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Selection assessment of promising forms of natural *Hippophae rhamnoides* (Elaeagnaceae) populations and their offspring in the Kazakhstan Altai Mountains

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Abstract. *Vdovina TA, Isakova EA, Lagus OA, Sumbembayev AA. 2024. Selection assessment of promising forms of natural* Hippophae rhamnoides *(Elaeagnaceae) populations and their offspring in the Kazakhstan Altai Mountains. Biodiversitas 25: 1809-1822.* This article presents the results of studying the genetic diversity of sea buckthorn, *Hippophae rhamnoides* L. in natural populations of the East Kazakhstan region. This made it possible to identify valuable forms based on which targeted breeding work was carried out. Selection work has shown that this species has a unique gene pool. As a result of the analytical selection of *H. rhamnoides* in the first, second, and third generations, promising seedlings were obtained: *Podarok Bajtulinu* Sh-9-81 (4-6) II, *Jubilejnaja Kotuhova* T-2-82 (2-22) III, *Dolgozhdannaja* No.5 (3-24) III, *Shetlastinka* No.7 (2-24) III, *Nesravnennaja* Sh-9-81 (3-27) III, *Krasavica* Sh-9-81 (3-30) III, *Solnyshko* Sh-12-81 (1-18) III with high yield, large fruits, long stalk and low fruit tearing force. Among the male plants, the following forms are distinguished: *Gustoj Tuman* T-2-82 (1-24) III, *Ljubimec* T-17-82 (2-20) III, *Krasavchik* K-8-82 (1-34) III, *Bogatyr* T-17-82 (2-20) III with high winter hardiness and pollen productivity. A scale has been developed for the force of fruit separation and the density of the “cob” for local forms. A selection achievement (variety) patent was received for the *Jubilejnaja Kotuhova* form. The next two forms (*Shetlastinka* and *Podarok Bajtulinu*) pass the state test for economic usefulness. The richest gene pool of *H. rhamnoides* in the Altai mountainous country indicates its high heterogeneity.

Keywords: Form, heritability, *Hippophae rhamnoides*, Kazakhstan, population, seedling, selection, variability

INTRODUCTION

Hippophae rhamnoides L.-Euro-Asian species, belongs to the family Elaeagnaceae L. since ancient times has attracted attention as a food, medicinal, vitamin, and ornamental plant (Ma et al. 2023). One polymorphic tertiary relict species represents sea buckthorn, *H. rhamnoides* has an extensive discontinuous (disjunctive) range (Li et al. 2020). *H. rhamnoides* is a polymorphic species that varies significantly throughout its wide range, and its different ecological forms are of interest for introduction and selection (Ivanišová et al. 2020).

The ability of *H. rhamnoides* to occupy a vast area with extremely diverse growing conditions indicates the high plasticity of this species and the ability to adapt to various environmental conditions, which determines a wide range of geographical variability and determines not only phenotypic but also genotypic variability (Kuhkheil et al. 2017; Wu et al. 2022; Yu et al. 2022). Hence, in studying *H. rhamnoides*, special attention was important to evaluate the populations composition in nature. When transferred to culture, the patterns of their formation were considered (Kukin et al. 2017; Żuchowski 2023).

This plant is selected in many countries (Yue et al. 2017; Jaśniewska and Diowksz 2021; Chen et al. 2023). The world’s first varieties of *H. rhamnoides*, i.e.: *Vitaminnaja*, *Velikan*, *Maslichnaja*, *Dar Katuni*, *Zolotoj pochatok*, *Oranzhevaja*, *Prevoshodnaja*, *Chujskaja*, obtained at the Scientific Research Institute of Horticulture of Siberia (Russia) were introduced into China, Poland, Romania, Germany, and currently serve as source material for the development of local varieties (Letchamo et al. 2018; Li et al. 2021). Altai varieties were tested in Kazakhstan at the Institute of Botany and phytointroduction (Kubczak et al. 2022) and in the Altai Botanical Garden.

Moreover, practical results were obtained in many countries by creating breeding plantations of *H. rhamnoides* by introducing artificial habitat forms selected in nature (Pundir et al. 2021; Tkacz et al. 2021; Ma et al. 2022; Netreba et al. 2024). A worldwide selection of *H. rhamnoides* is aimed at creating varieties with high adaptation to the natural and climatic conditions of each region, increasing winter hardiness and drought resistance, with high yields, low fruit tearing forces, low thorniness, and high-quality fruits (Aaby et al. 2020; Ghendov-Mosanu et al. 2020; Lee et al. 2021; Ahani and Attaran 2022; Janceva et al. 2022; Wang et al. 2022). An important direction in breeding is the production of varieties with a high content of biologically active substances (Górnaś et al. 2014; Olas et al. 2016; Zakynthinos et al. 2016; Hou et al. 2017; Jaroszewska and Biel 2017; Radulescu et al. 2019; Wei et al. 2019; He et al. 2023).

Many scientists' works (Krejcarová et al. 2015; Ciesarová et al. 2020; Criste et al. 2020) indicate that local *H. rhamnoides* varieties are more adapted to the agroclimatic conditions of these regions than foreign-introduced ones. Since 1981, work has been performed in the Altai Botanical Garden to preserve this species's most valuable gene pool. Breeding work on *H. rhamnoides* has made it possible to identify genetic donors based on certain traits and to identify promising forms and seedlings.

The main goal of our research was to study the genetic diversity, intraspecific variability, and ecological and biological characteristics of *H. rhamnoides* in natural populations. The selection of promising forms was based on their breeding work to obtain varieties and seedlings that combine a high degree of resistance to biotic and abiotic environmental factors and a high level of economically valuable traits.

MATERIALS AND METHODS

A well-tested route reconnaissance method was used in the field (Figure 1) (Sumbembayev et al. 2023a, 2023b). Studies of *H. rhamnoides* in natural populations-Kendyrlyk, Shetlasty, Tersayryk, Kaindysu, Karatal East Kazakhstan region-were carried out from 1981 to 1988 (Table 1); testing in culture and breeding work were carried out in the Altai Botanical Garden, Republic of Kazakhstan, from 1981 to 2023. Therefore, to determine the color of fruits, leaves, and shoots of *H. rhamnoides*, the colors of the solar spectrum were taken; fruits were conventionally described as yellow, orange, red, yellowish-orange, orangish-yellow, reddish-orange, orangish-red (MacAdam 1974).

The methods for species' population structure are based on an analysis of the genetic structure of traits, the law of homological series in hereditary variability and homology of genetic structures, the study of the geographical distribution of dominant and recessive genes, and the general principles of gene geography were used to analyze the population and evolutionary genetics.

The study of genotypic variability in a separate sample is carried out using the testing clonal progeny method. Selected forms were cloned by separating root shoots. Methods for studying genetic variability are based on determining the degree of influence of heredity and environment in the phenotype manifestation. The inheritance of traits and properties in *H. rhamnoides* seedlings was studied at the organismal and population levels using hybridological and genealogical methods. The method of population genetic analysis was also used to study how the degree of influence of genes and environmental factors on the development of traits and properties of organisms.

The inheritance of traits and properties in seedlings was studied at the organismal and population levels using hydrological and genealogical methods. Population genetic analysis was also used, which considered the degree of influence of genes and environmental factors on the development of plant traits and properties.

The widespread method of continuous (in each generation) individual selection was also used in breeding work. Heritability was determined by the transmission of characteristics of the maternal form to offspring in the family, and the offspring from seeds of the same maternal form are considered one family. For convenience, the work has adopted symbolic designations of forms and seedlings-in capital letters the names of the rivers: Sh-Shetlasty, K-Kendyrlyk, T-Tersayryk, Kan-Kaindysu and Ks-Karatal Sands, I-first, II-second, III-third generations. The number of seedlings in a family is from 9 to 32 pieces.

Genetic analysis was carried out in 52 families of the first generation, 35 families of the second generation, and 26 families of the third generation, with seeds collected from natural populations.

