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Effect of Various Concentrations of NaCl on the Growth of Seedlings of Bread Wheat (*Triticum Aestivum* L.) Genotypes With Contrasting Productivity and Drought Tolerance

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The effect of various NaCl concentrations on germination ability and morphophysiological indices of bread wheat (*Triticum aestivum* L.) genotypes, which differ in productivity, drought tolerance and heights, has been studied. Wheat seeds were germinated at 0 mM, 150 mM and 200 mM concentrations of NaCl using the roll method. With increasing salt concentration retardation in the growth of shoots and root system was observed in all samples. Salt effects were found to be different in various genotypes. Maximum germination ability was detected in the bread wheat varieties 12nd FAWWON № 97, Daghdash-94 and Gyrmyzygul-1, treated with 200 mM NaCl. Only in the highly productive variety Gobustan and drought tolerant Pirshahin-1 germination energy was relatively lower (16%-17%) at 200 mM NaCl. There were no marked differences in the lengths of shoots and roots of the studied varieties. The Daghdash-94 variety was found to be the tallest among the studied varieties and the highest chlorophyll content was detected in Gyrmyzygul-1.

Keywords: *NaCl, wheat varieties, germination energy, germination percentage, chlorophyll*

INTRODUCTION

Soil salinization is one of the significant environmental factors that limit the growth, development and productivity of plants. Currently, about 20% of all irrigated areas of the world are saline (Minus and Richard, 2003). Salinity of soils constantly increases due to the rising groundwater level and improper irrigation in agriculture (Flowers, 2004).

Salinization of soil leads to water deficiency in the plant. Influencing the stomatal conductance of plants, water deficiency can affect the CO2 fixation rate and, consequently, the intensity of photosynthesis (Marler and Zozor, 1996). The decrease in the content of photosynthetic pigments-chlorophyll a and b, carotenoids, and in the activity of photosystems located in thylakoid membranes are assumed to relate to weakened assimilation of carbon dioxide ()Yordanov et al., 2000). Under salt stress the chlorophyll b content was found to decrease more than chlorophyll b content, regardless of the plant genotype. Salt stress, depending on the degree of plant tolerance, leads to a significant change in the activity of antioxidant systems of the cell (Atoyev et al., 2011, 2014; Klimova, 2013).

Salts have a double effect on the plant. First, they create a high osmotic pressure in the soil solution, providing a strong bond with water. This complicates water absorption by roots, causing osmotic stress. Second, ions of salt absorbed with water exert a negative impact on the plant metabolic processes (Minus and Termaat, 1986). Disturbance of growth and development of plants under salt stress is a consequence of some physiological responses of plants, including changes in the ion balance, mineral nutrition, stomatal conductance, photosynthesis rate and, ultimately, fixation and utilization of carbon dioxide (Bongi and Loreto, 1992).

Salinity is the major factor affecting plant metabolism, thereby causing changes in morphological, anatomical structure, physiological and biochemical conditions of plants. The first morphological response of plants to salt stress is the limitation in the development of roots and leaves. If salinity continues the plant development stops completely and eventually the plant perishes.

The study of salt effects on plant growth and development, evaluation of plant adaptation mechanisms to salt stress are very important issues for the effective use of saline soils. Adverse environmental conditions cause structural and functional changes affecting, first of all, vital activity of the organism (Aliyev et al., 2014). An active reconstruction of intracellular connections occurs under adverse ambient conditions. Moreover, negative conditions lead to pivotal changes in physiological and biochemical processes proceeding in plants. Therefore, the comprehensive study of these processes is necessary for the evaluation of plant stress tolerance.

Considering the above-mentioned issues, the main purpose of the presented work was the comparative study of salt tolerance of bread wheat genotypes with contrasting productivity, drought tolerance and height based on their morphophysiological indices and establishing changes in leaf water regime, amounts of photosynthetic pigments and PSII activity.

