Bulgarian Journal of Agricultural Science, 25 (No 5) 2019, 986–993

Evaluation of salt tolerance of *Panicum miliaceum* L. collection at the germination stage in conditions of induced sodium chloride salinization

Aiman Rysbekova[1*], Elmira Dyussibayeva[1], Irina Zhirnova[1], Aiym Zhakenova[1], Abilbashar Seitkhozhayev[1], Carina Makhmudova[2], Svetla Yancheva[3], Nursaule Zhanbyrshina[1], Gulden Kipshakbayeva[1]

[1]*S. Seifullin Kazakh Agro-Technical University, Agronomic Faculty, Department of Agriculture and Plant Growing, 010011 Nur-Sultan, Republic of Kazakhstan*
[2]*Knowledge Partners Limited Liability Partnership (LLP), 050059 Almaty, Republic of Kazakhstan*
[3]*Agricultural University – Plovdiv, 4000 Plovdiv, Bulgaria*
[*]*Corresponding author:* aiman_rb@mail.ru

Abstract

Rysbekova, A., Dyussibayeva, E., Zhirnova, I., Zhakenova, A., Seitkhozhayev, A., Makhmudova, C., Yancheva, S., Zhanbyrshina, N., & Kipshakbayeva, G. (2019). Evaluation of salt tolerance of *Panicum miliaceum* L. collection at the germination stage in conditions of induced sodium chloride salinization. *Bulgarian Journal of Agricultural Science, 25*(5), 986–993

Present work evaluates the salt *tolerance* of 29 domestic and foreign samples of millet (*Panicum miliaceum* L.) for identification of valuable genotypes for further use in the breeding programs. The study aimed to estimate the salt tolerance by screening the collection of millet samples at the germination stage of ontogenesis based on the changes of morphometric indicators for forecasting the reaction of genotypes to salinization. The salt stress inhibited the growth of sprouts and roots of millet samples. Unequal effect of salt stress onto the length of sprouts and roots of seedlings was noted. The samples Aktyubinskoye kormovoye, K-9681, Shortandinskoye-10, and Yarkoye-7 demonstrated an insignificant decrease of sprouts length in comparison with the control. The cultivar Saratovskoye-6 (standard) showed about a 50% decrease of sprouts length at 75 and 100 mm of NaCl, and to 70% decrease at 150 mm of NaCl. At all salinity concentrations, the smallest length of germinal roots of 7-day seedlings was noted at samples Yarkoye-5 and Pavlodarskoye and the greatest length of sprouts at samples K-9681, Yarkoye-5, Pavlodarskoye, Shortandinskoye-10 and Aktyubinskoye kormovoye.

Keywords: salt tolerance; sodium chloride; salinization; *Panicum miliaceum*

Introduction

Abiotic stress and, particularly, salinization essentially reduces crops' productivity around the world. About 25% of soils on the Earth contain an excess of salts. It is known that soil salinity causes a significant loss to agriculture (Mujeeb-Kazi & De Leon, 2002).

The areas of the salted lands tend to continuous and significant increase as a result of processes of secondary salinization which annually brings an excessive loss to many branches of crop production and limits expansion of the areas under various crops in droughty areas (Udovenko, 1977; Kovrigina et al., 2006). According to the data provided by Szabolcs (1989), the total area of the salted soils in the world occupies more than 950 million ha (Pankova, 2006). In the Republic of Kazakhstan, 35.3 million ha of the soil are salted, and it is 16.4% of the total area of agricultural lands. The negative influence of salinization is expressed in the deterioration of various properties and functions of plants that as a result, leads to a decrease in their efficiency. Annually the loss of productivity at weak salinization is about 20%, and in strongly salted lands losses reach 70-80% (Munns & Tester, 2008).

For assessment of plant salt tolerance, indicators of biological and agronomical salt tolerance are used. Biological salt tolerance is the limit of salinization when plants are capable of completing its ontogenetic cycle and of reproducing viable germinating seeds. It is salt tolerance of a plant, and its quantitative expression is the concentration of soil solution, which is critical for the given species. Agronomical salt tolerance reflects the extent of decrease in plants' harvest under the influence of salinization (at its certain level) in comparison with the efficiency of the same cultivar without salinization (Koshkin, 2010).

It is known that plants are most sensitive to salinity effect at a juvenile stage of development. During the shoot appearing as in stress conditions, first of all, those metabolism links are damaged, which are connected with processes of active growth. It is possible to predict the reaction of plant growth onto salinization at the stage of seed germination (Cuartero et al., 2006). Moreover, because of the considerable heterogeneity of the salted soils, screening for tolerance to salinization in field conditions is inefficient and practically impossible; therefore, such research has to be carried out in controlled laboratory conditions. In this regard, almost all investigations of salt tolerance at different crops were carried out at the stage of seed germination (Meneguzzo et al., 2000; Sabir & Ashraf, 2008; Farhoudi & Motamedi, 2010; Mohammadizad et al., 2013; Ardie et al., 2015; Ajithkumar & Ibadapbiangshylla, 2017; Batayeva et al., 2017).

