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Assessing salt tolerance of wheat hybrids based on yield indicators[i]

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Salinity reduces wheat yield by adversely affecting the main structural elements of the spike. In this study, the yield-related traits of 24 fourth-generation (F4) lines, developed through the crossbreeding of various genotypes, were evaluated under both non-saline and saline soil conditions. The primary objective was to identify salt-tolerant hybrid forms. Field experiments were conducted in 2022 on normal soils at the Karabakh Scientific **Research Base in the Tartar district and on saline soils at the Experimental Base of the Institute of Soil Science and Agrochemistry in the Ujar district. The results revealed that salinity significantly affected key yield components, including spike length, number of grains, and grain weight. Salt tolerance was assessed using the tolerance index, and hybrids with lower yield losses under salt stress were classified as relatively salt-tolerant. Among the studied hybrids, Gobustan × Sheki-1, Dagdash × Murov, Vugar × Barakatli-95, Qirmizi Gul-1 × Tale-38, Mirbashir-50 × Shiraslan-23, Barakatli-95 × Gobustan, Karabakh × Mirbashir-128, and Karabakh × Sharq demonstrated superior tolerance based on yield performance under saline conditions. These hybrids are considered promising candidates for cultivation in moderately saline soils and for incorporation into breeding programs aimed at improving salt tolerance in wheat.**

Keywords: *Wheat hybrid, cultivar, grain, non-saline, saline soils, breeding*

INTRODUCTION

One of the most important problems in the world is the lack of food, and more than one billion people in the world suffer from “chronic” hunger. Wheat (*Triticum aestivum* L., *T. turgidum* subsp. *durum* (Desf.) Husn., Syn.: *T.durum* Desf.) is one of the most important and cultured food crops of the Earth and forms the basis of the human diet (FAO, 2016). This crop, along with rice and maize are major cultivated cereal and is the main food source for nearly two billion people, more than 36% of the world's population (El-Sabagh et al., 2021). Especially, the salinization of the soil over time creates more serious dangers. The limitation of suitable and productive land areas for agriculture poses a serious threat to meeting people's food needs (Khan et al., 2010). Therefore, in order to solve these problems, it is necessary to effectively use the existing genetic biodiversity in the world, to search for and find new genetic sources, to involve wild ancestors, carriers of many positive traits in the process of new breeding, etc., extensive research is being carried out in these areas, and interspecific and intersexual hybridizations are used. In 2050, the world's population is expected to exceed nine billion, and the demand for wheat is expected to exceed 900 million tons (Alexandratos et al., 2011).

The creation of new varieties that are productive and resistant to stress by using sustainable plant genotypes as initial material is one of the most important problems facing modern science. Therefore, the study of physiological and biochemical processes in plant metabolism is of great scientific and practical importance (Mecliche and Hanifi, 2015). The

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detrimental effects of salinity on germination and early germination of crops are mainly due to osmotic stress, which inhibits water uptake, or specific ionic toxicity (Wakeel et al., 2011). However, different plant species may exhibit different responses to saline conditions (Mehmet et al., 2006).

MATERIALS AND METODS

Hybrids of the F4 generation were planted and cultivated on certain days corresponding to the sowing of October 2022, both at the normal (October, 2022) Karabakh Scientific Research Base of the Tartar district, and on the saline soil areas of the Base Practice Station of the Ujar district of the Institute of Soil Science and Agrochemistry (October, 2025). The object of the study was wheat hibrids (F4) cultivated in both normal (Tartar) and saline soil conditions (Ujar). The objects of the study were 24 hybrids, which are as follows:

1. Layagatli-80 × Mirbashir-128, 2. Gyzyl bugda × Guneshli, 3. Tartar × Karabakh, 4. Taleh-38 × Gyrmyzy Gul-1, 5. Gobustan × Sheki-1, 6. Murov x Dagdash, 7. Bezostaya-1 × Gyrmyzy Gul-1, 8. Dagdash × Murov, 9. Nurlu-99 × Lyagatli-80, 10. Garabagh × Qarakilchig-2, 11. Sheki-1 × Gobustan, 12. Vugar × Barakatli-95, 13. Gyrmyzy Gul-1 × Tale-38, 14. Berakatli-95 × Vugar, 15. Qarabagh × Tartar, 16.Aran × Gyrmyzy gul-1, 17. Mirbashir-50 × Shiraslan-23, 18. Qarabagh × Gobustan, 19. Barakatli-95 × Gobustan, 20. Gobustan × Gyrmyzy Gul-1, 21. Gobustan × Barakatli-95, 22. Gobustan × Qarabagh, 23. Qarabagh × Mirbashir-128, 24. Qarabagh × Sharq are hybrids. The salinity of the experimental soil is given in Table 1, and the soil salinization occurred mainly due to Cl^-, SO_4^{-2}, and HCO_3^-. These soils were classified as slightly saline. In these soils, the salt types were chlorinated, chloro-sulfated, and sulfate-chlorinated depending on the Cl^-/SO_4^{-2} ratio.

