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INFLUENCE OF SODIUM CHLORIDE ON MORPHOPHYSIOLOGICAL CHARACTERISTICS OF WHEAT AND MAIZE PLANTS

Aim. The effect of sodium chloride on the physiological and biochemical parameters of wheat and maize genotypes, the identification of salinity-resistant varieties was studied. Wheat and maize plants were grown in pots in the soil with the addition of 0.5 % sodium chloride. To create new salt-tolerant varieties of wheat and maize, a comparative analysis of the morphophysiological parameters plants was carried out. ***Methods***. Morphophysiological parameters such as growth, chlorophyll and carotenoid content, photochemical activty of chloroplasts and PSII activity have been studied in wheat and maize plant. ***Results.*** The effect of salt on the amount of chlorophyll *a*, chlorophyll *b*, and carotenoids, which are the main physiological indicators, is manifested in different ways in both plants. When studying salt-tolerance of plants, differences were detected in the relative amounts of chlorophyll (a+b), carotenoids, as well as the photochemical activity of chloroplasts and efficiency of PS 2. ***Conclusions.*** Among the varieties, according to all morphophysiological parameters, the most tolerant to the action of salt was the soft wheat variety Mirbashir-128, and the corn hybrid Belaya x Gurur.

Keywords: wheat, corn, salt, chlorophyll, chloroplast, photosystem 2, tolerance.

Salinity is one of the abiotic stress factors decreasing plant productivity. The salinization of soils over time is particularly dangerous. The limitation of agricultural and fertile lands is an obstacle to meeting the food requirements of the population [1].

In particular, the rapid growth of the population and the need in ensuring food security make more urgent the development of salt-tolerant varieties capable to grow in saline soils, and their extensive use.

According to rough estimates, 521,700 hectares of plains in the Azerbaijan Republic were in a saline state in [2]. In 2007, this parameter increased to 661.9 thousand hectares and accounted for 46.6 % of the land. One of the most effective measures taken to achieve high productivity under stress is the development of plants capable to adapt to salinity. The expression of genes regulating stress tolerance increases under high salt concentrations and ensures salt tolerance of plants [3].

Salts in the soil water may inhibit plant growth for two reasons. Firstly, the presence of salt in the soil solution reduces the ability of the plant to take up water and this leads to reductions in the growth rate. This is referred to as the osmotic or water-deficit effect of salinity. Secondly, if excessive amounts of salt enter the plant in the transpiration stream, there will be injury to cells in the transpiring leaves and this may cause further reductions in growth. This is called the salt specific or ion-excess effect of salinity [4]. These salinity effects has threefold effects viz. it reduces water potential and causes ion imbalance or distur bances in ion homeostasis and toxicity; this altered water status leads to initial growth reduction and limitation of plant productivity. The detrimental effect is observed at the whole plant level as death of plants or decrease in productivity. Salt stress affects all the major processes such as germination, growth, photosynthetic pigments and photosynthesis, water relation, nutrient imbalance, oxidative stress, and yield. These are discussed under separate headings.

One of the initial effects of salt stress is the reduction of growth rate. Salt in soil water inhibits plant growth for two reasons. First, it reduces the plant's ability to take up water and this leads to slower growth. This is the osmotic or water deficit effect of salinity. Second, it may enter the transpiration stream and eventually injure cells in the transpiring leaves, further reducing growth. This is the salt-specific or ion-excess effect of salinity. The two effects give rise to a two-phase growth response to salinity given by [4].

Phase 1: The first phase of the growth response results from the effect of salt outside the plant. The salt in the soil solution reduces leaf growth and to a lesser extent root growth. The cellular and metabolic processes involved are in common to drought-affected plants. Neither Na^+ nor Cl^-

builds up in growing tissues at concentrations that inhibit growth: meristematic tissues are fed largely in the phloem from which salt is effectively excluded, and rapidly elongating cells can accommodate the salt that arrives in the xylem within their expanding vacuoles.

Phase 2: The second phase of the growth response results from the toxic effect of salt inside the plant. The salt taken up by the plant concentrates in old leaves: continued transport into transpiring leaves over a long period eventually results in very high Na^+ and Cl^- concentrations, and the leaves die. The cause of injury is probably the salt load exceeding the ability of cells to compartmentalize salts in the vacuole. Salts would then build up rapidly in the cytoplasm and inhibit enzyme activity. Alternatively, they might build up in the cell walls and dehydrate the cell. The excessive salt concentration correspondingly increases the osmotic potential of the soil that restricts the water uptake by plants.

According to some authors, developing more plastic wheat varieties, suitable for the regions of the republic is required because of the disturbance of ecological balance and the presence of abiotic stress factors. Therefore, stress tolerance in plant breeding is of great importance [4]. Currently, in our country, extensive research has been carried out on salt-tolerance of local wheat varieties as well as brought from abroad [5].Thus, numerous studies conducted in the world and in our country showed the perspectives of the development of the wheat varieties adapted to salinity. The purpose of the research was to study the effect of sodium chloride on the physiological and biochemical characteristics of wheat and corn genotypes, to identify varieties tolerant to salinity.

Materials and methods

The object of the study was wheat seeds Karakylchyk (*T. durum* L.), Mirbashir 128 (*T. aestivum* L.) and maize (*Zea mays* L.) seeds Zagatala 68 x Gurur, White x Gurur. Plants were grown in pots under normal soil conditions and under conditions of 0.5 % sodium chloride.

