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Screening of new sources of *Hordeum vulgare* genes for adaptive breeding in Aral Sea basin, Kazakhstan, for diversification of agriculture

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Abstract

The specifics of the soil and climatic conditions of the Aral sea region, Kazakhstan, primarily associated with salinization, various types of droughts, uneven distribution of precipitation during the growing season, and late spring frosts, make it necessary to create crop varieties with resistance to biotic and abiotic environmental factors. In this regard, the expansion of the area under crops of non-traditional salt-tolerant grain crops in the Kyzylorda region is one of the main directions of increasing the sustainability of agriculture in the region. Studies have shown that among the grain crops cultivated in the region, spring barley (*Hordeum vulgare* L.) is a reliable crop that can make the most of the region's bioclimatic resources to form sustainable yields. The purpose of this study is to create a new promising source material of barley based on a comprehensive study of collection material of various ecological and geographical origin by applying various methods of classical breeding. Based on a comprehensive assessment of the collection material of barley, a working collection of 250 varieties with agronomic resistance to environmental stress factors of the Aral Sea region was created. The selected samples are recommended for use in practical breeding in order to increase the adaptive potential of modern barley varieties.

Keywords: barley, world collection, plant development phases, variability, breeding, yield

Introduction

Lack of attention to climate change today has major economic implications for the future (http://agro-archive.ru/adaptivnoe-rastenievodstvo/; Budyko 1991; IPCC 2014). Not a single economy in the world today is able to actively withstand global climate change and the increasing frequency of extreme weather events. Particularly, the agricultural sector is most vulnerable to climate risk (Cho 2019). Providing food is impossible without a reliable plant genetic resources, which are the main source of improving crops and solving food security issues in any country. However, the decrease in varietal diversity observed in recent years in Kazakhstan has not only reduced the resistance of agroecosystems to weather fluctuations, but also significantly increased their genetic vulnerability. This situation may

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lead to the disappearance of traditional indigenous varieties and native forms in the future and will ultimately threaten the food security (Bergez et al., 2010).

Therefore, further expansion breeding scale, as well as the improvement of technologies to overcome water shortages and a number of other limiting factors, is extremely important. Providing the possibilities of creating new plant varieties, taking into account possible global and local climate changes, requires strengthening and expanding the adaptive principle in the choice of breeding goals and methods, as well as ensuring a greater functional relationship of the breeding, variety testing and seed production stages (Zelentsov 2012).

The extremeness of the soil and climatic conditions of the Kazakhstan Aral Sea region, associated primarily with salinization of arable soils, manifestation of various types of droughts, uneven distribution of precipitation during the growing season and late spring frosts necessitates the creation of varieties of agricultural crops with resistance to biotic and abiotic environmental factors. In this regard, within the framework of the program for diversification of plant growing in the Kyzylorda region, the expansion of the area under non-traditional salt-tolerant grain crops is one of the main directions of increasing the sustainability of agriculture in the region. Studies have shown that among grain crops cultivated in the region, spring barley (*Hordeum vulgare* L.) is a reliable crop that can make the most of the region's bioclimatic resources to form sustainable yield.

To maximize the realization of the genetically determined potential of productivity, it is important to adapt varieties to specific agroecological conditions (Nadolska-Orczyk et al., 2017). In particular, in the extreme ecological conditions of the Aral Sea region, varieties of local breeding become decisive, the success of which largely depends on the renewal of plant genetic resources by creating a variety of source material. One of the ways to solve the problem of diversification of crop production in the region is the creation, reproduction and production of new salt-resistant, drought-resistant, highly productive varieties of barley of local breeding with a high protein content in the grain. The purpose of the study is to identify the sources of economically valuable traits based on a comprehensive study of collection material of various ecological and geographical origin and, on their basis, the use of various methods of breeding and creation of a new promising source material.

Materials and Methods

Study site

The research was conducted on the scientific and experimental site of the "Kazakh Research Institute of Rice Growing named after I. Zhakhaev" LLP during three years (2017-2019). The climate of Kyzylorda region is sharply continental with hot and dry summers and cold winters with unstable snow cover. The average annual air temperature is 9.8°C. The average annual precipitation is 129 mm, while in droughty years, only 40-70 mm. The soil of the experimental plot is a meadow-boggy (*Anthrosol*

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Irragic, WRB 2015), typical for rice crop rotations in the region. The studied soil has low humus content of up to 1%, low porosity and a rather high value of a dry residue of 0.6-0.8%. Soil salinity is of a sulfate type with medium salinization level. Soil analyzes were carried out in the analytical laboratory of the Kazakh Research Institute of Rice Cultivation named after I. Zhakhaev (Table 1).