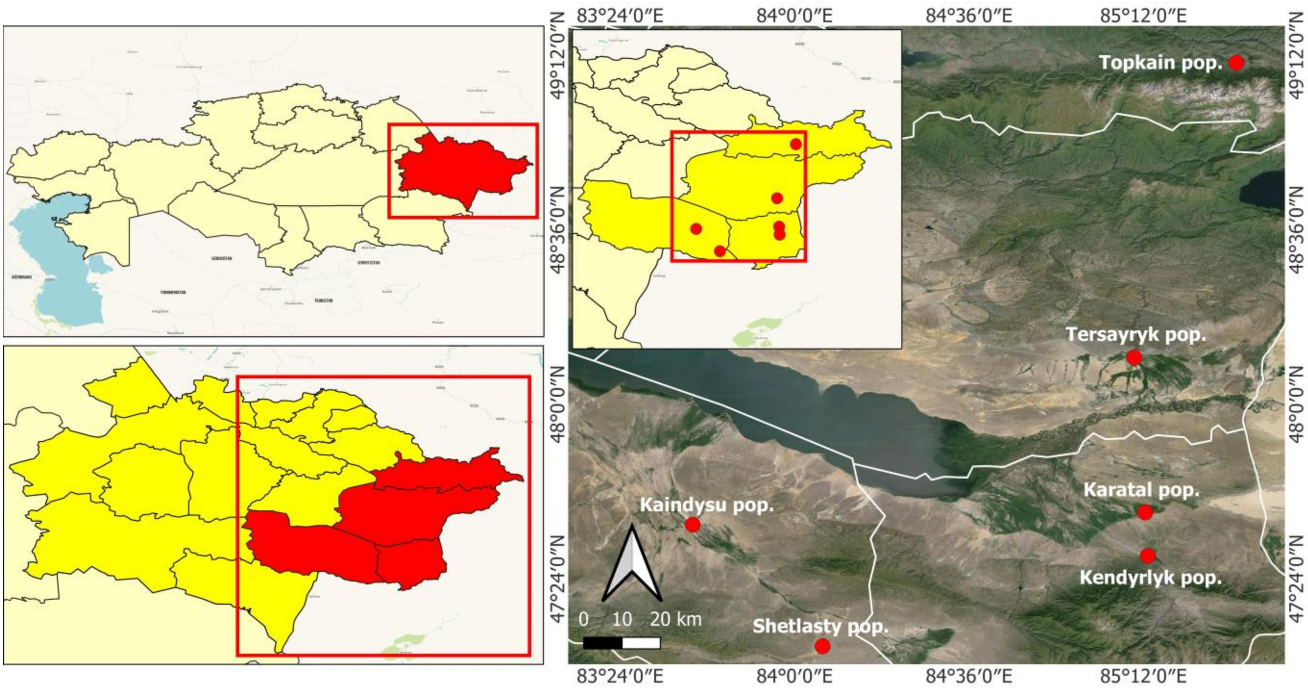

Figure 1. Location of populations of the studied species of *Hippophae rhamnoides* in East Kazakhstan

Table 1. Characteristics of the locations of the population of *Hippophae rhamnoides*

Population	Location	Coordinates		Altitude (m asl.)	Area (ha)
		Latitude	Longitude		
Kendyrlyk (K)	Saur ridge, the valley of the Kendyrlyk River, surroundings of the village of Saryterek, steppe meadows, loamy, meadow-chernozem soils	47.47830	85.21473	830	36
Shetlasty (Sh)	South-eastern foothills of the Tarbagatai ridge, Shetlasty river valley, wet meadows, loamy meadow-chernozem soils	47.16724	84.09574	1000	38
Tersayryk (T)	Tarbagatai ridge, the valley of the river Tersayryk, in the vicinity of the villages of Saryulen and Zhanaaul, wet meadows, soils are gray and loamy	48.16005	85.16727	1200	27
Kaindysu (Kan)	North-eastern foothills of the Tarbagatai ridge, the vicinity of the village of Akzhar, the Kaindysu river valley, wet pebble meadows, soils are gray loams	47.585513	83.64861	900	24
Karatal (Ks)	Zaisan depression, Karatal sands, environs of the village of Karatal, between the dunes in the lowlands, sandy dry soils	47.62766	85.20537	650	18
Topkain	Sarymsakty ridge, Topkain River valley, steppe meadows, the soil is rich in chernozem	49.17389	85.51889	945	5

The obtained data were processed using the variance analysis method (arithmetic mean error). $\overleftarrow{x} \pm S\overleftarrow{x}$ * table value of the t-test at the 0.05% significance level, coefficient of variation C%, experimental accuracy (P%).

When studying *H. rhamnoides*, biometric research methods were used, based entirely or partially on statistical or probabilistic patterns. The data obtained from the research was processed using variation statistics methods in the Statistica-Trial, R-studio, and R statistics programs.

RESULTS AND DISCUSSION

When assessing the adaptive properties of *H. rhamnoides* plants in the sharply continental climate of the East Kazakhstan region with cold, long winters, often reaching a critical level of 40-42°C and repeated thaws with temperature differences of 18-20°C, first of all, requirements were placed on the winter hardiness of vegetative and generative organs, which ensures high and sustainable yields. As a result of the research, highly adaptive promising forms and seedlings were identified as genetic sources for the main components of winter hardiness for further breeding use. Over all the years of research, no winter damage was noted in female and male plant specimens, indicating the species' ecological plasticity. The high adaptability of seedlings and forms to extreme factors is due to the genetically outstanding frost resistance of the East Kazakhstan *H. rhamnoides* ecotype.

An important property when selecting forms and seedlings is the time they enter the reproductive period. When cloning forms from natural populations with root shoots, the onset of fruiting age was noted at four to five years. During hybridological analysis, it was revealed that the largest number of early-fruiting seedlings at the age of six were isolated in the following families: T-17-8283-80.3%, K-13-8283, and Sh-17-8283-72.1%, seed sowing in 1983, (first generation); Kan-2-8195-76.5%, Sh-17-8295-68.8%, T-14-8295-65.4%, Sh-8-8195(4-15)-63.9%, seeding seeds 1995, (second generation), Sh-17-828305(3-35)-84.5%, K-2-8105-82.6%, K-13-828305(5-21)-78.2 %, Ks-2-848405(8-13)-73.7%, seed sowing in 2005 (third generation). From other families: Sh-12-8181, Sh-12-818105(6-8), Sh-9-8181, Sh-9-818105(4-5), Sh-9-8195, Sh-9-8105, *Ljubimaja*-T-2-8283, T-2-828305, T-2-8205, K-14-8105, K-16-828305(1-39), T-3-828305 (3-9), T-3-828305 (3-5) (in three generations) seedlings produced their first harvest in the seventh year. At the same time, the following pattern can be traced: seedlings whose fruiting begins in the seventh year have a higher yield, 1.5-2.5 kg/bush, than seedlings whose fruiting begins in the sixth year, their yield is 0.5-1, 4 kg/bush. Seed seedlings for high yield in each generation were selected for 16-19 years.

Comparison of the structure of trait variability in selected forms of *H. rhamnoides* in culture with their data in natural populations made it possible to identify ecological and genetic communities of individuals and assess the ecological factor roles in the formation of the population structure. The productivity and yield breeding potential were studied in three generations of *H. rhamnoides*. The productivity of *H. rhamnoides* is a complex integral trait that depends on the plant's productivity, the number of plants per unit area, the time of fruiting, and resistance to major diseases and pests. The components of *H. rhamnoides* productivity are the number of fruitful buds per 10 cm of two-year growth, “cobs,” the number of fruits from one fruitful bud, the weight of the fruit, and the total length of the “cobs.”