The sowing area of each line was 1-8 $m^{2,}$ depending on the seed material. The experimental area was plowed under the experimental field before sowing with 100 kg of physical weight of organic fertilizer per hectare, and in the early spring during the stem elongation, 90 kg of ammonium nitrate (NH_4NO_3) fertilizer was applied as an active substance per hectare. During the vegetation period, samples were irrigated at the stages of tube emergence (April 22), spike (May 19) and grain formation (June 08). Observations on plants and structural elements of the product were carried out in accordance with the existing methodology (Musayev et al., 2008). To determine the resistance of varieties to salinity stress, the stress tolerance index was used (Rosielle, Hambelen, 1981).

$$\boldsymbol{Tol = Yp\text{-}Ys}$$

here, *Tol* – resistance; *Yp* - productivity under normal conditions; *Ys* - productivity under saline conditions.

Statistical analyses: Graphical presentation of the data was carried out using the MS-Excel program and the standard error was calculated in the same way. The least significant difference (LSD) test was performed using STATISTIX 8.1 at a probability level of 0.05.

Table 1. The amount of salts in the soil (full water gravity analysis)

Layer depth	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na+k	Total salts (%)	Dry residue (%)
	mg. ekv (%)								
1,315/4sm	No	2.20 0.134	0.60 0.021	0.749 0.036	2.50 0.050	0.50 0.006	0.549 0.012	0.26	0.47
1,310/2 sm	No	2.60 0.159	0.60 0.021	0.249 0.012	2.25 0.045	0.003 0.949	0.949 0.022	0.26	0.43
1,330/1 sm	No	2.40 0.146	1.00 0.035	0.249 0.012	2.00 0.040	0.006 1.149	1.149 0.026	0.26	0.42
1,300/5 sm	No	1.60 0.098	0.80 0.028	1.748 0.087	2.75 0.055	0.006 0.898	0.898 0.020	0.29	0.37
1,010/3 sm	No	2.60 0.159	1.00 0.035	0.749 0.036	2.50 0.050	0.012 0.849	0.849 0.019	0.31	0.33

RESULTS AND DISCUSSION

One of the most useful indicators of wheat is grain yield and as it is well known, high salt concentration causes a decrease in grain yield. The decrease in grain yield under salinity conditions compared to plants under normal conditions was studied by applying the tolerance index formula. These indicators are reflected in the tables below (Table 2).

One of the main conditions is the study of yield losses (cob weight, grain weight and number of grains) as the main productivity indicator.

The wheat advanced lines showed differences in terms of spike weight, grain weight and grain number under normal and soil saline conditions. However, the zero percent yield loss was observed in the advanced line Murov x Dagdash, and the said genotype was found completely tolerant to salt stress with no yield loss. In other advanced lines, the yield losses were, Garabagh x Shark (3.2%), Barakatli-95 x Vugar (3.3%), Kyrmyzy gul-1xTale-38 (3.9%), Sheki-1 x Gobustan (4%), Tale-38 x Kyrmyzy gul-1 (4%), Garabagh x Mirbashir-128 (5.1%), Mirbashir-50 x Shiraslan-23 (5.6%), Leyagatli-80 x Mirbashir-128 (5.6%), Dagdash x Murov (6%), Garabagh x Tarter (7.9%), and Barakatli-95 x Gobustan (9%) were identified as long-lived hybrids with lower yield losses. These hybrids can be assessed as salt-resistant based on their yield indicator. The highest yield loss was observed in the hybrids Kyzyl bugda x Guneshli (32%), Karabakh x Gobustan (29.5%), Bezostaya x Kyrmyzy gul -1 (25%).