Analytical

The formation of the collection nursery was carried out according to the recommended methodology (Methodical recommendations, 1983). The complex program "Arpa" was developed in the Kazakh Research Institute of Agriculture and Plant growing for the soil and climatic conditions of the south-east of Kazakhstan. The size of the plots in the collection nursery is single-row plots with 1 m length, three replicates. The local barley variety Syr Aruy, placed every 10 numbers was a standard. The following observations and assessments were conducted:

1. Date of sowing
2. Date of tillering
3. Date of booting
4. Date of earing
5. Date of milky, waxy and full ripeness
6. Resistance to diseases and pests
7. Definition of varieties
8. Pre-harvest assessment and rejection
9. Harvesting and weight of the harvest
10. Biometric analysis of plants: Plant height; Productive bushiness; Length of the last internode; The length of the ear; The number of spikelets in an ear; The number of grains per ear; Weight of grain per ear and plant; Weight of 1000 grains; Grain weight from 1 m²

Phenological observations and biometric analysis were determined according to the VIR methodology (Methodological guidelines 1981). Statistical processing of harvest data, including the least significant difference (LSD_{05}) was done according to Dospekhov (1973). The coefficient of correlation was done in MS Excel, where $r < 0.3$ is a weak correlation; $r = 0.3-0.7$ is a medium correlation and $r > 0.7$ –strong correlation. Soil samples were analysed according to the methods described in Mineev (2001).

The hydrothermal coefficient (HTC) by Selyaninov (1928) is still a useful tool for determining the water status of the environment (Taparauskienė and Miseckaite 2017; Evarte-Bundere and Evarts-Bunders 2012; Bartoszek and Banasiewicz 2007). It is calculated as follows: $HTC= \Sigma x/\Sigma t$ x10; where Σx is sum of precipitation and Σt is sum of temperatures in the period, when the temperature has

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not been lower than 10ºC (Selyaninov 1928; Ziernicka-Wojtaszek 2009). The obtained HTC values allow categorizing hydrothermal regime as follow: a zone of excessive moisture has HTC> 1.3, a zone of sufficient moisture HTC =1.0–1.3; arid zone HTC =0.7–1.0, a dry farming zone HTC= 0.5–0.7, a dry or irrigated zone HTC <0.5 (Selyaninov 1928).

Table 1. Chemical characteristics of the experimental soil, 2017-2019, Kyzylorda, Aral Sea basin

Horizon, cm	pH	mV	Dry residue %	Anion, %/mg.eq. 100 g^{-1} soil				Cation, %/mg.eq. 100 g^{-1} soil			Sum of salts %
				CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	
0-20	7.64	-24	0.78	0	0.023	0.015	0.583	0.16	0.046	0.016	0.848
				0	0.462	0.5	12	8.3	3.75	0.700	
20-40	7.55	-19	0.65	0	0.029	0.013	0.605	0.15	0.046	0.025	0.864
				0	0.351	0.4	12.3	8.4	3.75	1.100	

Materials

The objects of research were samples of barley of various ecological and geographical origin, presented in Table 2. The general view of the experiments' parts are shown in the Figure 1.

Table 2. Working collection of spring barley

Country of origin	Number of forms	Two-row forms	Multi-row forms
Russia	10	10	-
Ukraine	10	10	
Syria(ICARDA)	50	30	20
Iran	25	20	5
Turkey	10	10	-
USA	24	15	9
Japan	5	3	2
Kazakhstan	116	95	21
Total	250	193	57

a) General view of the collection nursery b) Labelling of the samples

Figure 1. Samples of the world collection of *Hordeum vulgare* (L.) at the stage of full earing

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Results and Discussions

Based on the results of phenological observations, the samples from the Table 2 were ranked by ripeness group and their botanical varieties were determined. Of the two-row forms, there are mainly samples belonging to the “nutans” and “medicum” types, and four samples of the “inerme” type. Of the multi-row forms, genotypes of the “pallidum” - 72% and “ricotense” - 28% types are mainly found (Table 3).