MATERIALS AND METHODS

The objects of the study were bread wheat (*Triticum aestivum* L.) genotypes: high productive Gobustan, low productive 12nd FAWWON № 97, drought tolerant Pirshahin-1 and drought sensitive Tale-38, tall Daghdash-94 and short Gyrmyzygul-1. For the assessment of the morphometric and physiological parameters of drought tolerance, seeds of bread wheat varieties were germinated at various NaCl concentrations (0 mM, 150 mM, 200 mM) using the roll method (Shikmuradov, 2011; Belozerova and Rome, 2014). Seeds of each sample were maintained on the wet filter paper for 3 days in darkness and then in a 12h-light/ 12h-dark photoperiod for 11 days at 20-22°C. Germination ability of the wheat embryo was examined during 7 days (Aliyev et al., 2014). Based on some morphophysiological indices such as average root length, RWC, concentration of photosynthetic pigments and chlorophyll fluorescence indices, salt tolerance of the studied varieties were assessed on the 10th day of the germination stage.

RWC in leaves was determined according to the method of Tambussi et al. (Tambussi et al., 2005). Chlorophyll was extracted from leaves using 96% ethyl alcohol and quantification of chlorophyll a, chlorophyll b and carotenoids was conducted at 665 nm, 649 nm and 440 nm, respectively, using the spectrophotometric method of Wintermans et al. (Gavrilenko and Zhigalova, 2003). Leaf fluorescence indices were measured using the MINI-PAM (photosynthesis yield analyzer, Germany) device. The energy conversion efficiency of PSII was calculated using the formulas $F_v = F_m – F_0$ and F_v / F_m (Maxwell and Jonson, 2000).

RESULTS AND DISCUSSION

In spite of the negative impact of salt, a development relative to control variants was observed for bread wheat (*Triticum aestivum* L.) genotypes with contrasting productivity, drought tolerance and height during 10 days (Figure 1, A, B and C).

Various physiological methods are known for the determination of plant stress tolerance, which based on germination ability (Aliyev et al., 2014). For the initial assessment of salt tolerance of bread wheat genotypes, germination ability of control and salt-treated variants was compared (Figure 2 A, B). As seen in the figure, a decreasing trend in germination ability was observed in the all wheat genotypes germinated at various salt concentrations. Germination ability of the studied varieties changed in the following ranges: 100% - 92% in the control variants, 100% - 75% at 150mM NaCl and 83% - 33% at 200mM NaCl.

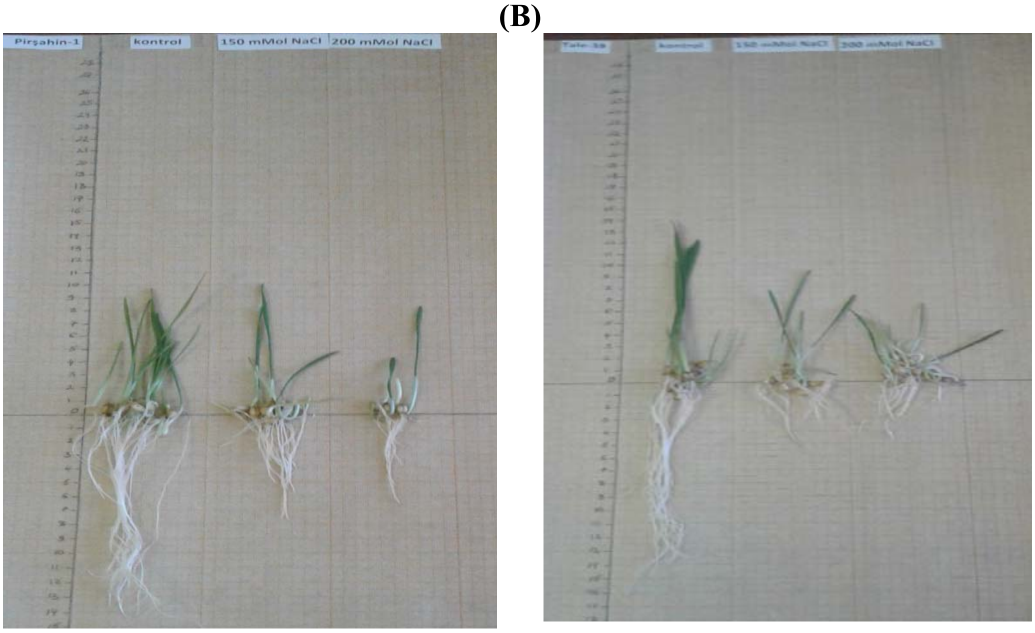
In 3-day-old wheat seedlings treated with NaCl, germination energy changed in the ranges: 92% - 58% in the control variants, 58%-33% at 150mM NaCl and 83%-33% at 200 mM NaCl. However, maximum germination percentage was observed in both variants of the all studied varieties. Maximum germination showed the varieties 12nd FAWWON № 97, Daghdash-94 and Gyrmyzygul-1. Germination energy was relatively low (16%-17%) only in high productive Gobustan and drought tolerant Pirshahin at 200 mM concentration of NaCl.