Proso millet or millet (*Panicum milliaceum* L.) is a valuable culture of the genus *Panicum,* which includes more than 400 species (Roshevits, 1980). Millet has food, fodder, and reserve strategic importance, and it is cultivated in 30 countries of the world, including 18 European countries. The leading producers of millet are five countries, such as the Russian Federation, India, China, USA, and Ukraine (Zotikov et al., 2012; Sidorenko & Gurinovich, 2015). According to the classification of plant salt tolerance developed by All-Russian Research Institute of Plant Industry (ARIPI), the millet belongs to the group of plants with weak tolerance to salinity. As a criterion for evaluation of the degree of plants' salt tolerance, various indicators are possible to use such as biomass of seedlings, seed germinating, ability to grow at a certain salinization level (Drahavtsev et al., 1995). The critical direction to solve the problem is the creation of tolerant of salinization cultivars, which is connected with the search for useful sources and donors of this trait. For that reason, reliable evaluation of its expression, especially at early stages of ontogenesis is necessary (Kurkiev et al., 2010; 2013). This research is directed to the evaluation of salt tolerance by screening the collection of samples of Millet at the early stage of ontogenesis based on changes of morphometric indicators for forecasting the reaction of genotypes for salinization and identification of tolerant forms with their subsequent use in breeding programs.

Material and Methods

Plant material

Objects of the research were cultivars and samples of millet of local and foreign selection. Totally 29 genotypes (Table 1) were analysed. The zoned cultivar Saratovskoye-6 was taken as a standard (St).

Evaluation of salt tolerance of millet at the seeds germination phase

Screening the cultivars and samples of millet for salt tolerance was carried out in laboratory conditions using selected seeds in the phase of germination according to the method of Krishnamurthy et al. (2007). Before the experiment, the seeds of millet were sterilized with 90% alcohol within two minutes for surface disinfection of the harmful microflora and washed out two times with distilled water. Each sample consisted of 25 grains was placed for germination *in Petri dishes* on *filter paper (bilayer) moistened* with solutions of sodium chloride (NaCl) with different concentrations (75, 100 and 150 mM) and distilled water (control). Each variant was performed in three replications. Samples were cultivated into the climatic chamber (GC-1000 Growth Chamber) with

Table 1. Cultivars and samples of millet

Origin	Number of genotypes	Samples
Kazakhstan	17	Aktyubinskoye kormovoye, K-9681, K-10278, K-10279, K-3742, K-803, K-9539, K-9645, K-9842, Kokchetavskoye-66, Pavlodarskoye, Pamyati Bersiyeva, Shortandinskoye-10, Shortandinskoye-7, Yarkoye-5, Yarkoye-6, Yarkoye-7
Russian Federation	11	Barnaulskoye kormovoye, Zolotistoye kormovoye, K-3137, K-367, K-9520, K-9671, K-9989, K-10312, Kormovoye-89, Omskoye-11, Saratovskoye-6 (St)
Uzbekistan	1	K-1437

a constant temperature of 24±1°C for seven days. At day 7, the following indicators: viability of seeds and raw biomass of seedlings; number and length of roots and sprouts were determined. The salt tolerance degree in percentage was defined as a ratio of the average indicators as seed viability (%), the fresh mass of seedlings (mg), lengths of sprouts and roots (mm) in the experiment to the corresponding parameters of the control.

Results and Discussion

In this work, for the first time, screening for salt tolerance of the local and foreign genotypes of millet at the early phase of vegetation was carried out. The obtained results revealed the negative impact of salt solutions on germinating viability of seeds. In comparison with the control, the salinization by increased concentration of sodium chloride resulted in a decrease of the seed germinating viability in all samples. In the control samples, the seed germinating viability fluctuated from 40 to 90%; while in the experimental treatments, it was decline depending on the NaCl concentration respectively, as of 75mM – from 24 to 80%, at 100mM – from 16 to 78%, and at 150mM – from 8 to 76% (Table 2).