Table 3. Ranking of the collection nursery of *Hordeum vulgare* (L.) samples by maturity and biological variety groups

Maturity groups	Two-row forms 2-R			Multi-row forms 6-R	
	nutans	medicum	inerme	pallidum	ricotense
Early ripening (up to 75 days)	288	10	-	58	-
Mid-season (76-82)	11	75	4	22	16
Mid late (83-89)	-	52	-	3	12
Late ripening (от 90 дней)	-	5	-	-	4
Amount	299	142	4	83	32
Total		445		115	

Nine samples were characterized by an extended growing season of more than 90 days and were assigned to the group of late ripening: Harrington, N942, N157, S26-3 (Japan); 23385 (Bolivia); 2/7-01, 2/3-01 (Syria); Scarlett, Maltz (Germany). In the collection nursery, the grain yield, depending on the ecological-geographical origin and climatic conditions of the year, varied from 0.25 to 7.5 tha^{-1}. Of particular interest were the highly productive forms of two-row barley of the nudum variety and the multi-row variety coeleste, which can serve as parental forms in the creation of hulless barleyvarieties (Figure 2).

The growing season. It should be noted that various conditions of moisture supply and temperature regime during the years of research allowed an objective assessment of collection samples of spring barley (Table 4).The most unfavourable in terms of weather and climatic conditions was 2019, which according to the hydrothermal coefficient (HTC) characterized as extremely dry (HTC for the entire growing season in 2019 was only 0.12). The average daily temperatures during the formation of the generative organs exceeded the average annual values by 5 and 3°C. During the flowering period of barley, daytime temperatures reached 50°C, which significantly reduced the formation of grains. Precipitation during the “earing-ripening” period did not have a positive effect on the crop yield, since during this period the plants were in the phase of wax ripeness. Such conditions contributed to the rapid passage of the main phases of development of barley, in particular, “tillering-booting” (HTC = 0.03) and “booting-heading” (HTC = 0.04). The exception was the “sowing-germination” period, when the sum effective temperatures were insufficient for grain germination, which led to late sprouting of

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seedlings and a decrease in field germination. Therefore, in 2019, the growing season shortened and averaged 74-76 days. The share of early maturing samples in the collection was over 75%.

Although, according to the HTC, the entire growing season of 2017 and 2018 characterized as arid, but such critical periods as “tillering-booting” and “booting-earing” were characterized by a sufficient supply of moisture (HTC were 1.55 and 1.17, respectively, Table 4). This had a positive effect on the formation of generative organs and determined the high yield of barley in these years.

a) Sample 2286 –inerme

b) Sample ICARDA-4 horsfordianum

c)SampleRihane –ricotense

d)SampleBi-54 –pallidum

e)SampleDonetsky 8 –nutans

f)SampleICARDA-160 –coeleste

Figure 2. Botanical varieties of the collection nursery of *Hordeum vulgare* (L.)

To determine the dependence of the duration of the growing season on meteorological conditions, a correlation analysis was carried out between moisture and heat supply, as well as the hydrothermal coefficient and the duration of the growing season by varieties. A strong influence of moisture conditions on the duration of the growing season of barley was revealed, which is confirmed by high correlation coefficients (r was from 0.83 to 0.91 ± 0.2). Regardless of the cultivar, an increase in precipitation and a decrease in the sum of active temperatures contributed to the lengthening of the growing season. Correlation analysis between the interphase periods and the duration of the growing season showed that a change in the duration of any period led to a significant change in the duration of the entire growing season. Thus, the analysis of the duration of the growing season showed that simultaneously ripening cultivars often differ sharply in the duration of individual phases.

Table 4. Hydrothermal conditions of the interphases of spring barley (*Hordeum vulgare* L.) in the Kyzylorda, Aral Sea basin (2017-2019)

Year	Variable	Phases of plant development						
		Sowing-sprouting	Sowing - tillering	Tillering-booting	Booting-earing	Earing-ripening	Sowing-heading	Total for the growing season
2017	∑precipitation, mm	3.0	18.7	5.6	32.4	7.0	59.7	66.7
	Average temperatures °C	14.6	17.9	22.3	19.8	28.2	18.8	22.1
	∑active temperatures	133.7	294.4	290.0	276.9	844.9	939.1	1759.8
	HTC	0.22	0.64	0.19	**1.17**	0.08	0.64	0.38
2018	∑ precipitation, mm	12.0	20.5	42.6	10.5	2.0	85.6	87.6
	Average temperatures °C	12.5	17.8	21.8	19.6	28.7	17.9	20.1
	∑active temperatures	115.6	278.3	275.6	229.5	856.5	899.0	1725.5
	HTC	1.04	0.74	**1.55**	0.46	0.02	0.95	0.51
2019	∑ precipitation, mm	2.9	8.0	0	0	11.1	10.9	22.0
	Average temperatures °C	8.9	14.5	24.9	23.6	26.3	17.3	20.2
	∑active temperatures	77.7	213.8	374.5	259.4	983.5	863.1	1846.6
	HTC	0.37	0.37	0.03	0.04	0.11	0.13	0.12