Table 2. Characteristics of yield elements of (F4) hybrids planted in normal soils of the Tartar region and saline soils of the Ujar region.

Hyibrids (F4)	Spike mass (g)		grain mass per spike (g)		Number of grains in ear	
	Tartar normal soil	Ujar saline soil	Tartar normal soil	Ujar saline soil	Tartar normal soil	Ujar saline soil
Layaqatli-80 × Mirbashir-128	4.54±0.17	4.49±0.14	4.22±0.54	4.02±0.74	61.00±1.26	59.00±1.28
Golden wheat × Gunashli	3.13±0.07	2.24±0.11	2.31±0.72	1.42±0.23	39.00±1.26	31.00±1.24
Tartar × Karabakh	4.13±0.17	3.57±0.13	3.21±0.24	1.97±0.11	60.00±1.15	54.00±1.14
Tale-38 × Gyrmyzy Gul-1	3.49±0.27	3.32±0.13	2.44±0.62	2.40±0.16	48.00±1.28	46.00±1.19
Gobustan × Sheki-1	2.62±0.24	2.45±0.23	2.18±0.14	2.04±0.13	39.00±0.8 2	34.00±0.72
Murov × Daghdash	3.45±0.21	2.78±0.11	3.14±0.62	2.16±0.15	48.00±1.17	40.00±1.17
Bezostaya-1 × Gyrmyzy Gul-1	2.42±0.12	1.78±0.17	2.25±0.11	2.05±0.02	55.00±0.54	42.00±0.33
Dagdash × Murov	3.65±0.17	3.63±0.21	3.99±0.12	3.73.±0.11	65.00±0.54	63.00±0.43
Nurlu-99 × Layaqatli-80	4.41±0.19	3.78±0.09	3.13±0.16	2.74±0.15	62.00±1.48	60.00±1.33
Karabakh × Karakilchik-2	1.81±0.12	1.26±0.12	1.51±0.32	1.12±0.35	18.00±2.15	11.00±2.03
Sheki-1 × Gobustan	2.71±0.14	2.11±0.23	1.83±0.19	1.45±0.19	43.00±0.92	32.00±0.82
Vuqar × Barakatli-95	5.60±0.54	5.15±0.56	4.91±0.12	4.32±0.18	64.00±1.66	63.00±1.86
Gyrmyzy Gul-1× Tale-38	3.33±0.17	3.10±0.23	2.52±0.31	2.22±0.12	53.00±2.62	50.00±2.68
Barakatli-95 × Vuqar	4.64±0.21	4.62±0.20	4.26±0.16	4.24±0.12	66.00±0.22	64.00±0.42
Karabakh × Tartar	4.32±0.22	4.30±0.22	3.52±0.14	2.53±0.14	55.00±1.53	51.00±1.63
Aran × Gyrmyzy Gul -1	2.26±0.14	1.92±0.18	1.84±0.21	1.35±0.22	53.00±0.72	42.00±0.75
Mirbashir-50 × Shiraslan-23	4.47±0.21	4.24±0.31	3.54±0.36	3.42±0.61	60.00±0.13	55.00±0.14
Karabakh × Gobustan	3.18±0.22	2.53±0.12	2.12±0.32	1.81±0.22	41.00±2.11	33.00±2.11
Gobustan × Barakatli-95	3.82±0.23	3.24±0.21	2.71±0.23	2.18±0.33	44.00±0.81	34.00±0.72
Gobustan × Gyrmyzy Gul-1	3.79±0.30	3.27±0.33	2.78±0.54	2.43±0.44	38.00±0.22	31.00±0.44
Barakatli-95 × Gobustan	4.28±0.16	3.62±0.27	3.12±0.04	3.10±0.02	44.00±2.23	38.00±2.51
Gobustan × Karabakh	3.32±0.24	3.13±0.23	2.82±0.41	1.34±0.51	45.00±0.42	33.00±0.44
Karabakh × Mirbashir-128	3.56±0.17	3.41±0.12	3.11±0.14	3.10±0.12	57.00±0.15	53.00±0.64
Karabakh × Shark	5.42±0.15	5.18±0.12	4.21±0.11	4.01±0.11	67.00±0.33	65.00±0.16

Table 3. Tolerance indices of yield elements of hybrids.

