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Bringing medicinal plants of the native flora of the northern Tien Shan into cultivation

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Abstract: In the current study, it was tried to investigate the medicinal plants of the native flora of the Northern Tien Shan to bring them into domestication. The study was carried out on the territory of a botanical garden located at an altitude of 880 m a.s.l., in the foothill steppe zone of the Zailiysky Alatau ridge, People's Republic of China on light chestnut loamy soils. In 2018–2019, more than 90 samples of 51 species of medicinal plants of the Northern Tien Shan flora was selected from 17 families for introduction tests. The families Compositae (10 genera, 12 species) and Lamiaceae (12 genera, 13 species) were represented by the largest numbers of genera and species. The family Leguminosae was represented by four species from four genera; the families Polygonaceae and Ranunculaceae, by three species each; the family Rosaceae, by two species; and the remaining 11 families, by one species each. The results suggested that the majority of medicinal plants of the Northern Tien Shan tested can be successfully cultivated in the foothill zone of the Zailiysky Alatau. The results indicated that when propagated by seed, the laboratory germination varied from 2 to 30%, and the mass of seeds was 0.21 g. When sown in spring, the field germination was 8%, and when sown in autumn, 42% from 50 to 70% of seedlings survived until the end of the growing season. The massive flowering was observed in the third year, and the plants vegetated until the end of the growing season.

Keywords: botanical garden, loamy soils, medicinal plants, northern Tien Shan

INTRODUCTION

Many previous studies emphasized that the Indigenous Traditional Knowledge (ITK) which evolve in different human civilizations across the world are valuable. ITK used either direct plant parts (leaves, stems, flowers, seeds or roots) or extracts and dry powders rather a artificial chemical compounds [Reddy *et al.* 2019]. Herbal medicine refers to medicines that are made directly from plants and their compounds and have no chemical or laboratory role in their production. These drugs have long been considered for their lack of side effects. The use of valuable plant species and their products in various sectors of the economy including the pharmaceutical industry requires a wider and more comprehensive study of the possibility of cultivating plants in new areas [Minina 2020]. Unlike mass-produced crops, medicinal plants require different soil and climatic conditions, necessitating the study of their characteristic features and the development of methods of industrial cultivation [Kirichenko *et al.* 2019; Klubnikin *et al.* 2000; Rao, Ravishankar 2002].

By assessing the introduction potential of a species, it can estimate the degree of ecological plasticity of the species and its adaptive potential [Belyuchenko 2005]. Plant introduction tests include studying species' response to the soil and climatic conditions of the region of introduction. As a rule, introduction tests are carried out for a limited number of specimens taken from one or several localities. The results of such tests make it possible to predict the probability of growing the tested species at a specific introduction point and then project the results onto similar soil and climatic conditions [GONCHARENKO, YATSENKO 2020; KISHCHENKO 2019; MAKOVSKYY, VAKHNOVSKA 2018; SWEARINGEN *et al.* 2002; TORCHYK 2020].

A characteristic feature of the medicinal plants of the Northern Tien Shan flora studied is that the transfer of the species in geographic space is minimal. The points of origin and introduction are quite close together and are within the species' natural distribution ranges for almost all specimens. Therefore, the degree of success of cultivating plants of the Northern Tien Shan in the Zailiysky Alatau is determined mainly by the breadth of the ecological niche of the transferred species.

The current population-based approach to introduction involves increasing the introduction effectiveness by identifying the species' potential and complete coverage of the gene pool during the introduction experiment [KOROVKINA, ZHIROV 2019; MEDDEGODA *et al.* 2019]. In this regard, for the most valuable species in the collection, regular renewal and replenishment of existing introduction populations with new samples from natural habitats is undertaken. For these purposes, populations of valuable medicinal plants are constantly replenished, including those of *Aconitum soongaricum* Stupf. (wolf's bane), *Marrubium vulgare* L. (white horehound), *Peganum harmala* L. (wild rue / Syrian rue), *Thymus marschallianus* Willd and *Ziziphora* L.

The introduction of native Kazakh flora in the foothill zone of the Zailiysky Alatau began in the 1930s and became especially active in the 1940s with the formation of a collection of medicinal plants, targeted selection and industrial testing of the most promising species. To date, about 500 species of medicinal plants of the native flora have been tested there [CRELLIN, PHILPOTT 1990; GRITSENKO 2019; KRISHNAN *et al.* 2019; MAMEDOV *et al.* 2005; SHTEPHAN 2012; SYKURA, SYRYTSA 1990; ZENI, BOSIO 2006]. The most intense research efforts are concerned with cultivating essential oil plants of the family Lamiaceae (Fig. 1), both abroad [BOBOKALONOV, CHERYOMUSHKINA 2018; KOTYUK *et al.* 2017; RABOTYAGOV *et al.* 2007] and in Kazakhstan [JONES, KINGHORN 2008; POURHOSSEINI *et al.* 2020].

Based on the results of the studies of the native Kazakh flora at the collection site, it was established that, in the Zailiysky Alatau, the majority of cultivated plants (59%) take root well, have a normal ontogenetic cycle and regularly produce viable seeds [BELYAKOV, PHILIPPOV 2018; BIDARLORD *et al.* 2016]. However, a number of valuable medicinal species (including white horehound, wild rue / Syrian rue, and *Ziziphora*) flower and bear fruit

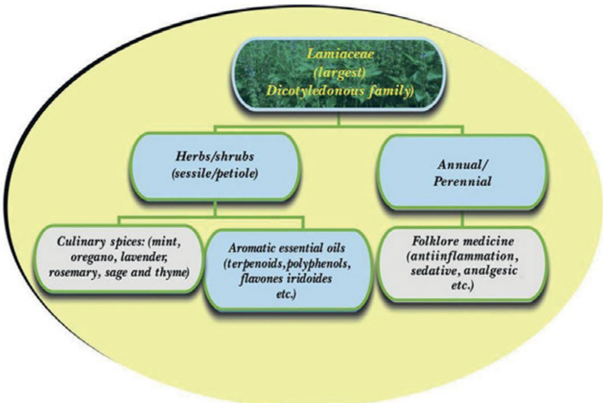

Fig. 1. The family of Lamiaceae plants and their applications; source: own elaboration

irregularly and die out very quickly, sometimes 2–3 years after planting. Such species require a more in-depth study in cultivation, with constant renewal of the introduction material.