As shown in Table 2, the most decreased germinating viability of seeds in conditions of salinization was found at genotypes K-367, K-9989, Kormovoye-89, and K-9539. For example, the germinating viability of the seeds in the cultivar Kormovoye-89 decreased up to 58% at 75 mM NaCl, up to 64% at 100 mM, and up to 77% at 150 mM. The sample K-367 in conditions of salinization with 75,

Table 2. Seed germination (%) of 7-day seedlings of the millet collection at different concentrations of salinization

Samples	Seed germination (%)							
	0 mM NaCl		75 mM NaCl		100 mM NaCl		150 mM NaCl	
	M	SD	M	SD	M	SD	M	SD
Aktyubinskoye kormovoye	66	8.8	34	4.8	34	5.8	32	4.4
Barnaulskoye kormovoye	70	12.0	72	8.9	58	6.5	50	6.8
Zolotistoye kormovoye	72	9.1	40	4.7	40	5.7	36	9.1
K -9681	50	5.1	52	5.5	44	4.5	30	5.5
K-10278	55	3.4	53	6.8	52	6.3	52	5.6
K-10279	78	4.2	76	10.1	64	8.5	42	4.7
K-10312	75	8.4	72	8.8	70	9.7	66	10.0
K-1437	80	5.6	80	12.7	72	12.4	64	5.8
K-3137	65	5.2	60	11.2	36	8.7	46	4.7
K-367	80	4.5	24	5.5	16	5.1	16	4.1
K-3742	40	3.2	40	8.8	34	4.0	28	3.5
K-803	62	4.4	30	4.8	28	5.6	20	2.2
K-9520	66	12.1	56	3.2	50	8.0	44	5.4
K-9539	72	7.1	32	5.8	26	2.5	26	3.6
K-9645	60	10.2	50	6.1	46	8.3	42	5.2
K-9671	84	5.8	64	5.9	54	5.4	44	6.4
K-9842	80	8.7	72	6.7	46	5.4	30	4.2
K-9989	78	9.1	28	8.1	18	3.2	8	1.0
Kokchetavskoye-66	44	4.4	50	6.9	46	5.2	38	5.1
Kormovoye-89	84	15.4	36	8.1	32	5.1	20	1.1
Omskoye-11	82	12.5	80	5.6	78	8.0	76	2.4
Pavlodarskoye	78	9.1	46	8.8	32	5.1	26	5.8
Pamyati Bersiyeva	90	12.1	58	5.0	50	5.0	48	4.4
Saratovskoye-6 (St)	64	9.9	60	7.4	46	8.4	36	5.6
Shortandinskoye-10	64	9.1	58	5.9	54	3.5	54	5.2
Shortandinskoye-7	65	5.4	64	6.4	60	8.4	40	4.1
Yarkoye-5	60	9.2	45	5.2	43	3.8	37	5.3
Yarkoye-6	58	12.1	38	3.8	36	3.2	36	2.2
Yarkoye-7	90	8.4	54	8.1	42	2.5	34	3.8

Note: M – Mean; SD – Standard Deviation

100, and 150 mM concentrations demonstrated 56-64% decrease of the germinating viability in comparison with the control. The smallest decrease in the germinating viability at all concentration of salinization was demonstrated by the samples K-1437, Shortandinskoye-7, Shortandinskoye-10, Kokchetavskoye-66, Barnaulskoye kormovoye, K-3742, and K-10278.

The degree of salt tolerance of the studied samples was also estimated according to raw biomass of 7-day seedlings of millet at various salinization concentrations in comparison with the sprouts growing in the control conditions. Raw biomass of experimental plants in comparison with control decreased in average twice, except for some samples where this indicator was from 4 to 10 times lower (Table 3).

The strongest inhibition of raw biomass accumulation of seedlings at all concentration of NaCl was established at genotypes: K-9539, Omskoye-11, Yarkoye-6, K-10312, and Pavlodarskoye. The decrease of raw biomass (up to 10% about the control) was observed at sample K-9539 at 150 mM of NaCl.

The best accumulation of raw biomass at 75 mM of NaCl was demonstrated in genotypes Barnaulskoye kormovoye (96.9%), Shortandinskoye-7 (96.8%), Shortandinskoye-10 (91.7%), Saratovskoye-6 St (91.7%), K-9842 (91.7%), Zolotistoye kormovoye (91.7%), K-9520 (91.7%), Aktyubinskoye kormovoye (91.7%), K-9989 (90.7%), K-803 (88.8%) and Kokchetavskoye-66 (84.3%). At 100 mM of NaCl the highest accumulation of raw biomass was counted at genotypes: K-9842 (91%), K-9520 (91%), K1437 (90.4%), Shortandinskoye-7 (88.8%), Zolotistoye kormovoye (83.5%), K-9989

Table 3. Influence of salt stress on the accumulation of raw biomass of 7-day seedlings