Individuals with a yield above 6.5 kg/bush were noted when assessing seedlings for high productivity. Such seedlings were noted in 49% of families, three generations of the total number participating in the experiment. A high percentage (58-67%) of the selected seedlings in terms of yield was observed in families whose mother plants grew in the Kendyrlyk, Shetlasty, and Tersayryk populations.

The study of forms of *H. rhamnoides* brought from nature and seedlings over generations showed that in the mountainous zone of the East Kazakhstan region, they still retain a dependence of yield on the genotype of individuals. Cultivated plants from the Shetlasty and Kendyrlyk populations have higher productivity-from 5.8 to 14.2 kg/bush-than others. The biological characteristics of plants in height are affected-3.7 m-4.9 m. Medium-sized bushes 3.1-4.0 m from the Tersayryk population are also productive (6.7-12.9 kg/bush) due to their spreading crown.

The genetically diverse forms from natural populations, K-22-82, K-14-84, K-12-86, T-7-82, T-13-82, Sh-9-81, Sh-5-86, Sh-3-86, Kp-2-86, Kan-1-81, and Kan-2-82, with a yield of 125-161 c/ha, served as the starting material for obtaining productive seedlings and varieties.

High yields in the first generation were noted in the families: Sh-8-8181-112 c/ha, Sh-9-8181-110 c/ha, Sh-12-8181-114 c/ha, Sh-10-8181-123 c/ha /ha, Sh-13-8181-104 c/ha, Kan-2-8181-91 c/ha, Kan-4-8181-171 c/ha, K-14-8181-194 c/ha, K- 16-8283-71 c/ha, T-14-8283-135 c/ha, T-2-8283-95 c/ha, T-18-8283-152 c/ha, T-20-8283-110 c/ha/ha, T-22-8484-114 c/ha. In the second generation: *Ljubimaja* T-2-8295-139 c/ha, Sh-17-8295-127 c/ha, Kan-2-8195-119 c/ha, T-14-8295-156 c/ha, Sh -8-8195-132.7 c/ha. Among the seedlings of the third generation, the leaders in terms of yield from 108.2 to 169.1 c/ha are *Jubilejnaja Kotuhova* T-2-82 (2-22) III, *Shetlastinka* No. 7 (2-24) III, *Dolgozhdannaja* No. 5 (3-24) III, *Solnyshko* Sh-12-81 (1-18) III, *Krasavica* Sh-9 -81 (3-30) III, *Nesravnennaja* Sh-9-81(3-27) III, *Plakuchaja* T-14-82 (2-32), *Fakel* K-14-8181(3-17), *Krasnoplodnaja* K-14 -81(4-27) III. We recommend these forms and seedlings with high and stable yields for further breeding work and cultivation in our region. A combination of a reliable level of adaptation with a high level of biological productivity ensures *H. rhamnoides*'s high and stable productivity.

Long-term yield data enabled identifying promising families: Sh-12-8181, Sh-9-8181, T-2-8283, T-14-8283, Kan-2-8181, and K-14-8181. The average yield during the productive period was 5.8 kg/bush, with a maximum of 14.2 kg/bush. This dependence persists in seedlings for three generations.

Hybridological analysis carried out in three generations showed that the highest yield of highly productive *H. rhamnoides* seedlings was obtained from the parent forms from the Shetlasty, Kendyrlyk and Tersayryk populations.

During the study of *H. rhamnoides* forms and seedlings, it was revealed that productivity depends on life expectancy and the reproductive period, external environmental conditions, the genotype of the maternal and paternal individuals, the average weight of the fruit, the number of fruits formed from one flower bud and the total length of fruiting branches.

Pollination of female plants by male plants is important in increasing productivity. The flowering of *H. rhamnoides* coincides with the beginning of the growth of young shoots and the unfolding of leaves. The staminate and pistillate flowers of *H. rhamnoides* are located at the base of young, newly developing shoots in the axil of the scales, collected in a spike-shaped raceme. The decisive role in pollination is played by the correspondence of the flowering dates of female plants with male ones. Typically, flowering in our conditions occurs at the beginning of May and lasts 6-10 days in one individual and up to 20 days in a selection planting.

For better fruit set during panmixia, the selection of male plants in the third generation for non-simultaneous flowering was carried out. The selection of male plants was carried out according to the timing of flowering and pollen production, forms were selected according to the size of the buds. For pollination of early forms and seedlings of female plants, the following forms were obtained: *Gustoj tuman* T-2-82 (1-24), *Krasavchik* K-8-82 (1-34), T-13-82 (1-30), Kan-2-86 (2-12), for later ones-K-14-81 (4-33), K-14-81 (4-24), Sh-19-82 (2-34), T-14-82 (1-28), Sh-9-81(1-2), K-16-82 (6-2), K-13-82(6-17) (Table 2), (Figure 2).

The issues of selecting valuable forms of *H. rhamnoides* with different fruit ripening periods are important to ensure guaranteed fruiting. Fruit ripening occurs in two periods: early-the second and third ten days of August and late-the first ten days of September. The early ones in the first generation include seedlings in the families: Kan-2-8181, T-2-8283, in the second-*Ljubimaja* T-2-8295, Kan-2-8195, T-14-8295, in the third-*Solnyshko* Sh-12-81(1-18) III, *Dolgozhdannaja* No. 5 (3-24) Sh, K-8-82 (4-22) Sh, to the later in the first generation Sh-12-8181, Sh-10-8181, Sh- 13-8181, in the second Sh-17-8295, Sh-8-8195, in the third *Jantarnaja* Sh-12 05 (2-1) III, *Jubilejnaja Kotuhova* T-2-82(2-22) III, *Plakuchaja* T-14-82 (2-32) III, T-19-82 (4-12) III, *Krasavica* Sh-9-81 (3-30) III, *Nesravnennaja* Sh-9-81 (3-27) III.

The creation of large-fruited varieties of *H. rhamnoides* is one of the ways to increase productivity and labor productivity during the harvesting of this crop. According to literature data on the mass of *H. rhamnoides* fruits in natural populations of Kazakhstan, wild forms are small-fruited. Thus, in the southeast of Kazakhstan, V.P. Besschetnov described wild populations in the valleys of the Lepsy, Karatal, and Karkara rivers, in which plants with an average of 18.5-20.9 g are represented in the floodplain of the river. Besagach with small 8.1 g fruits. I.I. Filatov provides data on fruit weight from 12.7 to 19.07 g in the southern populations of Kazakhstan for three types of forest conditions. According to our research in natural populations of the East Kazakhstan region, the weight of *H. rhamnoides* fruits is significantly higher, from 25 g to 65 g.

When examining natural populations of *H. rhamnoides*, special attention was paid to one of the economic characteristics -weight of the fruits; as a result, from 150 forms, 17 large-fruited forms were isolated, in which the weight of 100 fruits exceeded 41 g. Studying *H. rhamnoides* in various ecological and geographical conditions made it possible to discover colossal diversity forms by fruit size (length from 7.1 to 12.8 mm, diameter from 5.6 to 8.9 mm) and weight from 21.7 to 65.0 g. The study of fruit weight made it possible to establish the difference between populations in the frequency of occurring forms base. Thus, the Shetlasty and Kendyrlyk populations differ significantly regarding fruit weight. The proportion of individuals with large fruits in these populations is from 15.3 to 18.2%.

In the Shetlasty population, the largest number of forms with large fruits (18.2%) was noted compared to other populations. In this population, 69.3% of individuals have medium fruits, 12.5% have small fruits (Table 3).