Out of the 39 plant species brought in over the past two years, only ten accessions were new to the collection. Those were: *Alhagi pseudalhagi* (M. Bieb.) Fisch. *Alhagi maurorum* (camel-thorn), *Cerasus tianschanica* Pojark (Tienshan cherry), *Chondrilla lejosperma* Kar. & Kir. (Chondrilla), *Dracocephalum integrifolium* Bunge (Dracocephalum), *Echinops chantavicus* Trautv. (globe thistle), *Ephedra equisetina* Bunge (Ephedra), *Salvia deserta* Schangin (sage), *Urtica cannabina* L. (nettle), and *Verbascum songaricum* Schrenk (songar mullein).

There is evidence of high tolerance of *Alhagi maurorum*, to salinization and, as a consequence, increased turgor potential [ABEDINPOUR 2017; HEDJAL *et al.* 2018; KURBAN *et al.* 1998; 1999]. The characteristic features of the seed germination of *Prunus tianshanica* (plum) and the effects of stratification, GA3 and mechanical treatment of seeds on germination and seedling development have been studied. In addition, a method for rooting green cuttings of *Prunus tianshanica* has been developed, ensuring the survival of up to 98% of the planting material.

The technology of growing nettles under aeroponic conditions has been described, which gives an increase in yield, a reduction in ripening time and an improvement in the overall quality of products compared to field production [PAGLIARULO *et al.* 2004], the biological and economic characteristics of 30 genetic clones of the same species have been isolated and described [DREYER *et al.* 1996]. In the current study, as a novel strategy, it was tried to study explore the medicinal plants of the native flora of the Northern Tien Shan to conserve them in local gene sanctuary.

MATERIALS AND METHODS

Tien Shan, Chinese (Pinyin) the Tian Shan or (Wade-Giles romanization) T'ien Shan, Russian Tyan Shan, great mountain system of Central Asia is located in 42° N 80° E. Its name is Chinese for "Celestial Mountains". Stretching about 2,500 km from west-southwest to east-northeast, it mainly straddles the border between China and Kyrgyzstan and bisects the ancient territory of Turkistan. It is about 500 km wide in places at its eastern and western extremities but narrows to about 350 km in width at the centre. The Tien Shan is bounded to the north by the Junggar (Dzungarian) Basin of northwestern China and the southern Kazakhstan plains and to the southeast by the Tarim (Talimu) Basin. To the southwest the Hisor (Gissar) and Alay ranges of Tajikistan extend into part of the Tien Shan, making the Alay, Surkhandarya, and Hisor valleys boundaries of the system, along with the Pamirs to the south. The position of the Tien Shan in the centre of Eurasia governs its sharply continental climate, characterized by great extremes of temperature in summer and winter.

Ranges of the Northern Tien Shan (Zailiysky, Kungey, Ketmen, Terskey, and Kyrgyz Alatau), located in southeastern Kazakhstan, are characterized by high species diversity. As mentioned earlier, the objects of research were medicinal plants of the Northern Tien Shan taken from their native populations and added to the collection of medicinal plants of the Main Botanical Garden (Almaty) in 2018–2019. The geographic map of all sampling locations is indicated in Figure 2.

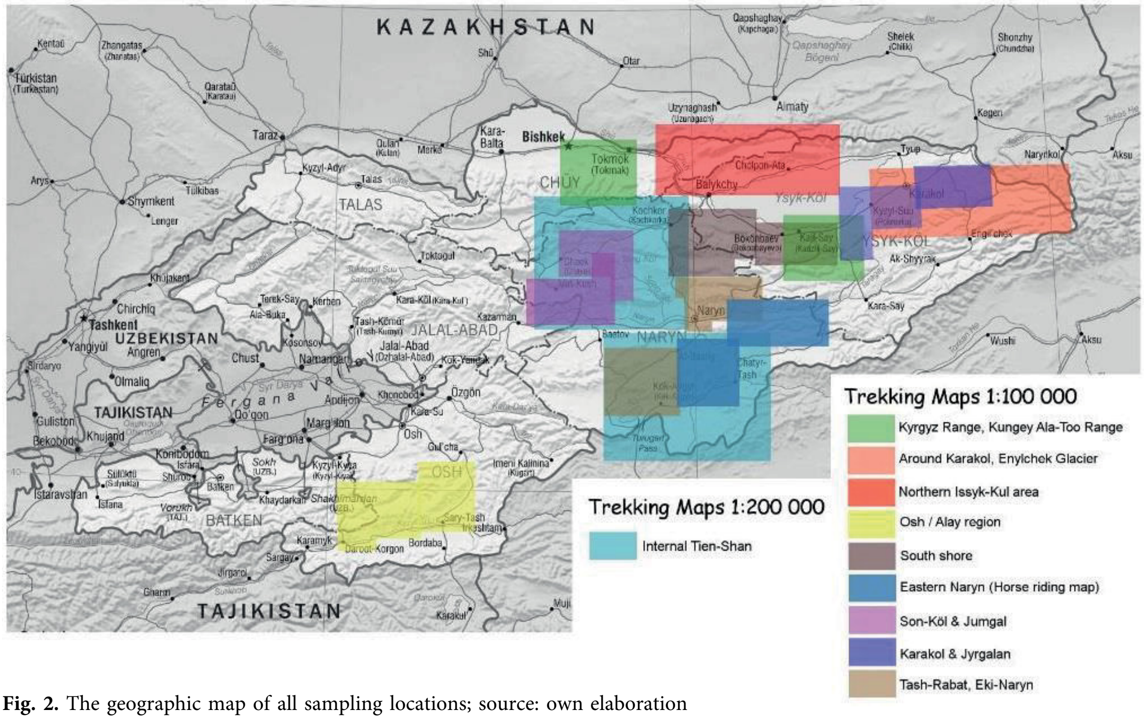

Fig. 2. The geographic map of all sampling locations; source: own elaboration

Studies of establishment success of medicinal plants of the native flora of the Northern Tien Shan were carried out in the Main Botanical Garden at an altitude of 880 m above sea level, in the foothill steppe zone of the Zailiysky Alatau ridge, in light chestnut loamy soils. The climate was extreme continental, with a large diurnal temperature range. The annual precipitation varied over the years, from 460 to 790 mm, and was characterized by an early spring maximum (up to 42%). The period with an average daily temperature of +10°C was 164–182 days [Sokolov *et al.* 1962].

The current study observed the growth and development of plants according to the method of [Beideman 1974; Minea *et al.* 2018; Noreldin *et al.* 2015] using "Recommendations for the study of the ontogenesis of introduced plants in the botanical gardens of the USSR" [Sykura, Syrytsa 1990]. The current study determined the productivity of raw material and seeds according to "Research methodology for the introduction of medicinal plants"; the current study also used methods adopted in other botanical gardens [Kirichenko *et al.* 2019; Klubnikin *et al.* 2000; Minina 2020], with slight modifications appropriate for the local conditions. Thus, from the entire array of phenological data, only the main indicators characterizing the annual ontogenetic cycle were visually determined: the beginning and end of the growing season, flowering and seed ripening. A generalization of these indicators by season and by year makes it possible to assess the adaptive capacity of different species, the features of their behaviour and sustainability in cultivation.