Seeds are known to experience high osmotic pressure of the environment during germination and certain physiological properties of plants are determined by absorption ability of seeds. Absorption ability of seeds facilitates the formation of a strong root system, which provides plant development under water deficiency.

The changes in the linear parameters of the growth process is a more reliable assessment of plant tolerance than seed germination indices. Therefore, during the initial stages of ontogenesis, the average length of roots and shoots of wheat genotypes grown at various concentrations of salt is of a great interest. Diagrams in Fig. 3 A, B present development indices (lengths of roots and shoots) of bread wheat varieties, grown at various concentrations of salt for 10 days. Thus, on the first 10 days the development of the studied wheat genotypes continued and then a decline relative to the control occurred. The development of roots and shoots of the all varieties was retarded as the concentration of NaCl increased. Thus, 2 times decline was observed in the length of shoots and 3-4 times decline in the length of roots relative to the control. The study of the effect of various NaCl concentrations on the growth of shoots and roots showed that, first of all, salt stress damaged the root system and then above ground organs of the plant. However, the varieties did not significantly differed in the lengths of roots and shoots (Figure 3 A, B). The variety Daghdash-94 was found to be tall in both variants.

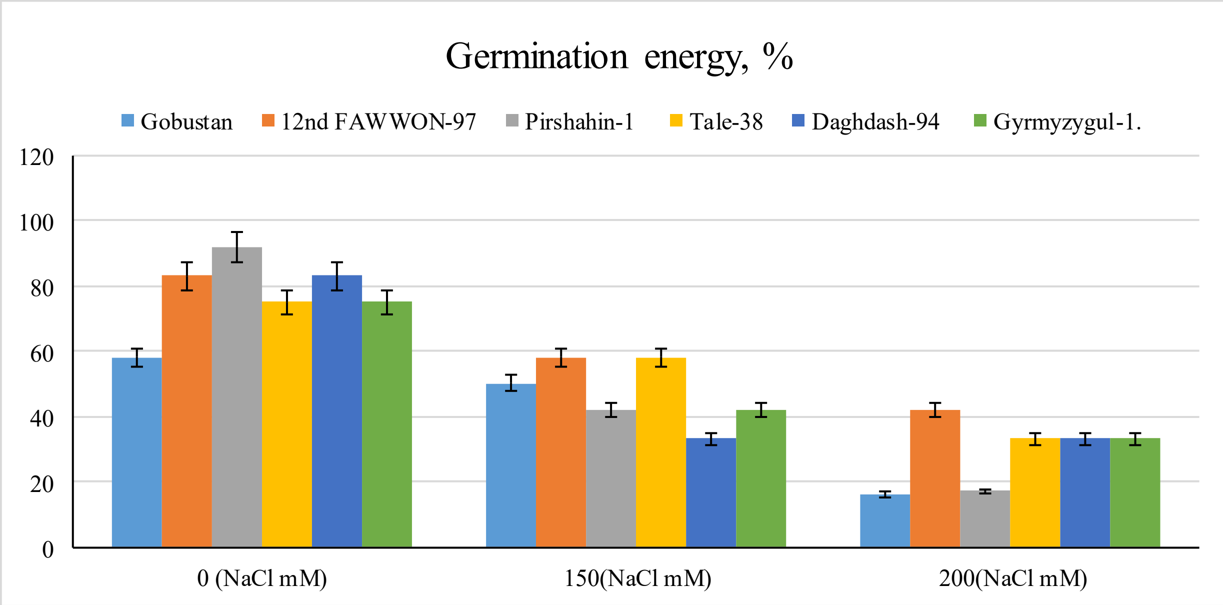
(A)