Samples	Raw biomass (mg)							
	0 mM NaCl		75 mM NaCl		100 mM NaCl		150 mM NaCl	
	M	SD	M	SD	M	SD	M	SD
Aktyubinskoye kormovoye	1.34	0.30	1.23	0.09	1.04	0.05	0.74	0.02
Barnaulskoye kormovoye	1.32	0.21	1.28	0.10	1.04	0.09	0.94	0.03
Zolotistoye kormovoye	1.34	0.25	1.23	0.14	1.12	0.06	0.96	0.09
K -9681	1.23	0.09	0.94	0.07	0.84	0.02	0.6	0.04
K-10278	0.94	0.02	0.75	0.05	0.59	0.03	0.34	0.02
K-10279	0.81	0.01	0.64	0.02	0.57	0.02	0.53	0.02
K-10312	1.21	0.09	0.86	0.02	0.61	0.05	0.31	0.03
K-1437	1.25	0.09	1.21	0.11	1.13	0.09	0.83	0.05
K-3137	1.21	0.09	0.86	0.02	0.85	0.05	0.94	0.02
K-367	1.52	0.24	1.23	0.08	1.06	0.04	1.01	0.09
K-3742	1.21	0.05	0.86	0.02	0.85	0.07	0.75	0.04
K-803	1.32	0.08	1.17	0.08	1.02	0.02	0.89	0.03
K-9520	1.34	0.09	1.23	0.05	1.22	0.05	0.96	0.05
K-9539	1.32	0.21	0.54	0.03	0.25	0.01	0.13	0.02
K-9645	0.94	0.04	0.65	0.02	0.6	0.02	0.54	0.03
K-9671	1.56	0.12	1.07	0.04	0.94	0.09	0.84	0.03
K-9842	1.34	0.08	1.23	0.05	1.22	0.01	0.96	0.07
K-9989	1.52	0.11	1.38	0.05	1.26	0.02	1.21	0.02
Kokchetavskoye-66	1.34	0.12	1.13	0.07	1.03	0.09	0.96	0.05
Kormovoye-89	1.46	0.11	1.12	0.08	0.97	0.05	0.64	0.08
Omskoye-11	1.34	0.09	0.68	0.05	0.47	0.02	0.21	0.02
Pavlodarskoye	1.52	0.12	0.78	0.05	0.62	0.05	0.43	0.02
Pamyati Bersiyeva	1.56	0.09	1.12	0.08	0.97	0.08	0.82	0.03
Saratovskoye-6 (St)	1.34	0.17	1.23	0.01	1.1	0.09	0.96	0.02
Shortandinskoye-10	1.34	0.21	1.23	0.06	1.02	0.01	0.96	0.05
Shortandinskoye-7	1.25	0.12	1.21	0.09	1.11	0.09	0.83	0.02
Yarkoye-5	1.32	0.08	0.8	0.02	0.63	0.05	0.52	0.03
Yarkoye-6	1.32	0.05	0.57	0.03	0.41	0.04	0.24	0.02
Yarkoye-7	1.56	0.09	1.12	0.02	1.01	0.03	0.86	0.04

Note: M – Mean; SD – Standard Deviation

(82.8%), Saratovskoye-6 St (82%), Barnaulskoye kormovoye (78.7%), K-803 (77.6%), Aktyubinskoye kormovoye (77.6%), Kokchetavskoye-66 (76.8%) and Shortandinskoye-10 (76.1%). At 150 mM of NaCl the accumulation of raw biomass was in the genotypes respectively: K-9989 (79.6%), K-3137 (77.6%), Shortandinskoye-10 (71.6), Saratovskoye-6 St (71.6), Kokchetavskoye-66 (71.6), K-9842 (71.6%), K-9520 (71.6%), Zolotistoye kormovoye (71.6%), Barnaulskoye kormovoye (71.2%), K-803 (67.4%), K-367 (66.4%), Shortandinskoye-7 (66.4%) and K-1437 (66.4%). At high concentration of NaCl (150 mM), the samples K-9989 and K-3137 surpassed the standard cultivar Saratovskoye-6 in accumulation of raw biomass with 6 and 8% respectively. The genotypes Barnaulskoye kormovoye, Zolotistoye kormovoye, K-9520, K-9842, and Kokchetavskoye-66 demonstrated accumulation of raw biomass at the level of Saratovskoye-6 (St).

The stress caused by NaCl salinization (75, 100, and 150 mM) also inhibited the growth of sprouts and roots of the studied experimental samples of millet (Table 4).

Table 4. Alteration of morphometric indicators of 7-day sprouts of millet at various salinization concentrations by sodium chloride