In addition to phenological data, we determined laboratory and field germination capacity of seeds obtained in nature and in cultivation. To determine the laboratory germination capacity, the cleaned seeds of the studied species were sown on filter paper, 100 seeds per one Petri dish, with three replicates. The experiments were carried out in the laboratory conditions at the day temperature of 20–25°C, in the light, with the seed moistened with distilled water. The experiment was carried out for 25 days. The field germination was determined by sowing seeds outdoors with the same replicates, but with more diverse options: soil mixture – sand; autumn – spring sowing. Very small seeds were sown in sowing boxes.

During the introduction of medicinal plants, indicators characterizing the effectiveness of their cultivation are of primary importance. Because of this, we determined such economic indicators as "raw material productivity" and "seed productivity." In our study, "productivity" of plants is defined as the amount of raw material or seeds obtained from one plant (min–max / average value in g); and "yield" is the amount of raw material or seeds per unit area [Belyakov, Lapirov 2019].

Based on long-term observations and in accordance with the fitness of collection plants, the success rate of introduction of the species (*SRI*) was calculated, varying from 1 to 6 [Gemejiyeva, Grudzinskaya 2018; Sitpayeva *et al.* 2020]:

1 – the plant dies during the first growing season;
2 – grows, sometimes produces flowers, but does not produce viable seeds;
3 – bears fruit under specific conditions;
4 – bears fruit outdoors, but not regularly;
5 – successfully grows and bears fruit;
6 – self-regenerating or weedy species.

The taxonomy of species is in accordance with the APG IV system [Chase *et al.* 2016; Petrisheva, Morgacheva 2020]. The species names of the studied plants are provided according to the open-source online atlas and field guide to plants and lichens of Russia and neighbouring countries [Plantarium 2007–2021] and the database of the Plant List [2013].

Plant domestication is the evolutionary process whereby a population of plants becomes accustomed to human provision and control. For many authors, domestication is generally considered to be the end-point of a continuum that starts with exploitation of wild plants, continues through cultivation of plants selected from the wild but not yet genetically different from wild plants and ends with the adaptation to the agroecology through conscious or unconscious human morphological selection, and hence genetic differences distinguishing the domesticated species from its wild progenitor. According to local communities, the collection of plants from the wild for cultivation on farm (fields or home gardens) is a common practice continually being carried out under diverse agro ecosystems. Many varieties, landraces and cultivars of plants have been developed through this process to meet human (and/or animal) demand for food, fibre, medicine, building materials, etc.

RESULTS AND DISCUSSION

In 2018–2019, we selected more than 90 samples of 51 species of medicinal plants of the Northern Tien Shan flora from 17 families for introduction tests. The families Compositae (10 genera, 12 species) and Lamiaceae (12 genera, 13 species) were represented by the largest numbers of genera and species. The family Leguminosae was represented by four species from four genera; the families Polygonaceae and Ranunculaceae, by three species each; the family Rosaceae, by two species; and the remaining 11 families, by one species each (Tab. 1). The names of families and species are in accordance with Royal Botanic Gardens [undated]. It should be noted that the main urgency of the current study was to local use of indigenous knowledge of medicinal use for diseases conservation of local flora in gene sanctuary.

Seeds and living plants of 13 species were added to the collection. Of these, 41 species have already been tested in the conditions of the collection site and were brought in to revive or renew the existing populations of cultivated plants. The following species had a high introduction success rate (5 and 6), and they regularly produced flowers and viable seeds.

Ten new to the collection species (*Alhagi maurorum*, plum, *Chondrilla, Dracocephalum*, globe thistle, *Ephedra*, mints, mullein, nettles, sage) and six species with unstable introduction indicators were tested (Tab. 2).

Wolf's bane (Ranunculaceae) is found at mid-elevations in the spruce forest belt and in meadows up to 3200 m above sea level, from Tarbagatai to the Kyrgyz Alatau [Pavlov 1961]. It grows only on the northern slopes, in fairly rich, moderately moist soils. It is a mesophyte.

By the beginning of the 20th century, in China and Kashmir, the roots of *A. soongaricum* were almost completely dug out of its natural habitat due to the high popularity of this plant in traditional Chinese medicine.

In Kazakhstan, despite its relatively wide distribution range, *A. soongaricum* does not currently form large commercially viable populations and is subjected to uncontrolled exploitation by the local population, which uses the underground parts of this plant for medicinal purposes. In this regard, it is advisable to strictly limit the commercial harvesting of *A. soongaricum* for the needs of the pharmaceutical industry, with the obligatory restoration of populations in its natural habitat and the creation of plantations. The study of the species *in vitro* using biotechnological methods is also promising.

The roots (tubers) contain carbohydrates, coumarins, organic acids, alkaloids (aconitine), flavonoids, fatty oil, etc. It is used as an antibacterial, psychotropic, anaesthetic, and antitumor agent [Sokolov (ed.) 1988]. The plant is highly poisonous and is used in both official and traditional medicine.

It was added to the collection of medicinal plants in the 1960s, 1980s and 2000s. It is unstable in cultivation, has specific demands for soil quality and moisture, and grows better in partial shade. It dies out after 2–4 years, although some specimens had been introduced in the 1960s and survived in an inactive state for up to 8–9 years. According to summarised phenological data, *A. soongaricum* starts to grow in late March (according to the data from the 1980s) – mid-April (according to the data from 2000s), produces flowers in the last ten days of June (1980s) – mid-July (2000s). Its flowers depending on the fitness of the population, for 10–30 days. Seeds ripen in 40–50 days. Flowering is not abundant, and fruiting is very weak. The period of vegetation stops in September. In the 2000s, the actual seed productivity ranged from 0.149 to 0.862 g, the weight of 1000 seeds from 2.75 to 3.92 g, the laboratory germination with stratification for one month from 0 to 13.7%, and the field germination reached 36%, when sown in autumn.

The plants have been grown from seeds, but mainly from living plants. The seeds were collected in the subalpine belt of the Terskey Alatau ridge, at an altitude of 2150 m above sea level. They had a mass of 4.317 g, field germination of stratified seeds sown in spring was only 2%, and the seedlings disappeared after 35–40 days. The existing cultivated population of *A. soongaricum* was created by living plants from three habitats of the same subalpine zone differing in microecological conditions and altitude. The survival rate of the plants ranged from 75 to 100% over the first year; in the second year, the survival rate ranged from 66 to 100%, one or two 140–210 cm tall generative shoots were formed. About 30% of all plants produced flowers. Actual seed productivity ranged from 0.89 to 1.322 g, and the weight of 1000 seeds ranged from 2.7 to 2.82 g.