(B)

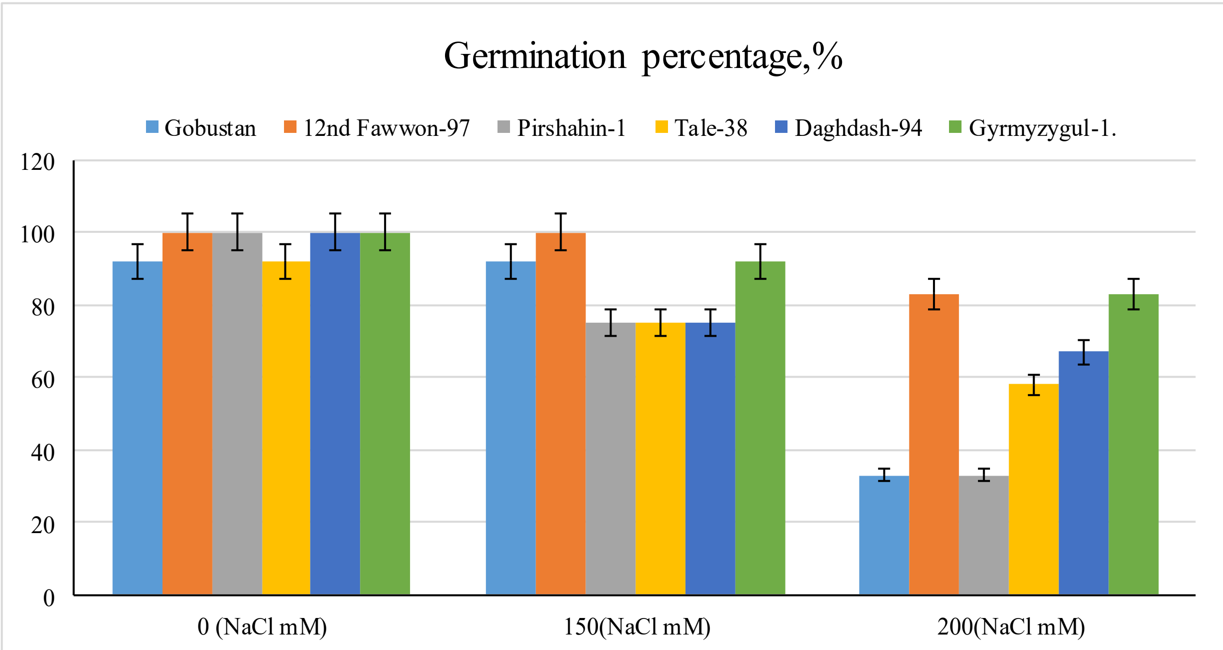


(C)

Fig. 1 (A, B, C). Development of 10-day-old seedlings of bread wheat genotypes (*Triticum aestivum* L.) with contrasting productivity (A), drought tolerance (B) and height (C) treated with different NaCl levels