Hybrids	Spike mass (g)	grain mass per spike	Number of grains in spike	Grain yield loss (%)
Layaqatli-80 × Mirbashir-128	0.05	0.2	2	5.6
Golden wheat × Gunashli	0.89	0.89	8	32
Tartar × Karabakh	0.56	1.24	6	20
Tale-38 × Gyrmyzy Gul-1	0.17	0.04	2	4
Gobustan × Sheki-1	0.17	0.14	4	8
Murov × Daghdash	0.67	0.98	8	0
Bezostaya-1 × Gyrmyzy Gul-1	0.64	0.2	13	25
Dagdash × Murov	0.02	0.26	2	6
Nurlu-99 × Layaqatli-80	0.63	0.39	4	27
Karabakh × Karakilchik-2	0.55	0.39	7	36
Sheki-1 × Gobustan	0.61	0.38	11	4
Vuqar × Barakatli -95	0.45	0.59	1	5.3
Gyrmyzy Gul-1 × Tale-38	0.23	0.31	3	3.9
Barakatli-95 × Vuqar	0.02	0.02	2	3.3
Karabakh × Tartar	0.02	0.09	4	7.9
Aran × Gyrmyzy Gul-1	0.34	0.49	11	21.2
Mirbashir-50 × Shiraslan-23	0.23	0.12	5	5.6
Karabakh × Gobustan	0.65	0.31	8	29.5
Gobustan × Barakatli-95	0.58	0.53	10	19.1
Gobustanx × Gyrmyzy Gul-1	0.52	0.36	7	19.2
Barakatli-95 × Gobustan	0.66	0.02	6	9
Gobustan × Karabakh	0.19	1.51	12	21
Karabakh × Mirbashir-128	0.15	0.01	4	5.1
Karabakh × Shark	0.24	0.02	2	3.2

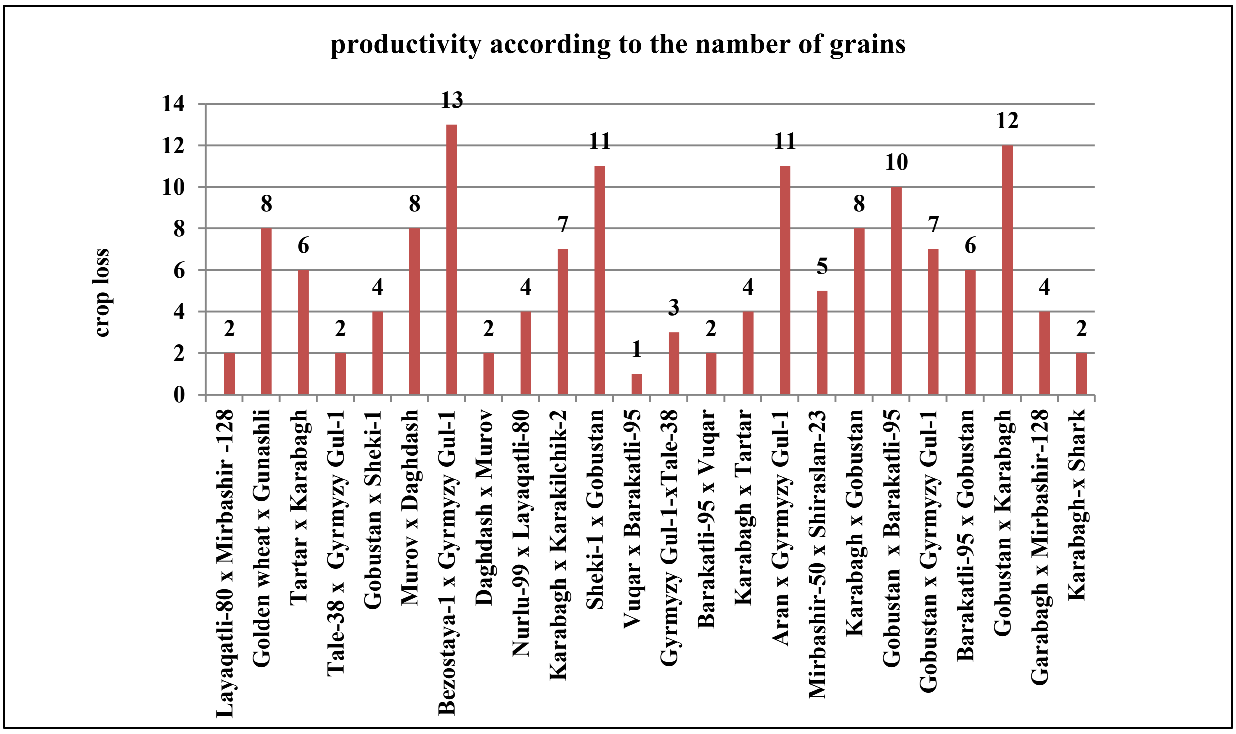

Fig. 1. Yield indicators of hybrids of F4 generations according to the tolerance index (by the number of grains).