Alhagi maurorum (Fabaceae) grows throughout the entire plain of Kazakhstan, as well as in the Caucasus, Western Siberia, Central and Asia Minor, in the dry steppes, clay and gravelly semi-deserts and deserts, along river banks and canals, and in wastelands and deposits. The whole plant contains essential oil, steroids, alkaloids, vitamins, coumarins, flavonoids, and tannins. It is used in official and traditional medicine as a hemostatic, choleretic, laxative, wound healing, antipyretic [Kirillov *et al.* 2016; Movsumov *et al.* 2020; Sokolov (ed.) 1988], lipid-lowering, antihypoxic, antisclerotic, antibacterial, and antiviral remedy [Aliyeva 2019]. It forms commercial-size thickets in western, central, and southern Kazakhstan [Crellin, Philpott 1990; Goodier 2018]; commercial-size populations have been identified in the floodplain of the Syr Darya River and on the Mangyshlak Peninsula. In the 1960s, the species was cultivated in the Main Botanical Garden on a site with an artificial sandy soil, and living plants from the Balkhash region were planted. Isolated specimens flowered poorly, the seeds were not formed, and the plants died out after 2–3 years.

Alhagi maurorum is a halophyte with a high turgor potential [Kurban *et al.* 1999], which must be artificially maintained in cultivation, seeds were collected from natural populations growing on the foothill plains of the Zailiysky Alatau ridge in the vicinity of the village of Teskensu. Seeds weighing 5.207 g had a very hard seed coat, and the laboratory germination was 60–83% when seeds were scarified. The field germination of scarified seeds reached 25%; without scarification, the seeds did not germinate for two years. In the second year, the survival of seedlings was 10%, the plants began to grow on April 13th, and the growing season ended on October 5th. The seedlings produced one or two juvenile weakly branched shoots, 7–12 cm tall.

Table 1. Medicinal plants of the Northern Tien Shan added to the collection of the native flora (selected for the first time)

Family	Genus	Number of species	Species
Apocynaceae Juss.	*Trachomitum* Woodson	1	*Trachomitum lancifolium* (Russan.) Pobed.)
Chenopodiaceae Vent.	*Krascheninnikovia* Gueldenst.	1	*Krascheninnikovia ceratoides* (L.) Gueldenst.
Compositae Giseke	*Achillea* L.	1	*Achillea millefolium* L.
	Arctium L.	1	*Arctium tomentosum* Mill.
	Artemisia L.	3	*Artemisia absinthium* L.
			Artemisia scoparia Waldst. et Kit.
			Artemisia serotina Bunge
	Carthamus L.	1	*Carthamus lanatus* L.
	Chondrilla L.	1	*Chondrilla lejosperma* Kar. & Kir.
	Cichorium L.	1	*Cichorium intybus* L.
	Echinops L.	1	*Echinops chantavicus* Trautv.
	Inula L.	1	*Inula caspica* F.K. Blum ex Ledeb.
	Saussurea DC.	1	*Saussurea salsa* (Pall. ex Pall.) Spreng.
	Tanacetum L.	1	*Tanacetum vulgare* L.
Ephedraceae Dumort.	*Ephedra* L.	1	*Ephedra equisetina* Bunge
Euphorbiaceae Juss.	*Euphorbia* L.	1	*Euphorbia lamprocarpa* (Prokh.) Prokh.
Hypericaceae Juss.	*Hypericum* L.	3	*Hypericum hirsutum* L.
			Hypericum perforatum L.
			Hypericum scabrum L.
Lamiaceae Martinov	*Betonica* L.	1	*Betonica betoniciflora* (O. Fedtsch. & B. Fedtsch.) Sennikov
	Dracocephalum L.	1	*Dracocephalum integrifolium* Bunge
	Leonurus L.	1	*Leonurus turkestanicus* V.I.Krecz. & Kuprian.
	Lycopus L.	1	*Lycopus exaltatus* L. f.
	Marrubium L.	1	*Marrubium vulgare* L.
	Mentha L.	1	*Mentha longifolia* (L.) L,
	Nepeta L.	1	*Nepeta pannonica* L.
	Origanum L.	1	*Origanum vulgare* L.
	Phlomoides Moench	1	*Phlomoides pratensis* (Kar. & Kir.) Adylov, Kamelin & Makhm.
	Salvia L.	1	*Salvia deserta* Schangin
	Thymus L.	2	*Thymus marschallianus* Willd.
			Thymus seravschanicus Klokov
	Ziziphora L.	1	*Ziziphora clinopodioides* Lam.
Leguminosae Juss.	*Alhagi* Gagneb.	1	*Alhagi pseudalhagi* (M. Bieb.) Desv. ex B. Keller & Shap.
	Glycyrrhiza Tourn. ex L.	1	*Glycyrrhiza uralensis* Fisch.
	Melilotus Mill.	1	*Melilotus officinalis* (L.) Pall.
	Vexibia Rafin.	1	*Vexibia alopecuroides* (L.) Yakovlev
Nitrariaceae Lindl.	*Peganum* L.	1	*Peganum harmala* L.
Onagraceae Juss.	*Chamaenerion* Ség.	1	*Chamaenerion angustifolium* (L.) Scop.
Plantaginaceae Juss.	*Plantago* L.	1	*Plantago major* L.
Polygonaceae Juss.	*Rheum* L.	1	*Rheum wittrockii* C.E. Lundstr.
	Rumex L.	2	*Rumex confertus* Willd.
			Rumex crispus L.
Ranunculaceae Juss.	*Aconitum* L.	2	*Aconitum leucostomum* Vorosch.
			Aconitum soongaricum (Regel) Stapf
	Aquilegia L.	1	*Aquilegia glandulosa* Fisch. ex Link
Rosaceae Juss.	*Agrimonia* L.	1	*Agrimonia asiatica* Juz.
	Cerasus Mill.	1	*Cerasus tianschanica* Pojark. (*Cerasus tomentosa* (Thunb.) Wall. ex T.T. Yu & C.L. Li)
Scrophulariaceae Juss.	*Verbascum* L.	1	*Verbascum songaricum* Schrenk
Urticaceae Juss.	*Urtica* L.	2	*Urtica cannabina* L.
			Urtica dioica L.
Valerianaceae Batsch	*Patrinia* Juss.	1	*Patrinia intermedia* (Hornem.) Roem. & Schult.
Total number: 17	total number: 43	total number: 51	

Source: own study.