(A)



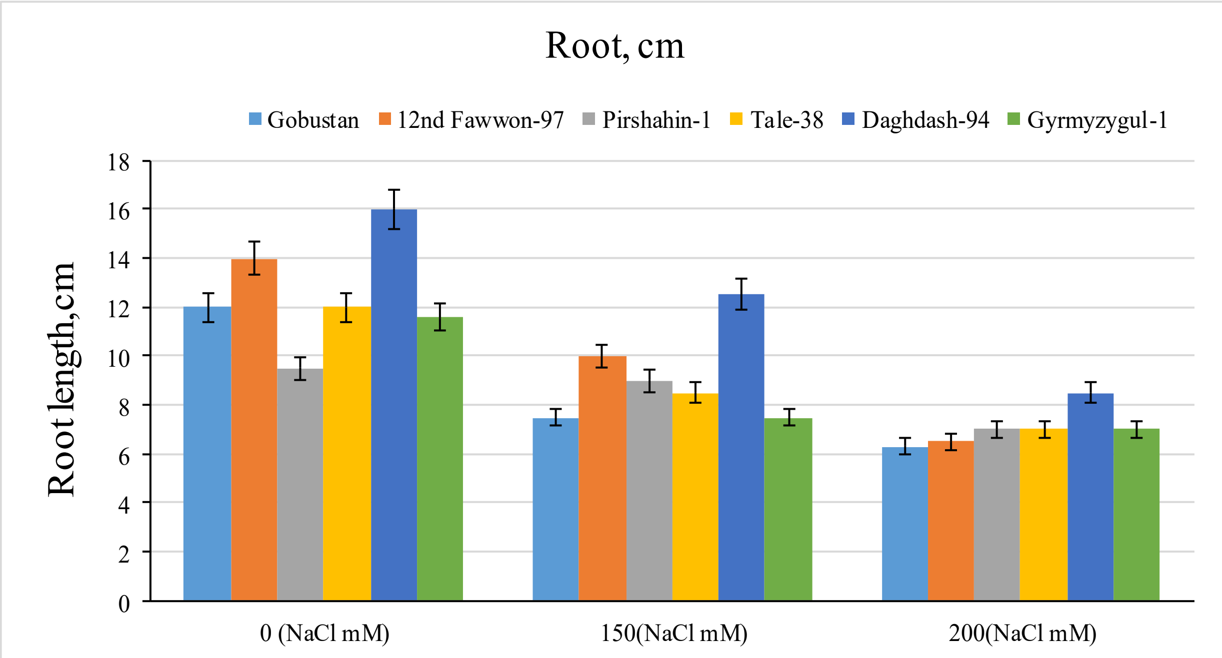
(B)

Fig. 2 (A, B). Effects of various NaCl levels on germination ability of bread wheat genotypes.
A - germination energy, B - germination percentage.