Figure 2. Male *Hippophae rhamnoides* plants, i.e. A. *Krasavchik*, B. *Bogatyr*, C. *Gustoj tuman* selected for pollen productivity

Table 2. Morphometric characters of male forms of *Hippophae rhamnoides* in the third generation

Form	Statistical data	Shoot length (cm)	Number of buds (pcs.)	Size of buds		Number of bud scales (pcs.)	Distinctive features
				Length	Width		
Gustoj tuman	(M±m)	19.11±3.10	22.5±5.47	16.5±1.47	6.7±0.45	15-17	The largest buds
T-2-82 (1-24) III	C%	31.52	28.93	13.48	10.07		
	P%	7.9	8.7	4.26	3.19		
Bogatyr	(M±m)	14.07±2.90	23.26±3.61	10.20±0.61	6.2±0.42	11-12	Large buds
T-17-82 (1-21) III	C%	40.30	32.39	9.01	10.20		
	P%	7.2	7.43	2.85	3.23		
Ljubimec	(M±m)	18.79±3.55	18.14±4.72	11.8±1.24	6.30±0.32	10	Very large buds
T-17-82 (2-20) III	C%	31.74	29.93	15.88	7.67		
	P%	6.9	7.4	5.02	2.42		
Krasavchik	(M±m)	10.91±2.09	22.07±3.36	9.40±0.34	5.7±0.36	16	Late start of growing season and flowering
K-8-82 (1-34) III	C%	26.39	27.27	5.49	9.43		
	P%	9.19	7.29	1.74	2.98		
Sh-9-81 (1-12) III	(M±m)	13.56±2.16	17.86±2.72	10.50±0.71	6.30±0.36	13	Large buds
	C%	28.46	27.25	10.29	8.53		
	P%	7.61	7.28	3.25	2.70		
Sh-19-82 (2-34) III	(M±m)	10.56±1.84	18.29±2.23	9.70±0.32	5.80±0.32	11-12	No thorns
	C%	31.21	21.81	4.98	8.33		
	P%	8.34	5.83	1.57	2.63		
T-14-82 (1-27) III	(M±m)	8.62±1.49	17.33±2.46	7.10±0.34	5.00±0.52	10	The color of the buds is deep brown with a bronze tint
	C%	28.66	23.51	7.27	15.63		
	P%	8.27	6.79	2.29	4.94		
Ananas	(M±m)	20.86±4.18	27.90±3.58	10.15±0.16	5.10±0.14	14	Early growing season
T-14-82 (6-29) III	C%	27.54	25.66	2.38	4.13		
	P%	8.03	6.95	0.75	1.31		
Podorozhnik	(M±m)	13.37±2.98	35.00±5.64	5.45±0.33	5.50±0.49	10	Small light brown buds with an ocher-golden tint
K-14-8181 (4-24)	C%	25.02	20.70	9.12	20.35		
III	P%	6.51	7.24	2.89	6.43		

Table 3. Percentage of forms by weight of 100 fruits in wild populations and by generation

Population	The average weight of 100 fruits (g)	Weight of 100 fruits (g)		
		Large >41	Average 21-40	Small <20
Kendyrlyk	29.2	15.3	76.3	8.4
Shetlasty	30.1	18.2	69.3	12.5
Tersayryk	27.5	6.8	86.8	6.4
Kaindysu	26.7	3.8	82.4	23.8
Population average	28.6	6.7	76.3	17.0
LSD*	0.33			
First generation F_1	29.3	10.1	77.4	12.5
Second generation F_2	30.1	9.8	80.6	9.6
Third generation F_3	37.4	43.7	47.5	8.8
LSD*	0.31			

Note: *least significant difference 0.5

The weight of the fruit varies from 27.2 to 65.5 g, the length of the fruit is from 6.0 to 12.8 mm, and the diameter is 5.8 to 7.5 mm. Here, the largest-fruited form, Sh-9-81, was isolated, weighing 100 fruits-65 g, the length of which is almost 13.0 mm. In the Kendyrlyk population, 76.3% of forms have medium fruits, 15.3% have large fruits, and 8.4% have small fruits. The weight range of 100 fruits is from 17.0 to 48.8 g. The length of the fruits varies-from 5.3 to 10.2 mm, in diameter-from 4.5 to 8.9 mm. In the Tersayryk population, 86.8% of plants are included in the group with medium fruits, and individuals with large and small fruits make up 6.8% and 6.4%, respectively. The range in fruit weight is from 16.4 g to 42.5 g, in length from 7.2 to 9.6 mm, and in diameter from 5.8 to 7.4 mm. In the Kaindysu population, the weight of 100 fruits varies from 16.2 to 41 g. The range in fruit length is 7.1-11.0, in diameter-from 6.8 to 7.6 mm. In this population, 82.4% of plants have medium fruits from 21 to 40 g, and 3.8% have large ones. The remaining plants have small fruits. Most individuals in all-natural *H. rhamnoides* populations, from 69.3% in Shetlasty to 86.8% in Tersayryk populations, have average fruits weighing 21 to 40 g. The following forms are distinguished by weight: Sh-9-81, 100 fruits-65.0 g, K-8-82-48.8 g, Sh-5-86-50.0 g, and others.

Over several years, a comparative analysis of the mass of fruits in plants in natural habitats and their clones was carried out. As a result, it was noted that in the studied plants in cultivation, the fruits became smaller by 0.2-1 mm; for example, in the forms: Ш-7-82, the length of the fruits in nature was 10.7 mm, in cultivation-9.6 mm, diameter fruits in nature-5.8 mm, in culture-5.7 mm; Ш-9-81, fruit length 12.8-12.7 mm, diameter 8.3-8.2 mm, respectively. For the Kan-2-81 form, the fruit sizes remained the same: fruit length in nature-10.1 mm, in culture-10.0 mm, fruit diameter in nature-7.6 mm, in culture-7.7 mm. In cultivation, the mass of 100 fruits decreased slightly by only 2-3 g. It follows that the mass and size of fruits, in our case, turned out to be an invariant property of individuals, retaining the same numerical value. When transferred into culture, they did not respond to changes in biotic and abiotic factors of the new environment.

Genetic-selection assessment of fruit mass in natural populations and during breeding work in generations showed that the average value for populations was 28.6 g, in Shetlasty-30.1 g, Kendyrlyk-29.2 g, Tersayryk-27.5 g, Kaindysu-26.7 g. Genetic analysis of fetal weight was conducted in 52 families of the first generation, 35 of the second, and 26 of the third generations. The seedlings were obtained through panmixia (free pollination) of selected forms in nature and over generations. In first-generation families, the average fruit weight was 29.3 g. It varies from 22.3 g to 60.3 g, length from 6.9 to 12.6 mm, diameter from 5.7 to 8.3 mm. There is a decrease in the number of seedlings with small fruits from 17.0% (average population value) to 12.5%, which is less by (4.5%). Large-fruited individuals increased to 10.1%, which is 3.4 % higher than the population average (6.7%). In the second generation F2, the average weight of fruits is 30.1 g. Here, the number of seedlings with small fruits also decreases from 17.0% to 9.6%, and the number of large-fruited ones almost does not increase (9.8%) compared to the first generation (10,1%) - the number of seedlings with medium fruits increases.

In most of the studied families of the first and second generations, as in nature, seedlings with fruits of average size 21-40 g predominated in the first generation 77.4% and in the second 80.6%. In some families of the first generation-K-16-8283, Sh-9-8181, K-13-8283, 60.0% of plants with large fruits above 40 g were isolated. Thus, for the weight of 100 fruits, the average values were: in natural populations-28.6 g, in seedlings F1-29.3 g, F2-30.1 g, F3-37.4 g.

An increase in fruit weight with a significant difference was noted in seedlings of the third generation by 7.3-8.8 g compared to the above-listed values. The average value of the third generation (F3) is 37.4 g. Small fruits, less than 20 g, are characteristic of only 6.3% of individuals versus 17.0% in natural populations. In the group with average fruits of 21-40 g (100 fruits), 37.5% of plants grow versus 76.3% in natural habitats. This redistribution occurred due to an increase in the number of individuals in the group with large fruits weighing 41-60 g (100 pieces) to 43.7%. In natural populations, their share was 6.7%. In places of natural growth over the years of research, almost no forms with very large fruits above 61 g were found.