HTC – hydrothermal coefficient by Selyaninov (1928)

The set of the studied barley genotypes under given conditions was characterized by a significant diversity in the duration of the growing season. Over the years of study, the amplitude of varietal variability for this trait was 60-95 days. Differentiation of varieties into four conventionally accepted groups showed that the specifics of the meteorological conditions caused an annual redistribution of varieties in these groups. According to numerous studies (Cosme and Niero 2017; Dijkmanet al., 2017), plants of early ripening varieties of barley and wheat are characterized by a shorter germination-heading period compared with late ripening. Therefore, many researchers characterize the duration of the growing season by the time of heading. Fine adjustment of heading date is important for understanding other developmental traits such as leaf area, plant height, tillering, and grain number (Li et al., 2006; Alqudah and Schnurbusch 2014). In addition, it is also considered as a decisive stage for improving yield and yield components (Esparza Martínez and Foster, 1998; Li et al., 2006; Cuesta-

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Marcos et al., 2009; Pasam et al., 2012). The timing of heading in barley has a substantial impact on range-wide eco-geographical adaptation and improving the yield (Alqudah and Schnurbusch 2017)

In the studied years, no differences found between the “sowing-earing” period, while statistically significant differences were observed in the “earing-ripening” and “sowing-ripening” phases. A significant correlation was found between the phase of “earing-ripening” and the duration of the growing season in multi-row (r = 0.49 - 0.55) and two-row barley varieties (r = 0.57 - 0.62). Thus, under the conditions of the Aral Sea region, the phase of “earing-ripening” has a significant effect on the duration of the growing season, which must be taken into account when differentiating varieties by ripeness groups.

Based on the results of the analysis of phenological observations, a group of samples was identified that retains a short growing season regardless of climatic conditions. These samples are of interest as sources of early maturation in practical breeding. A distinctive feature of this group of samples is the elongation of the “tillering-booting” period, which is reflected in the high adaptability to the conditions of the Aral Sea region (Table 5).

Table 5. Duration of the interphases of early ripening barley (*Hordeum vulgare* L.) samples

Catalog numbers	Field germination, %	Vegetation period, days	Period length, days			
			Sowing-tillering	Tillering-booting	Booting-earing	Heading - full ripeness
Syr Aruy, st	70.2	78	14	20	12	22
164/99-4K	82.0	76	12	18	11	22
2/07-4K	85.1	78	12	22	12	22
Kaisar	86.5	75	12	21	12	22
ICARDA 29	72.5	78	14	16	10	22
ICARDA 51	73.5	74	12	16	12	21
ICARDA 52	75.3	72	14	18	12	24
ICARDA 59	72.3	75	12	20	12	22
ICARDA 84	75.2	75	12	18	10	21
ICARDA-1	75.2	75	12	19	12	24
ICARDA-6	72.3	74	13	18	10	21
99/99-1	80.0	73	14	20	10	22
99/99-8	82.3	75	13	18	12	22
99/99-7	80.9	72	14	18	11	23
A24/05-2	79.3	74	12	22	11	20
Bi-16	78.6	78	11	22	12	20
ICARDA-29	72.4	70	14	16	16	22
5-146	72.0	72	14	17	18	22
ICARDA-52	82.3	74	14	15	18	24
ICARDA-59	76.5	76	14	16	15	24
15/07-7	74.5	70	14	15	15	21
Donetsky 8	80.2	75	14	15	11	22
Kaisar	82.0	68	12	15	11	22
Altyn aray	80.9	75	14	15	18	23
Bi 11	81.3	78	12	16	18	24