Samples	NaCl concentrations (mM)															
	0				75				100				150			
	Shoot length, mm		Root length, mm		Shoot length, mm		Root length, mm		Shoot length, mm		Root length, mm		Shoot length, mm		Root length, mm	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Aktyubinskoye kormovoye	1.53	1.86	3.34	0.96	1.31	1.10	2.55	0.60	1.18	0.98	2.44	0.53	1.00	0.81	1.20	0.45
Barnaulskoye kormovoye	2.23	1.55	3.43	1.36	1.67	0.87	2.69	1.12	1.25	0.64	2.20	1.01	1.08	0.52	1.38	0.90
Zolotistoye kormovoye	2.80	1.60	3.41	1.54	2.04	1.19	2.34	1.20	1.84	0.93	1.54	1.01	1.23	0.83	1.27	0.92
K -9681	1.90	1.11	2.66	1.63	1.49	0.92	2.14	1.45	1.31	0.57	1.56	0.93	1.18	0.52	1.33	0.60
K-10278	3.57	1.48	3.8	1.26	2.25	0.98	2.43	1.02	1.52	0.63	1.56	0.72	1.08	0.51	1.26	0.53
K-10279	2.21	1.10	3.86	1.29	1.70	0.81	2.87	1.20	1.20	0.41	1.57	0.74	0.87	0.34	1.23	0.63
K-10312	2.53	1.71	3.62	1.74	1.75	0.95	2.86	1.44	1.23	0.56	1.61	1.27	1.14	0.39	1.31	1.23
K-1437	1.84	1.11	3.22	1.48	1.42	0.89	2.21	1.23	1.14	0.76	1.45	0.85	1.05	0.63	1.26	0.45
K-3137	2.12	1.40	4.05	1.63	1.50	0.94	3.19	1.47	1.38	0.66	2.57	1.50	1.10	0.31	1.51	1.01
K-367	2.99	1.66	3.22	1.74	1.40	0.91	2.70	1.48	1.21	0.63	2.04	1.43	1.00	0.51	1.17	1.16
K-3742	2.30	1.56	2.14	1.15	1.69	0.98	1.35	0.75	1.43	0.76	1.12	0.50	1.13	0.62	1.04	0.40
K-803	3.41	1.45	4.54	1.40	2.38	1.20	3.44	0.94	2.13	0.84	2.20	0.60	1.50	0.72	2.11	0.54
K-9520	1.95	1.25	2.75	1.45	1.57	0.76	1.32	1.38	1.14	0.67	1.22	0.81	0.72	0.43	1.18	0.45
K-9539	3.00	1.36	2.56	1.39	1.61	0.92	1.54	1.14	1.48	0.52	1.25	0.93	1.08	0.42	1.13	0.68
K-9645	3.83	1.59	4.36	1.70	2.06	1.22	2.43	1.30	1.75	0.91	2.07	0.90	1.11	0.50	1.54	0.50
K-9671	2.1	1.29	3.56	1.38	1.38	0.64	2.40	0.93	1.21	0.52	1.34	0.60	1.00	0.41	1.14	0.51
K-9842	1.76	1.21	3.70	1.70	1.18	0.91	3.13	1.37	1.11	0.82	2.85	0.85	0.95	0.34	1.18	0.65
K-9989	3.01	1.56	2.81	1.50	1.60	0.91	1.96	1.25	1.20	0.78	1.71	0.48	0.89	0.28	1.21	0.35
Kokchetavskoye 66	2.31	1.32	3.57	1.20	1.96	0.96	2.89	0.82	1.49	0.76	2.18	0.45	1.17	0.32	1.01	0.28
Kormovoye-89	2.42	1.93	3.53	1.55	1.84	1.21	2.84	1.21	1.25	0.92	2.61	0.93	1.07	0.45	1.64	0.78
Omskoye-11	1.86	1.13	3.33	1.21	1.57	0.83	2.90	1.10	1.24	0.65	1.54	0.91	1.13	0.62	1.21	0.61
Pavlodarskoye	1.60	1.04	4.10	1.33	1.43	0.70	3.36	1.10	1.21	0.55	2.60	0.71	1.00	0.50	1.03	0.63
Pamyati Bersiyeva	3.23	1.46	4.48	1.63	1.97	1.20	3.62	1.39	1.85	1.11	3.23	1.27	1.29	0.83	1.94	0.90
Saratovskoye-6 (St)	4.24	1.38	5.36	1.61	2.50	0.87	3.25	1.42	1.96	0.85	1.80	1.10	1.31	0.45	1.64	0.74
Shortandinskoye-10	1.60	1.10	4.32	1.27	1.45	0.74	2.26	1.01	1.23	0.62	1.80	0.82	1.02	0.51	1.31	0.51
Shortandinskoye-7	1.97	0.83	3.38	1.39	1.28	0.62	2.74	1.20	1.04	0.50	2.50	0.95	0.96	0.42	1.92	0.82
Yarkoye-5	2.42	1.34	5.37	1.64	2.19	0.90	3.36	1.40	1.69	0.62	2.73	0.84	1.08	0.36	1.50	0.74
Yarkoye-6	3.55	1.38	3.47	1.54	1.77	0.79	2.30	1.25	1.38	0.45	2.01	1.10	1.17	0.32	1.29	0.90
Yarkoye-7	1.99	1.30	4.10	1.50	1.58	0.91	3.12	1.25	1.30	0.74	2.01	0.90	1.11	0.52	1.86	0.51