Table 2. Assessment of introduction potential of new species of medicinal plants

Method of propagation	Type of planting material	Laboratory germination (%)	Field germination or survival (%)	Survival at two years (%)	Flowering, fruiting
***Aconitum soongaricum*, family Ranunculaceae, life form – herbaceous perennial**					
Spring sowing	seeds	0–13	2	0	–
Autumn planting	living plants		100	100	++
Summer planting	living plants	–	75	66	++
Summer planting	living plants	–	90	90	++
***Alhagi pseudalhagi,* family Leguminosae, life form – small shrub**					
Spring sowing	seeds	–	0	–	–
Scarification	seeds	60–83	25	10	–
Summer planting	living plants	–	0	–	–
Summer planting	living plants	–	0	–	–
***Cerasus tianschanica*, family Rosaceae, life form – shrub**					
Autumn sowing	seeds	–	0	–	–
Stratification	seeds	20	10	0	–
Summer planting	living plants	–	90	90	+
Autumn planting	living plants	–	50	20	–
***Chondrilla lejosperma*, family Compositae, life form – herbaceous perennial**					
Spring sowing	seeds	88	15	30	–
Autumn sowing	seeds	–	11	22	–
Summer planting	living plants	–	70	44	+
***Dracocephalum integrifolium*, family Lamiaceae, life form – small shrub**					
Spring planting	living plants	–	87	70	++
Summer planting	living plants	–	70	48	++
***Echinops chantavicus*, family Compositae, life form – herbaceous perennial**					
Spring sowing	seeds	0	4	0	–
Autumn sowing	seeds	–	4	4	–
***Ephedra equisetina*, family Ephedraceae, life form – small shrub**					
Autumn sowing	seeds	–	88	60	–
***Leonurus turkestanicus*, family Lamiaceae, life form – herbaceous perennial**					
Autumn sowing	seeds	30–41	4	4	–
Plot, spring sowing	seeds	–	48	34	++
***White horehound*, family Lamiaceae, life form – herbaceous perennial**					
Box, spring sowing	seeds	28–81	52	18	++
Spring planting	living plants	–	78	50	++
Summer planting	living plants	–	90	–	++
***Peganum harmala*, family Nitrariaceae, life form – small shrub**					
Box, autumn sowing	seeds	66–94	29	3	–
Box, spring sowing	seeds	–	33	6	–
Plot, spring sowing	seeds	–	0	–	–
Plot, autumn sowing	seeds	–	0	–	–
Box, 1st year of storage	seeds	–	4–8	3–5	–
Box, 2nd year of storage	seeds	–	0–1.7	0	–
Box, 3rd year of storage	seeds	–	2	2	–
Box, 4th year of storage	seeds	–	2	0	–
Spring planting	living plants	–	83	48	+
Spring planting	living plants	–	29	12	+
Autumn planting	living plants	–	30	10	–

cont. Tab. 2

Method of propagation	Type of planting material	Laboratory germination (%)	Field germination or survival (%)	Survival at two years (%)	Flowering, fruiting
Autumn planting	living plants	–	50	11	–
Spring planting	living plants	–	83	30	+
***Salvia deserta*, family Lamiaceae, life form – herbaceous perennial**					
Autumn sowing	seeds	12–22	0	–	–
Spring sowing	seeds	–	16	56	++
***Thymus marschallianus*, family Lamiaceae, life form – herbaceous perennial**					
Spring sowing	seeds	20–98	10	7	–
Spring planting	living plants	–	87	50	+
Autumn planting	living plants	–	50	0	–
Summer planting	living plants	–	95	43	–
Spring planting	living plants	–	75	53	+
Spring planting	living plants	–	80	40	–
***Thymus seravschanicus*, family Lamiaceae, life form – herbaceous perennial**					
	living plants	–	70	56	+
***Urtica cannabina*, family Urticaceae, life form – herbaceous perennial**					
Spring sowing	seeds	100	12	7	–
Autumn sowing	seeds	–	6	2	–
***Verbascum songaricum*, family Scrophulariaceae, life form – biennial**					
Spring sowing	seeds	60–85	4	1	–
Autumn sowing	seeds	–	0	–	–
Spring sowing	living plants	–	90	90	++
***Ziziphora clinopodioides*, family Lamiaceae, life form – small shrub**					
Autumn sowing	seeds	2–30	42	25	–
Spring sowing	seeds	–	8	6	+
Spring planting	living plants	–	74	28	+
Autumn planting	living plants	–	60	40	+
Spring planting	living plants	–	83	35	+
Summer planting	living plants	–	100	19	–
Summer planting	living plants	–	81	25	+
Spring planting	living plants	–	76	50	++
Spring planting	living plants	–	90	61	+
Summer planting	living plants	–	50	–	–

Source: own study.

Prunus tianshanica (plum, Rosaceae) grows on rocky slopes and forms extensive thickets, mainly on the southern slopes, at 900–1000 m above sea level in the mountains of southeastern Kazakhstan, as well as in Central Asia (Tien Shan, Pamiroalai) and Western China. It is used as a decorative, food and honey-bearing plant. It is used in fruit farming as a vessel for obtaining new varieties.

Prunus tianshanica grows from late March to October, flowers in mid-April, and bears fruit in late June. It is quite stable in cultivation, but grows slowly, preferring sandy or loamy soils of slightly acidic or neutral pH levels. The plant can be propagated by seeds or vegetatively, using green cuttings or shoots. Seeds are sown in autumn or spring after 3–6 months of stratification at 1–5°C. When propagated vegetatively, more than half of the cuttings take root without growth stimulants.

The species has been added to the collection by seeds and living plants from various environmental conditions (Mount Sogeti, the Zailiysky Alatau ridge). The seed weight was 93.4 g, the laboratory germination after stratification for one month was 20%, the field germination after autumn sowing was 0%, and after spring sowing of stratified seeds reached 10%. Seedlings did not noticeably increase in height until the end of the first growing season, reaching a height of 2–3 cm, and forming 2–4 juvenile leaves. The vegetation stopped by September.

In the summer, the survival rate of *C. tianschanica* was 90%. All plants started to grow the next year, with the growing season starting on 10th April. Flowering started on 15th April but was not abundant, and seeds did not form. The shot size increased by 2–15 cm, the total height of the plants was 41–56 cm, and the plants completed their vegetation by 1st November.

When planted in autumn, the survival rate of plants was 50%, but only 20% of these survived the winter. The health of the plants was poor; they did not flower and did not grow.