The study of spring barley cultivars under the conditions of rice-based cropping systems showed that field germination is largely determined by the sum of active temperatures during the “sowing-germination” period, which is confirmed by a high correlation coefficient (r = 0.71). This is due to the fact that in the rice-based crop rotation, barley is placed after rice, and the natural moisture of the soil is quite sufficient to obtain seedlings.In the given conditions, the limiting factor during the “sowing-germination” period was the lack of heat. So, on average in the experiment in 2017 at the sum of active temperatures = 133.7, field germination was 78%, in 2018 at the sum of active temperatures = 129.6 field germination was 77% and in 2019 at the sum of active temperatures = 115.7, field germination was 68%.There were no significant differences in this trait between two-row and multi-row forms. The amplitude of variation in field germination in the context of genotypes increased from low to high levels (V = 9.5 to 93.2%).In general, the value of variability was 31.65%, which refers it to a highly variable trait, that is, this trait is highly dependent from the influence of meteorological conditions of the year. In general, among the studied lines and cultivars, up to 25% of the samples had low field germination (35-50%), and, depending on the environmental conditions, were characterized by high variability V = 35.4-62.3%.It should also be noted that along with the high field germination rate on saline soils, the intensity of the initial growth of barley is of particular importance. Genotypes with this trait in the initial phase of the growing season grow very quickly and intensively. This creates the best conditions for the growth and development of perennial grasses, shading them from direct sunlight, and most importantly, prevent the rise of salts to the soil surface.

In this regard, taking into account this adaptive trait, genotypes were identified in the collection nursery that combine high field germination and rapid growth in the initial phase of ontogenesis. They include two-row samples: Odessky 100, Odessky 164, Donetsky 650, Donetsky 164 (Ukraine); 520695, 520628 (Syria), BI-41, BI-55 (Iran); Urenga, Resonance and Divny (Russia); Kaisar, Inkar, Syr Aruy, Nutans 89, Medicum 8955, Susyn, 53\82-22, Bastau, 89\83-5, 93\80-14 (Kazakhstan) and multi-row: B 024, K 614 (Japan); 5-72, 5-75, 5-88 (Syria); Pallidum (Ukraine) (Table 6). As can be seen from Table 5, the average indicators of field germination in the selected samples were from 72 to 82%.For the stressful conditions of the Aral Sea region, these are rather high indicators. In our studies, a positive correlation was established between the number of productive stems preserved for harvesting and field germination (r = 0.721), which ultimately affects the formation of high productivity.

In this regard, an important feature that allows one to judge the adaptive properties of the studied genotypes at the early stages of ontogenesis is field germination. Therefore, the selected cultivars were included in the hybridization program as parental forms. The height of the plants varied significantly depending on the weather conditions of the year of study. In the conditions of the Kyzylorda region in years different in meteorological conditions the height of spring barley plants was largely determined by the moisture supply during the sowing-heading period(r = 0.654). So, on average in the experiment with HTC = 0.13 in this period, the plant height was 68.2 cm, HTC = 0.64 - 74.2 cm, HTC = 0.85 - 84.8 cm. The coefficient of variability of the trait in the two-row group was 6.9%, which is considered low varying, while in the multi-row group the coefficient was 17.6% attributing it to the medium-variability.

Table 6. Source materials of *Hordeum vulgare* (L.) resistant to late spring frosts, 2017-2019

Samples	Origin	Field germination, %			Deviation from the standard, %	V, %
		min	max	x_{cp}		
Syr Aruy, St	Kazakhstan	60.5	75.2	70.9	-	32.5
Nutans 89	Kazakhstan	72.6	82.5	80.6	+9.7	14.5
Kaisar	Kazakhstan	70.5	79.8	75.2	+4.3	9.1
Inkar	Kazakhstan	74.5	88.9	84.5	+13.6	15.4
Syr Aruy	Kazakhstan	72.5	84.2	80.0	+9.1	14.3
Susyn	Kazakhstan	68.5	79.2	74.5	+3.6	12.8
Bastau	Kazakhstan	70.2	80.4	76.5	+5.6	14.7
Odessky 100	Ukraine	68.0	78.0	74.5	+3.6	15.6
Donetsky 164	Ukraine	70.5	78.6	75.2	+4.3	18.2
Donetsky 165	Ukraine	69.5	78.6	76.2	+5.3	17.5
Divny	Russia	69.5	77.5	74.9	+4.0	16.8
Urenga	Russia	65.2	77.6	73.9	+3.0	17.5
B-024	Japan	70.2	78.5	75.0	+4.1	8.9
K 614	Japan	71.2	79.5	75.6	+4.7	7.8
Bi 41	Iran	70.5	76.2	74.3	+3.4	7.6
Bi 55	Iran	68.5	79.5	76.0	+5.1	15.6
ICARDA 96	Syria	69.5	75.9	73.5	+2.6	10.5
ICARDA 46	Syria	70.3	76.2	74.2	+3.3	8.6
LSD_{05}					2.05	

Our results showed that under the conditions of the Aral Sea region, multi-row samples were highly susceptible to stress factors. Therefore, because of inhibition of growth processes, a sharp decrease in plant height observed in climatically unfavorable years (Table 7). And only individual multi-row forms 44\87-14, (Kazakhstan), Orenburgsky 16 (Russia), BI-54 (Iran), I 643, I 342, E 812 (Japan) were distinguished by a low coefficient of variation with a plant height of more than 78 cm and of the standard variety Syr Aruy - 65.0 cm.