Note: M – Mean; SD – Standard Deviation

The studied samples demonstrated an unequal average value of sprouts' length of 7-day seedlings in comparison with control variant. At 75 mM of NaCl, Aktyubinskoye kormovoye, K-9681, Shortandinskoye-10, and Yarkoye-7 showed a slight decrease of sprouts' length. At the cultivar Saratovskoye-6 (St) this indicator decreased to 50% (at 75 and 100 mM NaCl), and to 70% – at 150 mM NaCl. Regarding the length of germinal roots of 7-day seedlings, cultivars Yarkoye-5 and Pavlodarskoye were more sensitive among the studied genotypes at all levels of salinization. The best values of sprouts' length at all levels of salinization were noted at samples: K-9681, Yarkoye-5, Pavlodarskoye, Shortandinskoye-10, and Aktyubinskoye kormovoye. The unequal seedlings reaction in the growth parameters of roots, over-ground part, and accumulation of raw biomass could be explained with various mechanisms of salt tolerance taking place at the studied samples.

The reason for the suppression of seedlings growth in saline substrates is sharp inhibition of their metabolic processes caused by the increased accumulation of salt ions in cells (Watson & Witts, 1959; Dzhanibekova, 1972). Further increase of salt concentration suppresses growth processes, up to plant death (Ashraf & Parveen, 2002; Veselov et al., 2007). It indicates the all-biological effect of growth inhibition at the increased salt concentration in the environment. The higher the level of the saline substrate, the stronger growth inhibition that leads to a noticeable decrease of all parameters characterizing growth processes (Ozernyuk, 1992; Udovenko, 1995). The present experiment confirmed such dependence. The increase of environment salinity (up to 150 mM NaCl) led to a significant decrease in germinating viability of seeds of millet experimental samples (Fig. 1).

A similar trend was also demonstrated by the data about the raw biomass of millet seedlings from the collection (Fig. 2).

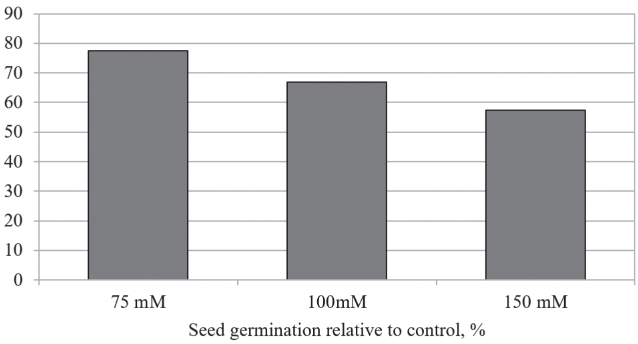

Fig. 1. Inhibition of seed germination from the collection of millet depending on the NaCl concentration

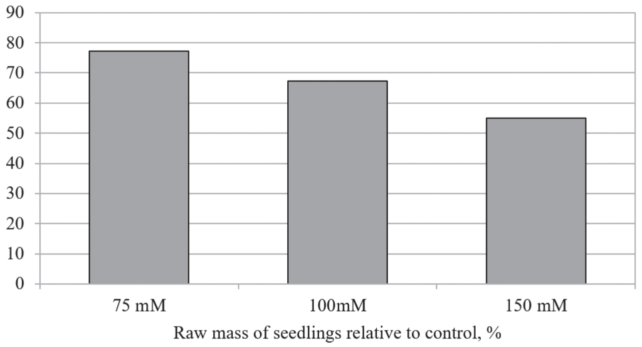

Fig. 2. Accumulation of raw biomass of the millet collection depending on the NaCl concentration

Data of fresh weight (FW) of millet plantlets showed that relative to control, salt stress caused a decrease of this indicator to 77.21% at 75 mM NaCl; 67.22% at 100 mM NaCl, and 54.91% at 150 mM NaCl, respectively. Salinization also led to the reduction of the development shown by the decrease in the growth parameters such as length of sprouts and roots of 7-day seedlings (Fig. 3).

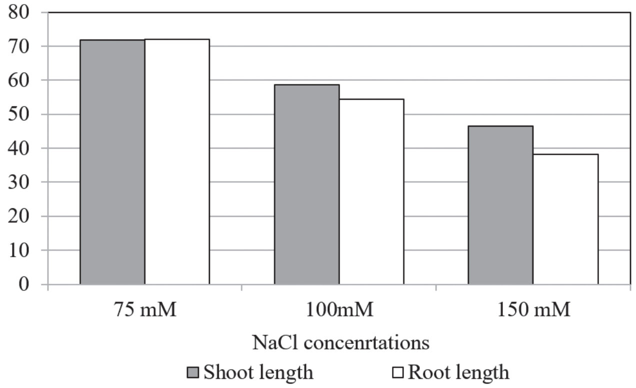

Fig. 3. Salt stress influence onto growth parameters of millet seedlings concerning control, (%)

As a result, an average value of sprouts' and roots' length at 75 mM of NaCl was in limits of 71.9%, at 100 mM – 58% and 54%, at 150 mM – 46% and 38%, respectively.