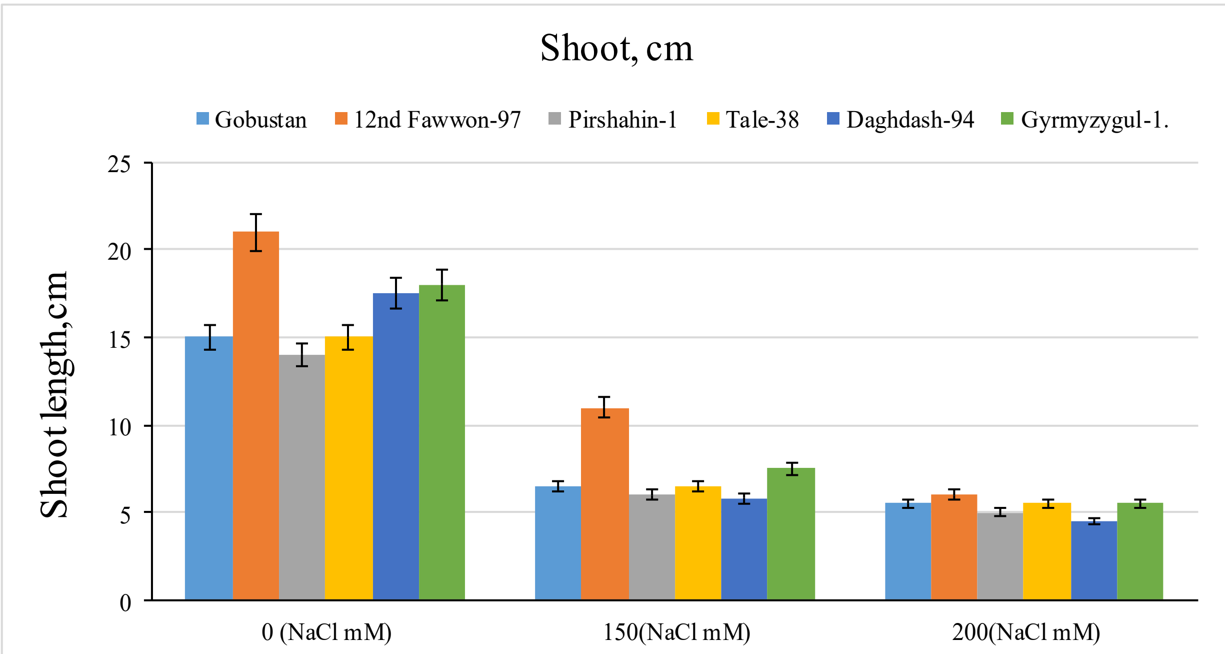
The effect of various salt concentrations on RWC of 10-day-old seedlings of bread wheat genotypes was studied (Figure 4). RWC was found to decrease significantly as salt concentration increased. As seen in the figure, RWC changed in the ranges 99% - 86%, 96% -79% and 94% -66% in the control variant, and at 150mM and 200mM concentrations of salt, respectively. However, there was no pronounced difference in the dynamics of the changes in RWC in the wheat varieties Daghdash-94 and Gyrmyzygul-1 depending on NaCl concentrations. A marked negative impact of 200mM NaCl was observed in the variety 12nd FAWWON № 97.

The content of leaf photosynthetic pigments was found to play a significant role in the function of photosynthetic apparatus and its productivity. A complex relation exists between photosynthetic productivity and amounts of the chlorophyll pigments. Salt stress disturbs chlorophyll structure and chloroplast membranes, leading to the violation of the structure and the decline in photochemical activity and light intake ability. Chlorophyll loses a part of its energy through the heat and fluorescence. But the energy waste increases due to the structural changes. Therefore, chlorophyll index is considered as the main parameter in experiments related to salinity (Aliyev et al., 2014). Chloroplasts of the sensitive plants are destructed more under salt stress and therefore, the study of salt effects on photosynthetic apparatus is of great importance for the assessment of plant tolerance to stress factors and its relation to physiological parameters.

The changes in the content of pigments provide an important information about physiological status and adaptation of plants to changing environmental conditions (Gang et al., 2010). The aim of our study was to evaluate the degree of stress effect based on the change in the pigment content of wheat leaves. According to the results of the experiments performed with leaves of 10-day-old seedlings of bread wheat varieties, the general amount of chlorophyll decreased with increasing salt concentration in the all varieties compared with the control. However, the highest chlorophyll content was observed in the variety Gyrmyzygul-1 (Table).



(A)



(B)

Fig. 3 (A, B). The length of 10-day-old seedlings of bread wheat genotypes treated with various NaCl concentrations.