The above samples are of practical interest as a material for breeding for tall growth, in particular, for the conditions of rice-based crop rotation, since barley is cultivated here mainly as a cover crop of perennial grasses.

The length of the undergrowth (last) internode is an important morphological feature in determining drought tolerance. It is known that varieties not resistant to drought do not eject an ear from a leaf wrapper, but the resistant varieties do it to one degree or another. For this trait with values of 18 cm and more, 25 samples were isolated, in combination with a plant height of at least 75 cm and resistance to lodging. The spike length varied from four in multi-row forms to 9.8 cm in two-row ones. We also took into account other external signs characterizing the resistance of plants to drought and salinity: the degree of turgor, wilting, yellowing and death of leaves. A number of researchers consider the functions of the few upper leaves of barley to be one of the main factors in determining the total grain productivity (Hay and Ellis 1998). In our studies, multi-row forms had a more developed leaf surface than two-row ones.

Table 7. Source materials of *Hordeum vulgare* (L.) resistant to lodging and early-ripening (2017-2019)

Samples	Origin	Plant height, cm	Lodging resistance, score	Deviation from the standard, cm	Vegetation period, days	V, %
		Two-row samples				
Syr Aruy, st	Kazakhstan	65.0	9	-	78	17.9
Kaisar	Kazakhstan	78.7	9	+13.7	68	7.4
Bota	Kazakhstan	72.5	9	+7.5	76	8.5
3/95-14	Kazakhstan	78.2	9	+13.2	75	7.5
164/99-4K	Kazakhstan	79.2	9	+14.2	72	7.3
Kharkovsky 74	Ukraine	75.8	9	+10.8	79	8.9
Dneprovsky 435	Ukraine	76.3	9	+11.3	76	8.7
Granal 447	Kazakhstan	74.5	9	+9.5	74	7.6
520695	Syria	73.2	9	+8.2	73	5.8
Bi 55	Iran	74.6	9	+9.6	72	7.4
		Multi-row samples				
2/07-4K	Kazakhstan	80.9	9	+15.9	75	12.9
44\87-14	Kazakhstan	81.2	9	+16.2	74	15.7
Orenburgsky 16	Russia	79.5	9	+11.5	79	14.9
Bi 54	Iran	79.6	9	+14.6	75	16.4
I 643	Japan	78.4	9	+13.4	73	18.4
I 342	Japan	76.9	9	+11.9	75	12.5
E 812	Japan	75.8	9	+10.8	72	17.4
ICARDA 51	Syria	80.2	9	+15.2	75	13.5
ICARDA 48	Syria	80.0	9	+15.0	75	12.8
LSD_{05}		2.05				

Final grain productivity is the most important property of the variety, which is the goal of all agricultural production and therefore is the main factor for breeding. Over the years of research, 25 high-yielding varieties have been identified among the two-row barley forms, and 17 among the multi-row barley forms. The yield of the standard variety Syr Aruy averaged 229 g m^{-2} with fluctuations from 195 g m^{-2} to 349 g m^{-2}. The average yield in two-row cultivars varied from 65 to 495 g m^{-2}, and in multi-row varieties from 110 to 750 g m^{-2}. The highest yield was obtained in favourable years, on average, with fluctuations in two-row samples of 490 ± 32.2 g m^{-2} and 615.2 ± 32.5 g m^{-2} in multi-row ones. In dry 2017, the average yield was almost twice lower.

Increasing the amount of protein is an important breeding challenge in the region. One of the solutions is the search for and widespread use in hybridization programs of hulless forms, which are characterized by a higher content of plant protein in comparison with membranous ones. Of particular interest are highly productive hulless barley forms (12 samples), isolated from the ICARDA collection for use in practical breeding of food varieties (Figure 4). Currently, hybrid populations have been created using hulless genotypes: 27 lines have been selected, which are in the process of studying in a breeding nursery of the 1styear.