We present this group in the third generation with the appearance of seedlings: *Jubilejnaja Kotuhova* T-2-82(2-22) III-95.8 g, *Dolgozhdannaja* No. 5(3-24) III-72.8 g, *Jantarnaja* (2-1) III-68.3 g, *Shetlastinka* No. 7 (2-24)-68.2 g, *Nesravnennaja* Sh-9-81(3-27) III-66.7 g, *Krasavica* Sh-9-81(3-30) III-60.2 g, *Solnyshko* (1-18) III-52.3 g, *Podarok Bajtulinu* Sh-9-81 (4-6) II-50.2 g and others. Their number is 12.5%. In large-fruited maternal forms, as a rule, the yield of large-fruited forms is higher (Table 4).

Some success has been achieved in selecting *H. rhamnoides* for high yields, large fruits, etc. Below are photos of promising forms (Figure 3).

Figure 3. Forms prepared for variety testing: A. *Ljubimaja*, B. *Plakuchaja*, C. *Nesravnennaja*

Table 4. Characteristics of morphological and economic characteristics of elite seedlings of *Hippophae rhamnoides* (first and third generation)

Form	Weight of 100 fruits (g)	Fruit size, mm		Fruit separation force (g)	No. of fruits per 10 cm of cob length
		Length	Diameter		
First generation					
K-16-8282 (1-39)	36.5				40.5
M±m		8.1±0.26	7.2±0.15	117.4±11.51	
C %		6.8	4.5	13.8	
P %		1.5	1.4	2.1	
K-14-8181(8-7)	37.2				43.7
M±m		7.7±0.20	6.8±0.30	103±5.73	
C %		5.4	9.2	12.4	
P %		1.2	2.1	3.6	
K-13-8283(5-21)	39.5				40.8
M±m		8.6±0.21	7.8±0.22	110±9.13	
C %		5.0	6.0	17.2	
P %		1.1	1.4	2.4	
K-13-8283(5-22)	32.6				28.7
M±m		8.8±0.29	7.4±0.29	91±12.43	
C %		6.8	8.1	21.4	
P %		1.5	1.8	3.6	
Sh-9-8181(4-5)	58.2				39.1
M±m		8.3±0.22	11±0.39	115±12.12	
C %		4.7	5.9	15.1	
P %		1.32	1.78	5.8	
Sh-9-8181(5-7)	60.3				32.7
M±m		8.2±0.26	12±0.21	112±9.6	
C %		3.8	3.2	12.3	
P %		1.1	2.01	3.1	
LSD*	0.9	0.03	0.13	0.86	0.33
Third generation					
Jubilejnaja Kotuhova T-2-82 (2-22) III	95.8				49.3
M±m		10.4±0.41	6.85±0.18	120.7±5.8	
C %		8.3	3.9	6.8	
P %		1.8	1.4	2.3	
Jantarnaja (2-1) III	68.3				31.3
M±m		11.0±0.31	10.1±0.21	109±4.57	
C %		3.2	5.4	8.8	
P %		2.1	1.8	2.0	
Shetlastinka No.7 (2-24) III	68.2				57.5
M±m		9.0±0.27	7.3±0.30	119.5±5.6	
C %		4.9	5.0	9.9	
P %		1.5	1.3	2.3	
Dolgozhdannaja No.5 (3-24) III	68.3				52.8
M±m		8.1±0.18	7.6±0.15	136±6.6	
C %		3.6	3.0	10.2	
P %		2.0	1.8	2.3	
Podarok Bajtulinu Sh-9-81 (4-6) III	52.2				24.1
M±m		9.3±0.22	7.25±0.19	132±5.6	
C %		5.0	3.2	9.2	
P %		2.6	2.0	1.8	
Krasavica Ш-9-81 (3-30) III	60.2				19.6
M±m		9.2±0.41	8.3±0.20	123±7.8	
C %		8.7	4.9	16.2	
P %		3.0	2.5	3.1	
Nesravnennaja Sh-9-81(3-27) III	66.7				46.9
M±m		10.2±0.36	8.1±0.28	134±4.7	
C %		6.7	5.9	10.7	
P %		2.9	3.0	3.3	
LSD*	0.72	0.04	0.03	0.52	0.9

Note: *least significant difference 0.5

The selection of seedlings from promising families based on fruit weight in the first generation made it possible to identify 10.1% of large-fruited samples (with a weight of more than 0.41 g) in the second generation-9.8%. A fairly high yield of large-fruited seedlings-43.7%-became possible thanks to the inclusion in the hybridization of the geneplasm of the forms Sh-9-81, K-8-82, K-14-81 from natural habitats, seedlings of the first and second generations, which are characterized by a positive Overall Combination Ability (OCA) by fruit size. In three generations, seedlings with higher values compared to the population average were obtained from them.

Analysis of intrafamily variability across generations showed a significant variation in fruit weight from 30.8 to 95.8 g; the range of variability depends on the severity of the trait in the original forms. Within almost every family, a continuous series of variations was noted. Intrafamily and interfamily variability for this trait is high (29.7-38.5%).

When studying the heritability of fetal mass, it was revealed that most maternal forms produced offspring similar to themselves. In many families, a predominance of up to 95% of plants with medium fruits was noted. It is interesting to note that the large-fruited (65.5 g) maternal form Sh-9-8183 produced seedlings with almost the same fruit weight of 50.1-60.3 g, but in none of the seedlings, the weight of fruits exceeded the weight of the fruits of the maternal form. The same picture can be seen in other families; even the best specimens do not reach 2-3 g of the mass of the mother’s fruit. Most seedlings (77.4% in the first and 80.6% in the second generations) have average fruits. The maternal and paternal forms determine the yield of large-fruited seedlings in the offspring. Most of the plants growing in the Shetlasty and Kendyrlyk populations differ significantly from all others regarding fruit weight, so they served as the source material for selecting large-fruited plants.

Among the forms and hybrid seedlings, variability in fruit shape was noted. Considering the ratio of the length of the fruit to its diameter (shape index), the fruits were described as spherical, cylindrical, barrel-shaped, round, oval, and teardrop-shaped. In natural populations, oval and cylindrical fruits predominate in shape-81.3% and only 18.7% are spherical fruits. The oval shape of the fruit dominates in seedlings of three generations. As shown by a hybridological analysis of seedlings of three generations, the shape of the fruit in *H. rhamnoides* is inherited through the maternal line.

Six populations of *H. rhamnoides* growing in the East Kazakhstan region were studied to obtain source material for further breeding work based on fruit color. As a result of studies of populations in different ecological and geographical conditions, forms with varied fruit colors were identified. Thus, in the Kendyrlyk and Shetlasty populations, the richest spectrum of colors was noted (red, yellow, orange, orangish-red, reddish-orange, yellowish-orange, orangish-yellow). In Tersayryk, Kaindysu, Topkain, and the Karatal sands, the color of the fruit is represented by the following colors: yellow, orange, orangish-yellow.

The percentage of forms for three main groups of flowers was calculated to assess the variability of *H. rhamnoides* in terms of fruit color in populations and across generations. In all studied populations, forms with orange fruits predominate, from 40% in the Kendyrlyk population to 75.0% in the Kaindysu population (Table 5).