Several hypotheses are explaining the suppression of growth and development of plants in salinization conditions as this phenomenon is caused by the osmotic influence of salt solutions, and the plant inhibition is a consequence of the toxic impact of the absorbed ions on physiology-biochemical processes. However, in salinization conditions, the plant is affected by two factors both osmotic and toxic, but the influence of each of them is defined by quality and degree of salinization and also by the norm of reaction of a plant to salt stress (Stroganov, 1962; Zhu, 2002; Donaldson et al., 2004; Colmenero-Flores et al., 2007; Gao et al., 2007; Flowers & Colmer, 2015; Chakraborty et al., 2016)

Conclusions

Analysis of the obtained data demonstrated the inhibiting effect of salinization on all morphometric traits (seed germination, raw biomass, length of sprouts and roots of seedlings) used for the evaluation of salt tolerance of millet (*Panicum miliaceum* L.). As a result of the laboratory screening among 29 genotypes, tolerance to sodium chloride salinization at a juvenile stage of development demonstrated K-9989, K-3137, Barnaulskoye kormovoye, Zolotistoye kormovoye, K-9520, K-9842, and Kokchetavskoye-66, which accumulated the maximum amount of raw biomass in percentage. The samples K-1437, Shortandinskoye-7, Shortandinskoye-10, Kokchetavskoye-66, Barnaulskoye kormovoye, K-3742, and K-10278 were characterized by high germinating viability at the studied salinization levels. These genotypes as the most adaptive were selected as valuable initial material for inclusion in breeding programs aiming to create more salt tolerant forms, and as a perspective for cultivation on the saline soils.

References

Ajithkumar, P., & Ibadapbiangshylla, I. (2017). Morphological and biochemical response to salinity stress on *Setaria italica* seedlings. *Journal of Applied and Advanced Research*, *2*(4), 235-248.

Ardie, S. W., Khumaida, N., Nur, A., & Fauziah, N. (2015). Early Identification of Salt Tolerant Foxtail Millet (*Setaria italica* L. Beauv). *Procedia Food Science*, *3*, 303-312.

Ashraf, M., & Parveen, N. (2002). Photosynthetic parameters at the vegetative stage and during grain development of two hexaploid wheat cultivars differing in salt tolerance. *Biol. Plant*, *45*(3), 401-407.

Batayeva, D. S., Ussenbekov, B. N., Rysbekova, A. B., Mukhina, Z. M., Kazkeyev, D. T., Zhanbyrbaev, Y. A., & Sartbayeva, I. A. (2017). Estimation and selection of parental forms for breeding Kazakhstan salt tolerant rice varieties. *Selskokhozyaistvennaya Biologiya*, *52*(3), 544-552.

Chakraborty, K., Bose, J., Shabala, L., Eyles, A., & Shabala S. (2016). Evaluating relative contribution of osmotolerance and tissue tolerance mechanisms toward salinity stress tolerance in three *Brassica Species*. *Physiol. Plant, 158*, 135-151. doi: 10.1111/ppl.12447.

Colmenero-Flores, J. M., Martinez, G., Gamba, G., Vázquez, N., Iglesias, D. J., Brumós, J., & Talon, M. (2007). Identification and functional characterization of cation chloride cotransporters in plants. *Plant J., 50*, 278-292. doi: 10.1111/j.1365-313X.2007.03048.x

Cuartero, J., Bolarín, M. C., Asíns, M. J., & Moreno, V. (2006). Increasing salt tolerance in the tomato. *J Exp Bot, 57*, 1045-1058.

Donaldson, L., Ludidi, N., Knight, M. R., Gehring, C., & Denby, K. (2004). Salt and osmotic stress cause rapid increases in *Arabidopsis thaliana* cGMP levels. *FEBS Lett., 569*, 317-320. doi: 10.1016/j.febslet.2004.06.016.

Drahavtsev, V. A., Udovenko, G. V., & Batygin, N. F. (1995). Physiological basis of plant breeding. VIR, St. Petersburg.

Dzhanibekova, L. S. (1972). Physiological features of germination of seeds of cultivated plants during salinization. Abstract. Dissertation, Rostov-N/D, RSU.

Farhoudi, R., & Motamedi, M. (2010). Effect of salt stress and seed size on germination and early seedling growth of safflower (*Carthamus tinctorius* L.). *Seed Sci Technol, 38*, 73-78.

Flowers, T. J., & Colmer, T. D. (2015). Plant salt tolerance: adaptations in halophytes. *Annu. Bot., 115*, 327-331. doi: 10.1093/aob/mcu267.