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A) ICARDA 4 B) ICARDA75, ICARDA76

Figure 4. Highly productive hulless samples of barely (*Hordeum vulgare* L.)

Thus, based on the results of a comprehensive assessment of spring barley cultivars of various ecological and geographical origin on saline soils of the Aral Sea region, a number of samples were identified that were adaptive to the stress factors of the Aral Sea region (Table 8).

Conclusions

To prevent genetic unification of the assortment of the studied culture, screening of the donors of economically valuable traits for hybridization programs of domestic barley breeding should be carried out among ecological and geographically distant sources that have not previously been used as parental forms. On the basis of a comprehensive assessment of the collection material of barley on saline soils of the Aral Sea region, a working collection of 250 varieties was created. The collection includes a number of samples with a short growing season up to 79 days and plant height above 65 cm.Mainly the density of the stand before harvesting determined a significant increase in yield. In turn, the density of the stand depended on high field germination, resistance to late spring frosts, diseases (fusarium root rot) at the early stages of ontogenesis, the weight of grain per spike, provided by the better grain size of the spike, i.e., in general, agronomic resistance to stress factors of the Aral Sea environment. The selected samples are recommended for use in practical breeding in order to increase the adaptive potential of modern barley varieties

Table 8. Representatives of the collection nursery of *Hordeum vulgare* (L.) with best economic signs

Traits	Name of samples
Field germination (over 75%)	2-R: ICARDA-99, ICARDA-84, ICARDA-104, ICARDA-52 (Syria), 13/06-116К, 9/06-4K, 9/06-34K, 13/06-190K, Tulpar, 44/00-14, 92/99-1, 38/86-9, 28/98-3 (Kazakhstan), Nutans 58 (Russia), Odessky 100 (Ukraine): 6-R: ICARDA-48, ICARDA-51, ICARDA-24, ICARDA-75, ICARDA-6, 12/29-01, 5-146 (Syria), Bi-11 (Iran), PI082 (Japan),
Plant height (over 80 cm)	2-R: ICARDA-29, ICARDA-52, ICARDA-59, ICARDA-14, ICARDA-143, ICARDA-106 (Syria), Inkar, Granal 447, 44\00-14, 4303H, 15\07-7, 102\80-7, 1\08-11К (Kazakhstan), Nutans 58 (Russia):6-R: ICARDA-3, ICARDA-160, ICARDA-75, ICARDA-32, ICARDA-14, ICARDA-15, ICARDA-23, ICARDA-24, ICARDA-51, ICARDA-64, 5-115, (Syria), I 643, I 342 (Japan), Rikotense, 13\06-190K, 13\06-147K, 13\06-118K (Kazakhstan)
Ear length (over 7.0 cm)	2-R: ICARDA-14, ICARDA-143, ICARDA-106, ICARDA-24, ICARDA-83, ICARDA-63, ICARDA-16, ICARDA-54 (Syria), Kaisar, Granal 447, Tulpar, 9\06-45K, 9\06-6K, 9\06-12K, 2\78-6K, 9\06-55K, 76\86-11K, 1\08-11K, 102\80-7, 88\86-9, 60\85-9 (Kazakhstan), 2586 (USA),Nutans 58 (Russia):6-R: ICARDA -57, ICARDA -75, ICARDA-24, ICARDA-56, 12\29-01, (Syria), BI-11 (Iran), 2613 (USA),Hulless, Rikotense, 13\06-185К, (Kazakhstan)
The length of the last internode (from 18.0 cm)	2-R:, ICARDA-99, 63, 83, 84, 59, 15\07-7 (Syria), Kaisar, Inkar, Granal 447, Rikotense, 13\06-16K, ,9\06-52K, 9\06-53K, 23\99-4, 38\86-9, (Kazakhstan),6-R: ICARDA-6, 5, 68, 40, 75, 10, ICARDA-32, ICARDA-24, ICARDA-51, 8\48-01 (Syria),Altyn Arai, 13\06-118К, (Kazakhstan)
The number of grains per ear (more than 24.0 pcs.)	2-R: ICARDA13,99,63, 54 (Syria), Granal 447, Tulpar, Shahristan,2\78-6К, 1\08-11K, 9\06-6K, 9\06\-55K, 28\98-3, 44\00-14, 60\85-9, 93\80-34 (Kazakhstan),2586 (USA), Nutans 58 (Russia),6-R: ICARDA-4, 25, 9, 140, 57, 73, 75, 10, 24, 64, 26, 152, 137, 76, 5-146, 12\29-01(Syria), Bi-11 (Iran), 2613 (USA), 13\06-185K, 8\87-01, 2\07-10K, 13\06-147K, 13\06-185K (Kazakhstan)
Weight of 1000 grains (over 45 g)	2-R: ICARDA-67, ICARDA-59, 15/07-7, 20/85-20 (Syria), Inkar, Kaisar, 9/06-45K, 13/06-161K, 26/86-5K, 13/06-16K, 31/86-22, 1/08-11K, 13/06-167K (Kazakhstan), 2586 (USA), $F_3$409-1 (Russia), Odessky 100 (Ukraine); 6-R: ICARDA-140, ICARDA-75, ICARDA-10, ICARDA-32, ICARDA-142, 12/29-01, 5-146, 12/28-01 (Syria), Bi-11 (Iran), Altyn Arai, 2/07-10K, 13/06-185K, 13/06-133K (Kazakhstan), E-812, I342, I643, PI082 (Japan)
Productivity (more than 420 g m^{-2})	2-R: ICARDA-65, 67, 84, 15/07-7 (Syria), Inkar, Kaisar, Shahristan, Pastbischny, Hulless, 27/83-14L, Granal 447, 23/99-4L, 9/06-45K, 13/06-161K, 26/86-5K, 13/06-16K (Kazakhstan), 2586 (USA); 6-R: ICARDA-24, ICARDA-64, ICARDA-104, ICARDA-51, 8/48-01, 5-115, 5-146 (Syria), I643 (Japan), BI – 11 (Iran), 2613 (USA), Altyn Arai, Rikotense, 2/07-10K, 13/06-185K, 13/06-133K, 13/06-116K, (Kazakhstan)
By a set of signs	2-R: ICARDA-29, ICARDA-52, ICARDA-67, ICARDA-59, 15/07-7, 20/85-20 (Syria), Inkar, Kaisar, Pastbischny, 27/83-14L, Granal 447, 23/99-4L, 9/06-45K, 13/06-161K, 26/86-5K, 13/06-16K, 31/86-22, 1/08-11K, 13/06-167K (Kazakhstan), 2586 (USA), $F_3$409-1, Nutans 58 (Russia), Odessky 100, Donetsky 8, Kharkovsky 54 (Ukraine); 6-R: ICARDA-140, ICARDA-75, ICARDA-10, ICARDA-32, ICARDA-142, 12/29-01, 5-146, 12/28-01, 12/29-01 (Syria), I643, PI082 (Japan), Bi-11 (Iran), 2613 (USA), Altyn Arai, 2/07-10K, 13/06-185K, 13/06-133K (Kazakhstan)