The yield indicators of hybrids (Spike mass, grain mass per spike and grain number) are reflected in the table showing the salt tolerance index (Table 3).

Hybrid forms were studied comparatively according to the yield indicators of plants grown in both normal and saline conditions, namely spike weight, grain weight and grain number. First, the productivity of hybrids under normal stress conditions was studied, and then the resistance index was calculated. When comparing the hybrid forms, it is clear that some of the hybrids were exposed to relatively less yield loss due to the effects of salt. The studied indicators are reflected in the following table and histogram images (Figure 1)

As can be seen from Fig. 1, there are differences between hybrids. The least yield loss occurred in Layaqatli-80 × Mirbashir-128, Tale-38 × Gyrmyzy Gul-1, Dagdash × Murov, Gobustan × Sheki-1, Nurlu-99 × Layaqatli-80, Vugar × Barakatli-95, Karabakh × Mirbashir-128, Karabakh × Sharq hybrids showed more tolerance to. Therefore, these hybrids can be considered more tolerant than others.

A comparative study of the main productivity indicators of (F4) hybrids grown both in normal and saline conditions once again shows that some of the hybrids were tolerant to the effects of salt, with relatively less yield loss. However, it has been established that the effect of salt may be less at one stage of development and more at another. According to most authors, the stage when plants are most sensitive to salinity is the beginning of ontogenesis grains (Turki et al., 2012). The response of plants to stress factors is diverse and is a response provided by genetic material. Thus, genetic material regulates the rate and sequence of synthesis of the protein needed in stress conditions. A number of difficulties in the cultivation of salt-resistant forms are related to the complex and polygenic nature of genes for resistance to salt stress. In the process of evolution, protective mechanisms against environmental stress factors are formed in all organisms, including plants. Studies conducted to study genes that control resistance under salt stress conditions have shown that the expression of these genes is enhanced at high salt concentrations and ensures plant resistance (Garratt et al., 2002). Therefore, in order to solve these problems, extensive research is being conducted in the areas of efficient use of genetic biodiversity existing in the world, the search for new genetic sources, the involvement of wild ancestors, which are carriers of many positive traits, in the process of creating new varieties, etc., interspecific and intergeneric hybridizations are used. J.Aliyev and Z.Akperov have shown that many of the valuable folk selection samples created in Azerbaijan over a long historical period have been displaced by modern selection varieties (in some cases, genetically modified plants) and have been lost or are in danger of being lost. In order to eliminate this threat, targeted research work should be continued (Aliyev and Akperov, 2002). Currently, in our country, under the leadership of Academician J.A.Aliyev, high-level research is being conducted on salt tolerance on local and imported wheat varieties and varieties (Huseynova et al., 2008). Genotypes with a powerful genetic apparatus cope with this task and grow well in salt conditions. Therefore, when assessing resistance to stress factors, it is necessary to take into account the individual characteristics of each plant genotype (Khanishova et al., 2024).

Thus, based on the research work conducted in the world and in our country on salt tolerance, it can be concluded that it will indeed be possible to obtain salt-tolerant wheat varieties adapted to salinity in the future.

CONCLUSIONS

Salinity negatively affected the main structural elements of the spike, causing a decrease in yield. However, among the 24 hybrids studied, there are also lines with relatively low yields in terms of spike weight, grain weight and grain number. Thus, Gobustan × Sheki-1, Dagdash × Murov, Vugar × Barakatli-95, Qirmız Gül-1 × Tale-38, Mirbashir-50 × Shiraslan-23. Barakatli-95 × Gobustan, Karabakh × Mirbashir-128, Karabakh-× Sharq hybrids had higher salt tolerance and lower yield losses compared to other hybrids due to a decrease in grain weight and grain number in the spike.

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CONFLICT OF INTEREST

The authors declare no conflict of interest related to this study.

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