The proportion of individuals with orange fruits (of various shades) in the Shetlasty population is high-65.7%. In the Shetlasty and Kendyrlyk populations, plants with reddish-orange and red fruits grow more than others, accounting for 20.0% to 34.0%. The red-fruited forms in the Kendyrlyk population have the ability to produce more offspring than the yellow-fruited forms under the same conditions. In this case, red-fruited forms become more common in these populations than yellow-fruited individuals, which produce fewer offspring. No red-fruited forms were found in the Tersayryk, Topkain, and Karatal populations. In Kaindysu, there are 4.5%. When calculating alternative variability, which applies to qualitative traits, each trait was contrasted with all the others, forms with orange fruits-forms that do not have this color. Table 5 shows the value of quadratic deviation shows high variability in group fruit color. In cases of qualitative or alternative variability, the coefficient of variation completely replaces the quadratic deviation. As is known, the distribution of genotypes based on fruit color in a population depends on the concentration of dominant and recessive allelic genes. The Hardy-Weinberg law states that in the absence of factors that change the concentration of genes, a population can have any ratio of alleles, and their relative frequencies are constant across generations. The distribution of genotypes in natural populations of *H. rhamnoides* depends on the concentration of dominant (orange) and recessive (yellow) allelic genes. Their relative frequency in populations is presented as follows: the concentration of the dominant (orange) phenotype is from 42% in the Karatal population to 65.7% in the Shetlasty population, and the recessive (yellow) phenotype is from 14.3% in the Shetlasty population to 43.8% in the Tersayryk population. A significant change in allele concentration leads to a noticeable change in heterozygous genotypes. A certain gene pool, including the fruit's color, characterizes each *H. rhamnoides* population.

Therefore, to study the genotypic and phenotypic variability of *H. rhamnoides* in terms of fruit color, 68 forms were introduced from nature into culture by root shoots. In all forms of *H. rhamnoides*, the color of the fruits did not change under the conditions of introduction, indicating that this trait is genetically fixed.

Moreover, work was carried out on the inheritance of fruit color in *H. rhamnoides* seedlings to evaluate the breeding prospects of forms with red and orange fruits. The presence of this color gives them a special attractiveness. The selection of red-fruited forms improves the biochemical composition of fruits regarding carotene content.

Table 5. Distribution of *Hippophae rhamnoides* forms by fruit color in wild populations and by generation (in percentage) and quadratic deviation

Population	**Fruit coloring**					
	red		**orange**		**yellow**	
	% ratio of individuals	**σ (square deviation)**	**% ratio of individuals**	**σ (square deviation)**	**% ratio of individuals**	**σ (square deviation)**
Shetlasty	20.0	40.0	65.7	47.3	14.3	35.0
Kendyrlyk	34.0	47.3	40.0	48.9	26.0	43.8
Tersayryk	0	0	56.2	49.6	43.8	49.6
Kaindysu	12.5	33.0	75.0	43.3	22.5	41.7
Topkain	0	0	48.2	49.9	51.8	49.9
Karatal	0	0	42.0	49.3	58.0	49.3
Population average	10.4	30.5	53.7	49.8	35.9	47.9
First generation (F_1)	34.2	47.4	43.9	49.6	21.9	41.9
Second generation (F_2)	21.6	41.1	44.5	49.6	33.9	47.3
Third generation (F_3)	15.3	36.0	46.2	49.8	38.5	48.6

Hybridological analysis of this trait was conducted in 110 first-and third-generation families. Selection improvement of seedlings was aimed at creating forms with attractive red fruits. The selection test showed that all seedlings from the red-fruited forms, K-14-81, K-13-82, Sh-9-81, and Sh-17-82, received the maternal color of the fruit. Thus, the following seedlings were subsequently used in selection for red fruit: K-14-8181 (8-7), Sh-17-8283 (1-4), K-14-8195 (8-1), K-14-8105 (8-9), Sh-9-8195 (2-19) Sh-9-8105 (2-30) from the forms mentioned above.

The first-generation seedlings from the red-fruited forms K-14-81, K-13-82, Sh-9-81, and Sh-17-82, created in the process of long evolution by nature itself, were given the maternal coloring of the fruits; such seedlings account for for for 34,2%. In the second and third generations, their number decreases to 21.6 and 15.3%, respectively. Orange seedlings in the first-third generations were 43.9, 44.5, and 46.2, respectively. In some families, T-14-82, Kan-2-84, Sh-12-86, and K-16-82, regardless of the color of the fruits of the mother form, seedlings with yellow, yellowish-orange, and orange fruits were produced. The nature of the interaction of genes that control the manifestation of the trait-fruit color-is not the same in different varieties, and splitting occurs according to this trait. Variation in fruit color is explained by hereditary differences and is associated with different genotypes.

Hybridological analysis showed that in breeding for red fruit, it is necessary to use seedlings from the Kendyrlyk and Shetlasty populations from the selected forms Sh-9-81, Sh-17-82, K-14-81, and K-13-82. Their description is given below.

Winter-hardy, late-ripening seedling Sh-9-8181 (4-5) was obtained from seeds from open pollination of the form Sh-9-81, the seeds of which were collected in 1981 in the Shetlasty River valley. The seedling is 2.5 m high; the stem diameter is 5.2 cm. The crown of the bush is compact. The fruits are large, length 11.0 mm, width 8.3 mm, orange-red, cylindrical, index 1.5, weight 100 fruits-58.2 g, stalk 5-6 mm long. The number of fruits in a bud is 2-3 pcs. Ripening was noted in the second ten days of September. The average yield is 6.5 kg/bush. The fruit separation force is 115 g.

Seedling K-14-8181 (8-1) late ripening (in the second ten days of September), obtained from open-pollinated seeds of the K-14-81 form, the seeds of which were collected in 1981 in the valley of the Kendyrlyk River. It has a height of 3.0 m and a stem diameter of 5.8 cm. A distinctive feature of this seedling is its beautiful red fruits, 7.5 mm long, 6.7 mm wide, barrel-shaped, index 1.24, weight of 100 fruits-32,5 g. The fruit separation force is low-105 g. The average yield per bush is 9.6 kg/bush. This seedling is valuable for growing in the mountainous zone of Western Altai and for further breeding work as a donor for red fruit.

Analysis of the heritability of fruit color from red-fruited forms in the first generation made it possible to conduct breeding work based on the Kendyrlyk and Shetlasty populations. The value of the forms and seedlings identified on this basis contributed to producing the *Krasnoplodnaja*, *Podarok Bajtulinu*, etc. The selection effect of red-fruitedness is achieved only from red-fruited forms and seedlings.

For convenience in work, many authors replace the density of fruits per 10 cm length of a two-year shoot with the term “cob” density or “fruiting coefficient.” Ear density refers to one of the morpho-structural components of productivity. High indicators for the number of fruitful buds per 10 cm of “cob” are not always optimal. As a result of the research, a selection of forms in natural populations and a genetic selection assessment of the density of the “cob” in generations were carried out.

When examining natural populations, plants were described by a set of characteristics, including those that characterize the appearance of the “cob”: the number of fruits from one bud, the number of fruits per 10 cm length of a two-year shoot. Depending on the number of fruits in one bud, from 2 to 6 pieces, on the location of the buds, close together, sparse, we have proposed the following gradation in the density of the “cob”: loose up to 20 pieces of fruit, medium density-from 21 to 40 pieces, dense-from 41 to 60 pieces of fruit and very dense-over 60 pieces of fruit.

The study of *H. rhamnoides* in various ecological and geographical conditions made it possible to discover a significant diversity of forms in terms of “cob” density, from 9.2 pieces of fruits per 10 cm of the length of a two-year shoot for the form Sh-9-81 (Shetlasty population)-to 84.6 pieces in the K-9-84 form (Kenderlyk population). The number of fruits from one bud is from 2 to 8 pieces. The fruits are located less frequently on perennial wood than on the “cob” of a two-year-old branch. With an equal number of fruits per 10 cm of the length of the “cob” of a two-year shoot but a long stalk from 6 to 11 mm, the cob looks looser, with a short stalk, 2-3 mm, small fruits weighing 100 fruits 20-30 g and the number of fruits from one bud above 5 pieces the “cob” looks denser. When up to 5-8 fruits are formed from each bud, and the buds are close together to 0.5 cm, the number of fruits on a 10 cm segment of the “cob” length reaches 60-86 fruits.

When distributing the forms of *H. rhamnoides* in wild populations according to the number of fruits per 10 cm of the length of a two-year shoot of the “cob” as a percentage, it was revealed that forms with a loose arrangement of fruits were identified in only two populations: the Shetlasty 6.8% and the Kaindysu 35.0%; in the rest, such forms were not found (Table 6).