Chondrilla (Asteraceae) is distributed throughout Central Asia, Western China (Dzungaria) and Western Mongolia; within Kazakhstan, in Betpakdal, Muyunkum, foothills and low mountains of Tarbagatai, the Chu-Ili Mountains, Dzhungarsky, Zailiysky, Kungei, Ketmen and Terskey Alatau, Karatau and Western Tien Shan. It grows on rocky and gravelly slopes, sometimes as a weedy plant in the fields.

The underground parts contain latex, tar, and steroids; they can be used as a detoxification remedy [Sokolov (ed.) 1988], and are used in traditional medicine.

The species has been added to the collection by seeds and living plants from the Sogety Mountains and the Zailiysky Alatau ridge. The mass of seeds was 0.56 g, the laboratory germination reached 88%, the field germination of the seeds sown in autumn was 22%, and 30% in spring. The survival of seedlings at the time of transplantation was 72%, and the survival rate of seedlings reached 100%. By the end of the first growing season, seedlings formed one or two 35–43 cm long shoots, but no flowers were observed, and the vegetation stopped in the first ten days of November.

Live plants of *C. lejosperma* were planted on 17th July, 2018. They started to grow in April 2019 and the survival rate varied from 34 to 70%. Single flowers were produced in mid-July, mass flowering started in mid-September, and flowering ended in mid-October. Seeds ripened in 20–25 days; the plants formed 2–3 strongly branched generative shoots, 50–70 cm long, and the growing season ended on 4th November.

Dracocephalum (Lamiaceae) grows on stony, gravelly and grassy slopes of the lower mountain belt; within Kazakhstan, from Altai to the Western Tien Shan. It is also found in Central Asia, Mongolia and China. Above-ground parts of the plant contain alkaloids, flavonoids, tannins, vitamins, and essential oils. It is used as a sedative, hypotensive, and antiseptic remedy [Sokolov *et al.* 1962] in traditional medicine.

Living plants from the same habitat, the Sogety Mountains, where they grew on rocky-gravelly slopes, were added to the collection on two separate occasions. When planted in spring, the survival rate of plants reached 80%; over 70% of them started to grow in the spring of the next year. Flowering began on 10th May and lasted for about a month, but the seeds did not form, and the vegetation lasted until mid-September. When planted in summer, the survival rate of plants reached 70%; 50% of plants started to grow the next year, flowering began in late May but was not abundant, there were no viable seeds, and the vegetation lasted until September.

Globe thistle (Compositae) grows in meadows, and on the slopes of the foothills and medium-size mountains of southern Kazakhstan and Kyrgyzstan (Tien Shan) which are covered with mixed grass and shrubs.

Fruits contain alkaloids, and are used in traditional medicine as a hypotensive and vasodilator remedy [Sokolov (ed.) 1988].

Seeds were collected in two ecologically diverse habitats of the Zailiysky Alatau ridge (the Sogety Mountains, Turgen ravine). The seed weight was 26.6 g, the laboratory germination reached 60%; the field germination of seeds sown in autumn was 16% and in spring, fell to 12%. The survival of seedlings at the time of transplantation varied from 0 to 9%, the survival rate of planted seedlings reached 100%. By the end of the first growing season, the seedlings formed a rosette with 2–3 juvenile leaves, but no stem development was observed. They were still green when the snow arrived in early November.

Ephedra (Ephedraceae) grow on the stony southern slopes in the lower and middle elevation of the mountains of southeastern and southern Kazakhstan. Green branches contain alkaloids, flavonoids, carbohydrates and related compounds, monoterpenoids and higher fatty and aromatic acids, steroids, tannins, essential oils, proanthocyanides, and vitamins [Budantsev, Lesiovskaya 2001]. It is used as an adrenostimulating, psychostimulating, anti-allergic, cardiotonic, vasoconstrictive, bronchodilator, antipyretic, diaphoretic, general strengthening, hemostatic, and wound healing remedy. It is used mainly in official medicine. Large commercial reserves of this plant were found in Zailiysky, Dzhungarsky Alatau, Ketmen Ridge, Azutau Ridge [Kubentayev *et al.* 2019; Saparbaeva *et al.* 2019].

It was cultivated on the plot of medicinal plants in the 1980s, but the population completely died out after six years. Single specimens flowered, but seeds were not formed.

In the second attempt, seeds were brought from a natural habitat of the species, the rocky-gravelly slopes of the Sogety Mountains near the Kokpek pass. The seed weight was 19.3 g, seeds were sown in autumn, and seedlings appeared at the end of March. Germination rate was 88%, seedling survival by the time of transplantation was 60%, and seedling survival rate reached 100%. By the end of the first growing season, seedlings formed 1–2 juvenile shoots, 4–7 cm long, and were covered by the snow while still green, in early November.

Leonurus turkestanicus V. Krecz. et Kuprian. (Lamiaceae) occurs in the forest and shrub mountain belt, from the Dzungarian Alatau to the Western Tien Shan.

Above-ground parts of the plant contain saponins, alkaloids, flavonoids, triterpenoids, steroids, organic and phenol carboxylic acids, tannins, essential and fatty oils. The plants are used as a sedative, hypotensive andantibacterial, similar to *L. quinquelobatus* [Sokolov (ed.) 1988]. It is used in folk medicine. Commercial-size populations have been identified in Western Tarbagatai, Kyrgyz Alatau and Western Tien Shan [Sermukhamedova *et al.* 2017].

It was periodically cultivated on the plot for medicinal plants in the 1960s and 1980s. The existing population was grown from seeds brought by expeditions to the species' natural habitats (Kaskelen, Shamalgan, Turgen gorges, Sogety Mountains, the Zailiysky Alatau ridge) in 2015–2019. The adaptive potential and characteristics of the species are very different in samples from different origins. In cultivation, the productivity of the raw material varied from year to year, from 15.9 to 45.6 g of dry matter, with seed productivity from 2.96 to 6.687 g per plant. The mass of 1000 seeds of cultivated plants was 0.32–0.88 g, and the laboratory germination was 30–42%. When seeds were sown in spring, the field germination was 48%, in autumn, 4–10%. Seedling survival before transplanting was above 70%, and seedling survival of about 93%. The life expectancy in cultivation was 3–5 years, and the population was most productive in the second and third years of cultivation. The cultivated population can be maintained by regular reseeding; self-seeding was not observed.

White horehound (Lamiaceae) occurs in the Caucasus, in Central and Southern Europe, Central and Asia Minor, India, China, and the Himalayas. It usually grows like a weed on the roadsides, near settlements, and in gravelly and stony habitats in western, southeastern and southern Kazakhstan.

