zhangyr and Coneu Rivers are characterized as young and those in the vicinity of Imankara Mountain and on the Taisoigan sands as stable and middle-aged. The annual harvestable volume of above-ground organs is estimated at 209.26 tons in the catchments 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 these raw herbal medicinal materials.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d16040219/s1, Table S1: Floristic composition of populations with *Alhagi pseudalhagi.*

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