The group with an average density of 21 to 40 fruits includes 43.1% of the forms in the Shetlasty population, 53.8% in the Karatal population, and a third of the plants from the Kenderlyk, Tersayryk, and Kaindysu populations. Plants with such “cobs” are of interest for selection for convenient fruit removal, both for manual and mechanized harvesting.

The largest number of forms with dense “cobs” was noted in the Kendyrlyk population-59.2%, from 30.9 to 36.5%. In Tersayryk there are 40.0% of such forms. These forms are less interesting in *H. rhamnoides* breeding. In these same populations, from 11.3% to 26.6%, forms with very dense “cobs” are found. Only in the Kaindysu population were no forms with a very dense arrangement of fruits identified. On average for populations, the “fruiting coefficient” was 48.5 pieces in the Kendyrlyk population, 39.0 pieces in the Shetlasty population, 48.4 pieces in the Tersayryk population, 30.8 pieces in the Kaindysu population, and 44.1 pieces in the Karatal population. The study of this trait made it possible to establish a slight difference between populations in the frequency of occurring forms. The optimal arrangement of fruits on a two-year-old shoot was noted in the forms Sh-9-81 and K-14-81 from 20 to 40 pieces.

During the fruiting of selected forms of “clones” for several years in culture, a comparative characteristic was carried out on the density of the “cob” in plants from natural habitats. As a result, it was noted that in cultivated plants under study, this trait is genetically fixed and slightly depends on external conditions and fruit set.

Genetic analysis of the density of fruits on a two-year-old shoot by generation was carried out in 110 families from four populations. As a result of the high heterogeneity of natural populations of *H. rhamnoides*, the offspring obtained from sowing seeds collected from wild plants are characterized by great diversity in the number of fruits per 10 cm of length of two-year-old shoots from 12 to 68 fruits. One bud produces from 2 to 7 fruits. Seedlings K-16-8283 (1-30), K-13-8283 (5-22) from the Kendyrlyk population, T-14-8386 (2-6) from the Tersayryk population has a very dense “cob,” the number of fruits per 10 cm of the length of a two-year shoot is more than 60. Loose ear in seedlings T-3-82-83 (3-5), T-3-8283 (3-9), Sh-9-8181, Sh-9-8195, K -14-8195. When studying this trait, it was revealed that the heritability of this trait is about 30%. The variation in cob density within a family reaches 32%.

The length of the stalk is one of the most important economic characteristics; the longer the stalk, the more convenient it is to collect the fruit. In natural habitats, the limits of variation in the length of the stalk are 4-11 mm. The third part of individuals in the Kendyrlyk, Karatal, Shetlasty, and Kaindysu populations have a long (6.1 mm and above) peduncle, from 67.4% to 75.9% have a medium peduncle (3.1-6.0 mm) (Table 7).

Table 6. Distribution of *Hippophae rhamnoides* forms in wild populations and by generation (number of fruits per 10 cm of the length of a two-year “cob” branch, %)

Population	Average number of fruits per 10 cm cob length	Proportion of individuals, % by number of fruits per 10 cm “cob” length			
		less than 20 pieces	from 21 to 40 pieces	from 41 to 60 pieces	more than 60 pieces
Kendyrlyk	48.5	0	29.5	59.2	11.3
Shetlasty	39.0	6.8	43.1	36.5	13.6
Tersayryk	48.4	0	33.4	40.0	26.6
Karatal	44.1	0	53.8	30.5	15.7
Kaindysu	30.8	35.0	31.6	33.4	0
Population average	42.1	8.7	38.9	39.9	13.4
LSD*	0.45				
First generation F_1	41.4	10.3	44.5	40.2	0
Second generation F_2	38.9	9.4	55.0	35.6	0
Third generation F_3	41.7	7.9	54.2	37.9	0
LSD*	0.10				

Note: *least significant difference 0.5

Table 7. Distribution of *Hippophae rhamnoides* plants in wild populations and generations (peduncle length, in%)

Population	Average stalk length (mm)	Proportion of plants (in %) by stalk length		
		Less than 3.0 mm	3.1-6.0 mm	More than 6.0 mm
Kendyrlyk	6.6	0	75.9	24.1
Shetlasty	5.8	0	67.4	32.6
Tersayryk	5.6	0	80.0	20.0
Topkain	5.8	0	91.4	8.6
Karatal	6.0	0	75.3	24.7
Kaindysu	6.0	0	69.8	30.2
Population average	5.9	0	76.6	23.3
First generation (F1)	5.8	1.0	79.6	20.4
Second generation (F2)		0	76.2	23.8
Third generation (F3)	6.0	0	70.2	29.8

The forms from these populations served as the starting material for selection for stalk elongation. No forms were found with a short stalk, less than 3 mm. The average stalk length in these populations is 5.6-6.6 mm. A quarter of the plants in the Karatal and Kendyrlyk populations have a long stalk, and the rest have a medium one. The limits of variation in the length of the stalk are from 4 to 7 mm, and the average value for populations is 5.8-6.0 mm.

In the Tersayryk and Topkain populations, the frequency of occurrence of plants with an average stalk from 3.1 to 6.0 mm is 80%-91.4%, with a length of more than 6 mm, 20%-8.6%, respectively. The average stalk length in populations is 5.6-6.0 mm. Even though the Topkain population contains significantly fewer plants with a long stalk, 8.6% than in other populations, no plants with a short stalk were found. The length of the stalk varies from 4 to 6 mm. Average values for the length of the stalk in different populations show the independence of this trait from the external environment. The coefficient of variation, which serves as the most convenient measure of variability, ranges from 15 to 20%, varying at an average level of variability.

A selection assessment of *H. rhamnoides* based on the length of the stalk showed that it ranges from 4.6-10.5 mm in most forms and seedlings. This trait has high ecological stability and is largely determined by the genotype. Selection for stalk elongation has prospects. After three generations, almost a quarter of the seedlings have a long stalk.

In *H. rhamnoides* cultivation technology, manual harvesting of fruits accounts for more than 80% of the costs. Since this method of harvesting will be one of the main ones for a long time, it is necessary to create varieties for machine harvesting that increase labor productivity. An effective solution to this problem lies in the field of selection for low fruit separation force from 50 to 100 g. The starting material was the forms growing in the Tersayryk, Kendyrlyk, and Karatal populations, in which this trait is 30-40% lower than in varieties bred in different countries and amounts to 52.9%, 21.6%, and 62.9%, respectively, by population (Table 8).

Inheritance of the effort to tear off fruits by seedlings showed that wild forms can hereditarily transmit this trait. Good results were obtained in the family K-13-8283, where the lifting force is, on average, 102 g; the seedling K-13-8283(5-22) has the lightest lifting force—91 g. In other families, significant variation was noted in the force of fruit separation, from 91.0 to 187.3 g.

Analysis of the (offspring) seedlings of three generations obtained from free pollination of forms of various ecological and geographical origins showed that wet separation of fruits is predominant (from 42.3% to 87.0%). The proportion of seedlings with dry fruit detachment is not large-in most families, by generation, it ranges from 12.8 to 19.2% of samples. Any trait in plants has its biological limits. Knowledge of the patterns of optimal (compromise) combination of productivity components in one genotype is of great importance for practical selection. Long-term studies of morphological characters in *H. rhamnoides* in natural populations, as well as in seedlings, allowed, based on outstanding characteristics in terms of yield-14 kg/bush in seedling K-14-8181 (8-1), weight of 100 fruits up to 65 g in form Sh - 9-81, tear-off force of 88 g for seedling Sh-12-8181(6-8), stalk length of 12 mm for seedling Kan-8-8486 (10-2) to create a "model" of an ideal variety (Figure 4).