The above-ground parts contain flavonoids, saponins, terpenoids, coumarins, alkaloids, phytosterols, nitrogen-containing compounds, phenol carboxylic acids, tannins, essential oils, and diterpenes. It is used as a hypotensive, sedative, choleretic, appetite stimulant, diuretic, analgesic, hemostatic, antibacterial, and gastroprotective remedy, as well as for treating respiratory diseases [Budantsev, Lesiovskaya 2001]. It is used in official and traditional medicine.

It has been cultivated on the plot for medicinal plants since the 1990s, and the population was grown from seeds of various origins. The adaptive potential and characteristics of the species are very different in samples from different origins. In cultivation, the productivity of the raw material varied over the years, from 1.9 to 26.7 g of dry matter, and seed productivity from 0.295 to 11.35 g per plant. The weight of 1000 seeds of cultivated plants was 0.83–1.01 g, the laboratory seed germination was 28–99%, and seed germination in the field was up to 52%. When sown in spring, the seedling survival rate was above 70%; about 35% of seedlings started to grow the next year. Plants started to flower after 3–4 years; up to the fifth or sixth year, productivity increased; in cultivation, the maximum life expectancy was up to 10–11 years. The cultivated population can be maintained by regular reseeding; self-seeding was not observed.

The existing population was created by living plants taken from different ecological conditions (Shamalgan gorge, the Sogety Mountains, the Zailiysky Alatau ridge) in spring and summer. When planted in spring, the survival rate of plants reached 100%, and over 65% started to grow in the spring of the next year. Plants flowered and produced viable seeds, and the vegetation continued until mid-October. The next spring, about 50% of plants started to grow, but flowering was sparse, and only a few seeds formed. In the third year, the plants did not grow. When planted in summer, the survival rate of plants reached 70%, and the vegetation stopped in September.

The analysis of the introduction characteristics of the species indicates that mature plants taken from their natural habitats can be used to quickly establish a population of the cultivated plants with desired qualities. This can be done by using selected plants with desired properties, and collecting viable seeds from those plants; however, such a population can only survive for three or four years. It is necessary to maintain the population by seeding, which significantly extends its lifespan; the qualitative spread of seedlings is very large and requires re-selection of seedlings

Wild rue or Syrian rue (*Peganum harmala*) occurs in the steppes, deserts and semi-deserts (except for the highlands) of the southern regions of Kazakhstan, and from the Mediterranean to China.

All parts of the plant contain alkaloids, saponins, organic acids, tannins, and fatty oils. It is used as an anticholinesterase, laxative, lactogenic, sedative, hypnotic, diuretic, antipyretic, diaphoretic, anthelmintic, potency enhancer, and abortive remedy [Budantsev, Lesiovskaya 2001]. It is used in traditional and official medicine. Commercial-size populations have been identified in southern Kazakhstan.

P. harmala had been grown on the collection site of medicinal plants since the mid-1960s [Shtephan 2012], and again in the 1980s. Plant fitness started to deteriorate, and productivity decreased in the early 1990s, a massive decline was observed in the late 1990s, and the population completely died out by 2000. In cultivation, the productivity of raw material varied over the years from 35.4 to 184.9 g of dry matter per plant, and seed productivity, from 1.78 to 5.93 g per plant. In cultivation, the weight of 1000 seeds was 1.45–2.18 g and biological storage life ca. 20 years, as the laboratory germination of seeds obtained from the collection plot in 1995 was 30%.

In the current experiment, the laboratory germination of seeds collected in nature (the Sogety Mountains and foothill valley) ranged from 56 to 94%, and the field germination, from 0 to 33%, depending on the conditions and timing of sowing (Tab. 2). The loss of seedlings was very high; by the end of the growing season, less than 10% of seedlings survived, and only single specimens were still alive (3–6%) by the next spring. A field experiment to assess the storage life of seeds demonstrated that, after a year of storage, seed germination decreased five-fold, and after 2–4 years, ten to fifteen-fold (down to 2%).

Compared with seed propagation, transplanting young plants of *P. harmala* from natural habitats appears to be more promising. When transplanted in spring, plant survival reached 83%, and 62% survival rate by the end of the growing season. The following spring, 30–48% of seedlings started to grow. When transplanted in autumn, 30–50% of plants survived the winter, and after a year their number decreased to 10–11%. In 2018, only 29% of the spring plantings of *P. harmala* survived; the best results were obtained when juvenile plants had been used. In the planting year, plants did not grow well, and flowering was not observed.

The rapid death of plants in the cultivated population, their very weak flowering and the absence of fruiting once again confirmed the conclusion [Kurban *et al.* 1999] about the high turgor potential of this halophyte, which must be artificially maintained in cultivation.

Sage (Lamiaceae) is found in the Caucasus, Central Asia and Western Siberia. It grows in the steppe zone, and along forest fringes and river banks, often as a weed, everywhere in Kazakhstan. The above-ground parts contain organic acids, alkaloids, tannins, flavonoids, phenol carboxylic acids and their derivatives, quinones, essential and fatty oils, and vitamins. It is used to produce quinones, as well as an antibacterial agent in traditional medicine [Budantsev, Lesiovskaya 2001].

It has been tested in cultivation on the collection plot of medicinal plants for the first time. The plants were propagated by seeds collected from two habitats (slope and floodplain) of the gorge of the Shamalgan River, and the Zailiysky Alatau ridge. The mass of the seeds was 0.48–0.64 g, the laboratory germination was 12–22%, the field germination (spring sowing), was 16% but when sown in autumn, the seeds failed to germinate. The following spring, 56% of seedlings were alive. The plants formed 1–2 generative shoots, 55–97 cm long; they flowered in abundance, from early July to September. The seeds began to ripen in August, with masses varying from 0.6 to 0.9 g. The vegetation stopped in early November.

Mints is found everywhere in Europe, Western Siberia, Central Asia and Kazakhstan; it grows from the steppe slopes to the middle elevations, in steppe meadows and on the fringes of ribbon forests.

The above-ground parts contain phenol carboxylic acids and their derivatives, flavonoids, anthocyanins, and essential oils. It is used in traditional medicine as a wound healing, analgesic, sedative, antispasmodic, and expectorant remedy [Budantsev, Lesiovskaya 2001]. This is an essential oil plant of industrial importance. Small commercially important populations were found in Kungey, Terskey and Dzhungarsky Alatau, on the Ketmen ridge.

It has been cultivated on the collection plot since the 1980s; the species is very variable, both in nature and in cultivation. Living plants were collected from different habitats (from the slopes of the mountains of the Shamalgan River gorge, and the Zailiysky Alatau ridge). The survival rate of plants, depending on the planting time, varied from 50 to 95%; the next spring from 40 to 53% of all plants started to grow. By the third year, 30–40% of the plants remained; one individual died during autumn planting. Flowering and fruiting of the selected plants occurred at the usual time; in the first years, the productivity of raw material and seeds was low. In cultivated samples, the mass of seeds varied from 0.06 to 0.12 g.