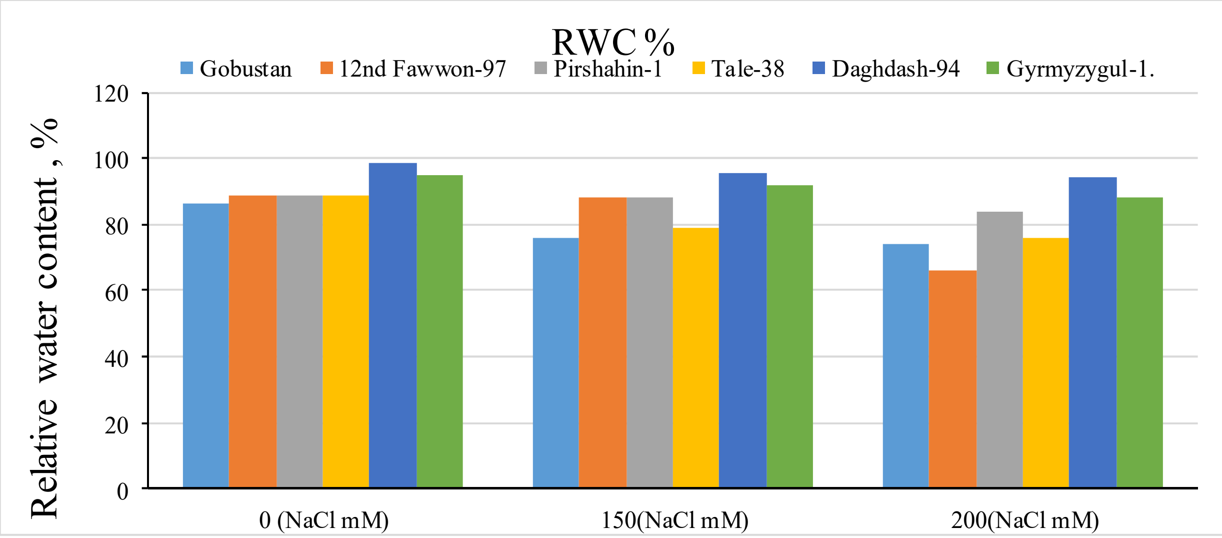


Fig. 4. RWC in 10-day-old leaves of bread wheat varieties treated with various NaCl concentrations.

Table. The influence of various NaCl concentrations on the content of chlorophyll and carotenoids (mg/g), and the energy conversion efficiency of PS II (Y).

№	Varieties	NaCl, mM	C_a	C_b	C_{a+b}	C_{kar}	Y
1	**Gobustan**	0	0.56	0.23	0.79	4.9	0.86
		150	0.55	0.23	0.78	4.6	0.84
		200	0.22	0.18	0.40	2.0	0.87
2	**12nd FAWWON** № 97	0	0.64	0.30	0.94	4.7	0.89
		150	0.42	0.27	0.69	4.5	0.90
		200	0.10	0.21	0.82	1.9	0.92
3	**Pirshahin-1**	0	0.67	0.46	1.13	4.2	0.79
		150	0.55	0.17	0.72	3.7	0.83
		200	0.54	0.15	0.69	1.6	0.83
4	**Tale-38**	0	0.61	0.23	0.84	4.8	0.81
		150	0.50	0.25	0.75	2.0	0.84
		200	0.25	0.11	0.36	1.7	0.81
5	**Daghdash-94**	0	1.12	0.38	1.50	4.8	0.82
		150	0.33	0.16	0.49	1.7	0.82
		200	0.24	0.27	0.51	1.0	0.73
6	**Gyrmyzygul-1**	0	1.16	0.58	1.74	2.2	0.81
		150	0.82	0.28	1.10	0.8	0.83
		200	0.72	0.21	0.93	0.4	0.83

As seen in the table, chlorophyll a+b and amounts of carotenoids decreased and a slight decrease occurred also in the energy conversion efficiency of PS II as salt concentration increased.

According to some authors, plants experience stress effects mainly due to the weakening function of the root system. Our results suggest that the manifestation of stress effects begins with the changes in seeds. The study of morphological and physiological effects of salinity would contribute to overcoming multiple issues related to negative effects of salt stress.