Gao, J. P., Chao, D. Y., & Lin, H. X. (2007). Understanding abiotic stress tolerance mechanisms: recent studies on stress response in rice. *J. Integ. Plant Biol., 49*, 742-750. doi: 10.1111/j.1744-7909.2007.00495.x.

Koshkin, E. I. (2010). Physiology of crop stability: a textbook. Drofa, Moscow. ISBN 978-5-358-07798-0.

Kovrigina, L. V., Zaushintseva, A. B., & Petunkin, J. (2006). Comparative assessment of salt tolerance of barley varieties in the laboratory. *Proceedings on Applied Botany, Genetics and Breeding*, *162*, 44-48.

Krishnamurthy, L., Serraj, R., Rai, K. N., Hash, C. T., & Dakheel, A. J. (2007). Identification of pearl millet [*Pennisetum glaucum* (L.) R. Br.] lines tolerant to soil salinity. *Euphytica*, *158*, 179-188.

Kurkiev, M. D., Dibirov, D. M., & Anatov, M. A. (2010). The effect of salinization on the productivity of hexaploid triticale varieties. *Proceedings of the DGPU, 4,* 54-59.

Kurkiev, K. U., Magomedov, A. M., Kurkiev, M. A., Gadzhimagomedova, M. K., & Magomedova A. A. (2013). Agroecological study of wheat varieties and triticale in the Republic of Dagestan. *Problems of Development of the Agro-industrial Complex of the Region, 2*(14), 18-22.

Meneguzzo, S., Navari-Izzo, F., & Izzo, R. (2000). NaCl effects on water relations and accumulation of mineral nutrients in shoots, roots and cell sap of wheat seedlings. *J Plant Physiol, 156*, 711-716.

Mohammadizad, H., Khazaei, I., Ghafari, M., Fatehi Sinehsar, M., & Barzegar, R. (2013). Effect of Salt and Drought Stresses on Seed Germination and Early Seedling Growth of *Nepeta persica. International Journal of Farming and Allied Sciences*, *2*, 895-899.

Mujeeb-Kazi, A., & De Leon, J. L. D. (2002). Conventional and alien genetic diversity for salt tolerant wheats: focus on current status and new germplasm development. In: *Ahmad, R., Malik, K. A. (eds). Prospects for saline agriculture, Kluwer, Dordrecht,* 69-82.

Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. *Annu. Rev. Plant Biol*, *59*, 651-681.

Ozernyuk, N. D. (1992). Mechanisms of adaptation. Science, Moscow.

Pankova, E. I. (2006). Saline soils of Russia. Academkniga, Moscow.

Roshevits, R. Y. (1980). Grasses: An introduction to the study of fodder and cereal grasses. Indian National Scientific Doc. Center, New Delhi.

Sabir, P., & Ashraf, M. (2008). Inter-cultivar variation for salt tolerance in proso millet (*Panicum miliaceum* L.) at the germination stage *Pak. J. Bot*., *40*(2), 677-682.

Sidorenko, V. S., & Gurinovich, S. O. (2015). Selection of new varieties of proso millet for fodder production. *Selecciia and Usinnitstvo, 108*, 69-76.

Stroganov, B. P. (1962). Physiological basis of salt tolerance of plants. Publishing House of the Academy of Sciences of the USSR, Moscow.

Szabolcs, I. (1989). Salt affected soils. CRC-Press.

Udovenko, G. V. (1977). Salt tolerance of cultivated plants. Kolos, Moscow.

Udovenko, G. V. (1995). Plant tolerance to abiotic stresses. In: *Physiological Basis of Plant Breeding, VIR, St. Petersburg,* 293-346.

Veselov, D. S., Sharipova, G. V., & Kudoyarova, G. R. (2007). Comparative study of the reaction of barley plants (*Hordeum vulgare*) and wheat (*Triticum durum*) to the short-term and long-term effect of sodium chloride salinization. *Agrochemistry*, 41-48.

Watson, D. I., & Witts, K. I. (1959). The net assimilation rates of wild and cultivated beets. *Ann. Bot. N. S., 23*(91), 431-439.

Zhu, J. K. (2002). Salt and drought stress signal transduction in plants. *Annu. Rev. Plant Biol., 53*, 247-273. doi: 10.1146/annurev. arplant.53.091401.143329

Zotikov, V. I., Sidorenko, V. S., Bobkov, S. V., Kotlyar, A. I., & Gurinovich, S. O. (2012). Area and production of proso millet (*Panicum miliaceum* L.) in Russia. In: *Advances in Broomcorn Millet Research.* Proceedings of the 1st International Symposium on Broomcorn Millet, Northwest A&F University (NWSUAF), 25-31 August, Yangling, Shaanxi, PR of China, 3-9.

Received: January, 8, 2019; *Accepted:* August, 8, 2019; *Published:* October, 31, 2019