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Skrining novih izvora gena *Hordeum vulgare* za adaptivno oplemenjivanje u bazenu Aralskog mora, u Kazahstanu radi diverzifikacije poljoprivrede

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Izvod

Specifičnost zemljišta i klimatskih uslova regiona Aralskog mora, Kazahstan, prvenstveno povezanih sa salinizacijom, raznim vrstama suša, neravnomernom raspodelom padavina tokom vegetacije i kasnim prolećnim mrazevima, nameću potrebu za stvaranje novih sorti useva otpornih na biotičke i abiotčke faktore životne sredine. S tim u vezi, širenje površine pod usevima netradicionalnih useva žitarica tolerantnih na salinitet u regionu Kizilorda jedan je od glavnih pravaca povećanja održivosti poljoprivrede u regionu. Studije su pokazale da je među žitaricama koje se gaje u regionu, prolećni ječam (*Hordeum vulgare* L.) odgovarajuća kultura koja može maksimalno da iskoristiti bioklimatske resurse u regionu da bi stvorila održive prinose. Svrha ove studije je bila da se formira novi perspektivni izvorni materijal ječma zasnovan na sveobuhvatnom proučavanju sakupljenog materijala različitog ekološkog i geografskog porekla, primenom različitih metoda klasične selekcije. Na osnovu sveobuhvatne procene Kolekcije materijala ječma formirana je radna kolekcija od 250 sorti sa agronomskom otpornošću na faktore stresa u okruženju Aralskog mora. Selektovani uzorci se preporučuju za upotrebu u praktičnom oplemenjivanju radi povećanja adaptivnog potencijala savremenih sorti ječma.

Ključne reči: ječam, svetska kolekcija, faze razvoja biljaka, varijabilnost, oplemenjivanje, prinos

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