Seed propagation of the species was less effective, with the laboratory germination of seeds varying from 20 to 98%. The mass of seeds was 0.08–0.09 g; when sown in spring, field germination was 10% and 7% of seedlings survived until the end of the growing season.

Mints grows on rocks, gravels, gravelly mountain slopes, in mountain steppes and in alpine meadows in the Dzhungarsky, Zailiysky, Kungei Alatau and Western Tien Shan regions. It is also found in the mountain systems of Central Asia (Tien Shan).

Flowering plants (turf) were added to the collection for the first time, taken from the natural population of the species (the vicinity of the Big Almaty Lake at an altitude of 1974 m above sea level, on the Zailiysky Alatau ridge). Until the end of the growing season, both turfs were in good condition, but the number of vegetative and generative shoots decreased by 35–40%; there were no viable seeds, and vegetative shoots survived until the daily temperature dropped below zero.

Nettles (Urticaceae) is found on the slopes and terraces of river valleys and mountains of southeastern Kazakhstan, Siberia, the Far East, Mongolia and China [Ryabushkina *et al.* 2008].

The above-ground parts contain organic and phenol carboxylic acids, flavonoids, and fatty oil. It is used mainly in traditional medicine as a hemostatic, anti-inflammatory, diuretic, lactogenic, and anthelmintic remedy [Budantsev, Lesiovskaya 2001]. Commercial-size populations have been found in West Tarbagatai, Saur and Manrak.

It was cultivated in the collection of medicinal plants in the 1960s. The species was added to the collection by seeds from the floodplain of the Turgen River and Zailiysky Alatau ridge, where it grew at an altitude of 1420 m above sea level. The mass of seeds was 0.6–0.75 g, and the laboratory germination were 100%. When sown in spring, the field germination was 12%, and when sown in autumn, 6%; the survival of seedlings until the end of the growing season was 7 and 2%, respectively. One vegetative shoot, 5–17 cm long, developed on each plant which vegetated until the growing season ended.

Mullein (Scrophulariaceae) grows on meadow and steppe slopes and in river valleys. It occurs in the foothills and mid-elevations of the Dzungarian Alatau and Tien Shan, in the Caucasus, Central Asia, and Iran.

The above-ground parts of the plant contain iridoids, saponins and flavonoids. They are used in traditional medicine for the treatment of laryngitis, cough, rhinitis, pulmonary tuberculosis, rheumatism and chronic skin diseases.

The species was added to the collection for the first time. One-year-old plants were taken from different habitats, including the floodplain of the Shamalgan River and the Zailiysky Alatau ridge. The survival rate was 100%. The next spring, 83% of the plants were alive. They formed 1–2 generative shoots, 1.3–1.8 cm tall. The plants flowered abundantly. Seed productivity was 2.959 g; in cultivated plants, seed weight was 0.115 g, and the germination rate was 77–94%. When propagated by seed, the mass of seeds was 0.1 g, and the laboratory germination was 60–85%. When sown in spring, the field germination was 4%, and in autumn, 0%; the survival of seedlings until the end of the growing season was low (about 1%).

Ziziphora grows on stony and gravelly steppe slopes, in meadows, and on rocky river banks. It occurs throughout mountainous Kazakhstan, in Western and Eastern Siberia, Mongolia and China.

The above-ground parts contain essential oils, saponins, coumarins, and flavonoids. It is used mainly in traditional medicine as a cardiotonic, antipyretic, hypotensive, restorative, stimulating appetite, diuretic, antibacterial, and anthelmintic remedy [Budantsev, Lesiovskaya 2001]. Commercially important populations were found in the Zailiysky and Kyrgyz Alatau, in the Karzhantau and Ugamsky ridges, in mid-elevations of Boroldaytau, Karatau, Kalbinsky ridge, in Western Tarbagatai, Saur, and Manrak [Mamadalieva *et al.* 2017; Sitpayeva *et al.* 2020].

It has been repeatedly added of the collection but fell out very quickly. The existing population has been growing since the spring of 2017. It was established by seeds, and living plants from eight different habitats of the Zailiysky Alatau ridge (the Sogety Mountains and Shamalgan River Gorge) added to the collection in spring and summer. The survival rate of specimens varied from 50 to 100% (on average 76.4%), depending on the planting period. The next spring, from 19 to 61% (on average 36.8%) of plants continued to grow; however, by the third year, less than 20% of the plants remained. Flowering and fruiting occurred at the normal time. The raw material and seed productivity were reduced. In cultivation, the mass of seeds varied from 0.1 to 0.16 g.

When propagated by seed, the laboratory germination varied from 2 to 30%, and the mass of seeds was 0.21 g. When sown in spring, the field germination was 8%, and when sown in autumn, 42% from 50 to 70% of seedlings survived until the end of the growing season. The massive flowering was observed in the third year, and the plants vegetated until the end of the growing season.

CONCLUSIONS

The analysis of the results of the experiments suggests that most of the medicinal species of the Northern Tien Shan studied can be successfully cultivated in the foothills of the Zailiysky Alatau; they have a normal ontogenetic cycle and regularly produce viable seeds. This is largely explained by the fact that the movement of the specimens in geographic space is very insignificant, the points of growth and introduction are quite close, and almost all of these species are within their distribution ranges. As for the ecological niche, there were certain difficulties in cultivating such species as *Alhagi maurorum* and wild rue (Syrian rue), the habitats of which are located in the desert-steppe foothill zone.

In addition, the life expectancy of the number of valuable medicinal species is reduced significantly in cultivation, although the yields of raw material and seeds are acceptable (wolf's bane, white horehound, mints, *Ziziphora).* For such species, it is necessary to revive and replenish the existing cultivated populations on a regular basis with new specimens taken from natural populations, as well as through individual sampling of plants with improved commercial characteristics. New species of medicinal plants added to the collection demonstrated positive responses at the initial stages of development. For a reliable assessment of the adaptive potential of these species, longer trials in cultivation are necessary.

The results of the study of the selected medicinal plants in cultivation indicate that planting material from nature (planting with live plants) allows us to quickly establish a population of the desired quality, by selecting specimens with desired properties, and obtain viable seeds from selected plants. However, the life expectancy of such a population is significantly lower than the potential life expectancy of the species in nature. The creation of a cultivated population by seed significantly extends its lifespan, but the qualitative spread of seedlings is very large and requires re-selection (rejection of low-quality material).

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