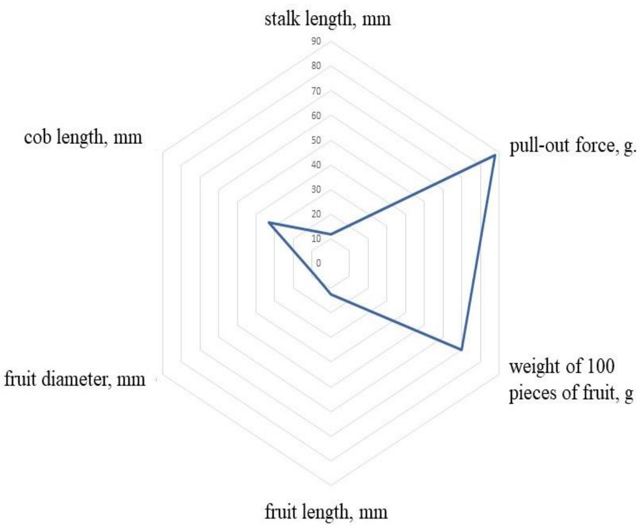

Figure 4. Model of ideal *Hippophae rhamnoides* variety

Table 8. Distribution of *Hippophae rhamnoides* forms by fruit tearing force in natural populations and by generation

Population	Average tear force (g)	Percentage of forms with tear force (g)			
		from 50 to 100	from 101 to 150	from 151 to 200	above 200
Tersayryk	109.9	52.9	41.3	5.8	0
Kendyrlyk	116.5	21.6	73.8	4.2	0.4
Shetlasty	136.9	17.2	49.4	33.4	0
Karatal	99.9	62.9	37.1	0	0
Kaindysu	130	9.6	54	36.4	0
Population average	118.6	32.8	51.1	15.9	0.08
First generation (F_1)	117.1	29.7	62.8	7.5	0
Second generation (F_2)	120.4	28.1	60.7	11.2	0
Third generation (F_3)	119.9	21.9	63.4	14.7	0

Combining these traits in one genotype is a task for the future. Systematic research in this direction is constantly being carried out. The creation and gradual updating of donors for each of the selection traits on a genetically diverse basis made it possible to accelerate the implementation of this model into specific varieties and forms: *Jubilejnaja Kotuhova, Plakuchaja, Podarok Bajtulinu, Shetlastinka, Nesravnennaja, Fakel.* According to the results of the state examination for economic efficiency, the varieties that received a patent showed high winter hardiness, annual fruiting, and high yields for the *Podarok Bajtulinu* variety-9.6 t/ha, and for the *Shetlastinka* variety-13.5 t/ha.

Studies of *H. rhamnoides* conducted in natural populations of the East Kazakhstan region, and cultivation in the Altai Botanical Garden indicate high ecological plasticity and variability, allowing this species to maintain genetic diversity. The results of breeding work on *H. rhamnoides* serve to develop the main directions for preserving the gene pool, the value of which lies in the fact that each form almost completely reflects its diversity. The value of breeding work with *H. rhamnoides* is associated with significant polymorphism and the presence of geographical forms of this plant. A comparative assessment of *H. rhamnoides* plants based on a set of traits made it possible to determine the degree of differences between populations and conclude that the Kendyrlyk, Shetlasty, and Tersayryk populations have the greatest diversity of forms.

The advantage of new forms of *H. rhamnoides* is to obtain high yield (8-10 t/ha) compared to previous varieties with yield (7.8-9 t/ha), large fruit (weight of 100 fruits above 95 g, length 12-13 mm, diameter-9-10 mm), low fruit separation force.

The richest gene pool of wild *H. rhamnoides* in the East Kazakhstan region indicates the high heterogeneity of natural populations with a mobilizing reserve of hereditary variability, ensuring high plant cultivation polymorphism. The current geographical and ecological range and evolution determine the plasticity of *H. rhamnoides* plants in cultivation.

Comparison of the structure of trait variability in selected forms of *H. rhamnoides* in culture with their data in natural populations allows us to objectively identify individuals' ecological and genetic communities and evaluate the role of ecological and geographical factors in forming the population structure. These forms retain their inherent hereditary characteristics and properties when tested in culture.

When studying *H. rhamnoides* in natural populations and culture, additional attention was paid to the interaction between the genotype and the external environment, and the ecological and climatic growth conditions. As a result, a weak (invariant) reaction to changes in growing conditions was revealed and a high adaptive potential to new environmental conditions was established.

The study of the inheritance of the most important economic and biological traits by the offspring of three generations of panmixia and distant ecological and geographical forms showed the possibility of creating genotypes with a high level of adaptability, winter hardiness, productivity, and fruit quality.

The study of seed progeny, selected forms in natural populations, revealed a high percentage of heritability of the following economic traits (yield, weight, fruit color, tearing force, length of the stalk). High variability among *H. rhamnoides* seedlings for many traits contributes to selection efficiency and opens up great prospects for breeding. The observed differences between seedlings are determined to a large extent by genotypic characteristics. The resulting varieties of *H. rhamnoides* contribute to the conservation of plant biodiversity and the development of fruit growing in the Republic of Kazakhstan. This work contributes to the conservation of the gene pool of this species.

In conclusion, carrying out a comprehensive assessment of the genetic material of *H. rhamnoides* in its natural habitats made it possible to identify 120 forms. The study of the same forms under natural conditions and during introduction revealed phenotypic and genotypic variability of *H. rhamnoides* plants.

Therefore, 26 promising seedlings and forms with optimal expression of the main economic and biological characteristics were identified for introduction into production and further breeding work. Of great breeding value for fruit color are the forms and seedlings K-14-81, Sh-9-81, Sh-17-82, K-13-82, K-14-8181 (8-7), Sh-17-8283 (1-4), and Sh-9-8195 (2-19), which produce the largest number of red-fruited individuals in the offspring. The yield of high-carotenoid seedlings is largely determined by the initial forms and their specific combination during hybridization.

The result of the research was a selection and genetic assessment of three generations of *H. rhamnoides*. The high phenotypic and genotypic variability of *H. rhamnoides* in all respects is determined both genetically and by the environment. Among the seedlings of the third generation, 16 variety clones were selected: *Jubilejnaja Kotuhova* T-2-82(2-22) III, *Dolgozhdannaja* No.5(3-24) III, *Jantarnaja* (2-1) III, *Shetlastinka* No.7 (2-24) III, *Nesravnennaja* Sh-9-81(3-27) III, *Krasavica* Sh-9-81(3-30) III, *Solnyshko* (1-18) III, *Podarok Bajtulinu* Sh-9-81 (4-6) II, with large fruits, high yields and low fruit tearing forces. A varietal certificate was received for one of them (*Jubilejnaja Kotuhova*), and an application for a selection achievement was submitted for two *Shetlastinka* and *Podarok Bajtulinu*. With the creation of the hybrid stock of *H. rhamnoides*, it became possible to form a data bank about the elite gene pool of this crop.

Also, certain successes have been achieved in selecting male plants characterized by high pollen productivity. These are the forms: *Gustoj Tuman* T-2-82 (1-24) III, *Ljubimec* T-17-82 (2-20) III, *Krasavchik* K-8-82 (1-34) III, *Bogatyr* T-17-82 (2-20) III. Introducing these winter-hardy pollinators into production is expected to reduce the number of male plants per hectare by two (usually about 10% is recommended), which will help increase productivity due to fruit set, including increasing the number of female plants on the plantation.

All varieties and promising seedlings were obtained from open pollination (analytical selection), without genetic engineering. There are no genetically modified varieties. They cannot have a negative impact on the environment.

The results of studying intra-population, inter-population, intra-family, and inter-family variability complement theoretical and fundamental research, contributing to the theory of *H. rhamnoides* selection and biodiversity conservation.

Research data confirm the need to preserve *H. rhamnoides* as one of the solutions to the issues of preserving plant biodiversity in Kazakhstan. The results have practical value in preserving the rich diversity of *H. rhamnoides* in the East Kazakhstan region ex-situ. The work will continue in the future.

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