So salt stress was found to exert a negative impact on germination ability, leaf RWC, photosynthetic pigment amounts and PSII activity. The obtained results confirm that plant tolerance to stress conditions is a result of various adaptive responses.

Among the studied wheat genotypes 12nd FAWWON № 97, Daghdash-94 and Gyrmyzygul-1 were found to have high germination ability at 200 mM concentration of NaCl.

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NaCl Duzunun Müxtəlif Qatılıqlarının Məhsuldarlığına və Quraqlığa Davamlılığına Görə Fərqlənən Yumşaq Buğda Genotiplərinin (*Triticum Aestivum* L.) Cücərtilərinin İnkişafına Təsiri

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NaCl duzunun müxtəlif qatılıqlarının məhsuldarlığına, quraqlığa davamlılığına və boylarına görə fərqlənən yumşaq buğda genotiplərinin (*Triticum aestivum* L.) cücərmə qabiliyyətinə və cücərtilərin morfo-fizioloji göstəricilərinə təsiri öyrənilmişdir. Buğda toxumları NaCl duzunun 0, 150, 200 mM qatılılıqlı məhlullarında rulon metodu ilə cücərdilmişdir. Duzun qatılığı artdıqca bütün nümunələrdə cücərtilərin və kök sistemlərinin böyüməsində ləngimə müşahidə edilmişdir. Duzun müxtəlif qatılıqlarının ayrı-ayrı cortlara təsiri müxtəlif olmuşdur. Duzun 200 mM qatılığında isə maksimal cücərmə ilə fərqlənən sortlar 12nd FAWWON № 97, Dağdaş-94 və Qırmızıgül-1 yumşaq buğda sortları olmuşdur. Yalnız yüksək məhsuldar Qobustan və quraqlığa davamlı - Pirşahin-1 sortlarında NaCl-un 200mM qatılığinda cücərmə enerjisi nisbətən az (16% -17%) olmuşdur. Lakin köklərin və cücərtilərin uzunluguna görə sortlar arasında kəskin fərq müşahidə edilməmişdir Dagdaş-94 sortu bütün variantlarda hündürboylu sort olaraq özünü doğrultmuşdur. Qırmızıgül-1 sortu isə xlorofilin yüksək miqdarına malik olmaqla digər sortlardan fərqlənmişdir.

Açar sözlər: *NaCl, buğda sortları, cücərmə enerjisi, cücərmə faizi, xlorofil*

Влияние Различных Концентраций NaCl на Развитие Проростков Генотипов Мягкой Пшеницы (*Triticum Aestivum* L.) Отличающихся по Продуктивности и Засухоустойчивости

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Изучено влияние различных концентраций NaCl на способность к прорастанию и морфофизиологические параметры генотипов мягких пшеницы (*Triticum aestivum* L.), отличающихся друг от друга по росту, продуктивности и засухоустойчивости. Семена пшеницы выращивались по методу рулон в 0, 150, 200 мМ растворах NaCl. При увеличении концентрации соли у всех образцов наблюдалась задержка в росте проростков и корневой системы. Различные концентрации соли оказывали разное воздействие на изученные сорта пшеницы. При концентрации соли 200 мМ максимальное прорастание было обнаружено у сортов 12^{nd} FAWWON № 97, Дагдаш 94 и Гырмызыгюль 1. Только у продуктивного сорта Гобустан и засухоустойчивого Пиршахин энергия прорастания при концентрации 200мМ NaCl была относительно низкой (16% -17%). Однако, в длине корней и проростков не между сортами существенной разницы не наблюдалось. Во всех вариантах Дагдаш 94 оказался высокорослым. Гырмызыгюль 1отличался от других сортов по высокому содержанию хлорофилла.

Ключевые слова: *NaCl, сорта пшеницы, энергия прорастания, процент прорастания, хлорофилл*