In two-week-old plants, growth, the amount of photosynthetic pigments, the photochemical activity of chloroplasts, and the activity of photosystem 2 were measured. 0.1 g of leaf samples taken from plants grown under both normal and saline conditions were homogenized using a pestle and mortar in 96 % alcohol by adding $CaCO_3$, centrifuged at 200 g, and a pure extract of chlorophyll pigments was obtained. The optical density of a solution of chlorophyll in alcohol was measured on an SP-2000 spectrophotometer at 665, 649, 440 nm, and the amounts of chlorophyll and carotenoids were determined [6].

The photochemical activity of chloroplasts was measured on the polarography OH-103 by oxygen evolution using the Clark electrode. Potassium ferricyanide was used as an electron acceptor.

The effisience of photosystem II (PSII) was established based on F_v/F_m using a photosynthesis analyzer (PAM Germany).

$F_v=F_m–F_0$, Y= F_v/F_m ;

where F_0 – fluorescence of leaves illuminated after dark treatment, F_m – fluorescence of light-saturated leaves.Data analysis and statistical analysis were conducted using Microsoft Excel. Statistical analysis was performed with the aid of the Statgraphics Plus 5.1 statistical package. The means of values were compared by Duncan's multiple range test (p=0.05).

Results and discussion

Morphophysiological characteristics of wheat and maize plants exposed to salt action are shown in tables 1 and 2.

Table 1. Effect of NaCl (0.5 %) on morphophysiological characteristics of wheat genotypes*

Genotype	Variants	Plant growth, cm	Chl (a+b), mg/g fresh weight	PS 2 activity, Mkmol O_2/mg chl h	Carotenoids, mg/g fresh weight	F_v/F_m
Karakylchyk-2	Control	16±2	3.2±0.5	55±2.5	0.8±0.01	0.75
	NaCl	9±1	1.9± 0.2	20±1.4	0.4±0.02	0.62
Mirbashir-128	Control	15±2	3.5±0.6	56±3.1	0.9±0.03	0.75
	NaCl	11±1	2.7±0.5	35±2.2	0.6±0.01	0.66

Note. * Each value represents the mean ±SD (standard deviation) for the mean n=3 independent experimets p=0.05.

Table 2. Effect of NaCl (0.5 %) on morphophysiological characteristics of maize genotypes*

Genotype	Variants	Plant growth, cm	Chl (a+b), mg/g fresh weight	PS 2 activity, Mkmol O_2/mg chl h	Carotenoids, mg/g fresh weight	F_v / F_m
Zagatala 68X Gurur	Control	29±2	12.6±2.1	65±2.5	3.8±0.01	0.75
	NaCl	15±1	9.9± 0.2	30±1.4	1.4±0.02	0.62
White X Gurur	Control	31±2	13.5±0.6	66±3.1	3.9±0.03	0.75
	NaCl	25±1	11.7±0.5	36±2.2	2.6±0.01	0.66

Note. * Each value represents the mean ±SD (standard deviation) for the mean n=3 independent experimets p=0.05.

When measuring growth, it turned out that under saline conditions, the growth of Karakylchyk-2 plants was inhibited by 50 %, while growth inhibition in the Mirbashir-128 variety was 26,6 %, The content of chlorophyll in the Karakylchyk-2 variety decreased by 40 %, while in the Mirbashir-128 variety it decreased by 22,8 %, The activity of PS 2 in the variety Karakylchyk-2 decreased by 63,6 %, in the variety Mirbashir-128 – 37,5 %, The same pattern was observed in the content of carotenoids in the work of PS 2, Apparently, this is due to the fact that Mirbashir-128, as soft wheat, contains the D genome, which affects the tolerance of this variety to the action of salts.

Salinity could affect chlorophyll concentration of leaves through inhibition of synthesis of chlorophyll or an acceleration of its degradation. Impairment of the carboxylation capacity, which in turn inhibits electron transport, is indicated by the measurements of chlorophyll fluorescence. A reduced quantum yield may result from a structural impact on PS II although some authors [7] found PS II to be highly resistant to salinity stress. Salinity has been concluded to affect reaction centers of PS II either directly or via an accelerated senescence. High external salt concentrations could affect thylakoid membranes by disrupting lipid bilayer or lipid-protein associations and thus, impair electron transport activity. The efficiency of the photochemical conversion of the PS II energy decreased with increasing salt concentrations. Some authors indicate the decrease of the root system function in plants exposed to salt stress. They assumed a more important role of toxic effects of ions [8].

0.5 % NaCl also contributed to growth inhibition in corn plants, In Zagatala 68X Gurur, plant growth decreased by 48 %, while in the White X Gurur hybrid it decreased by 20 %, The content of chlorophyll in the variety Zagatala 68X Gurur decreased by 22,5 %, in the hybrid White X Gurur - by 13,4 %, The decrease in PS2 activity under the action of NaCl was 54 % in Zagatala 68X Gurur and 45,5 % in White X Gurur, The same trend was observed in the content of carotenoids and in the efficiency of photosystems (F_v/F_m), From this we can conclude about the relative tolerance of the White X Gurur maize hybrid to the action of NaCl.

It known that under the salt stress, the external water potential decreases, the absorption of biogenic metal ions by the roots becomes difficult, and the chlorine and sodium ions have a toxic effect on plant metabolism. These three possible effects of salt stress have a detrimental effect on plant growth, development and yield [4]. Osmotic stress is associated with the accumulation of ions in the soil solution, while malnutrition and the specific effects of ions are associated to the accumulation of ions, mainly sodium and chloride, to toxic levels which inhibits the availability of other important elements such as calcium and potassium. Toxic levels of sodium in plant organs damage biological membranes and subcellular organelles, reducing growth and causing abnormal development before plant death. Several physiological processes, such as photosynthesis, respiration, starch metabolism and fixation of nitrogen also disrupted in salt conditions, which leads to a decrease in crop productivity. In response to this, the plant synthesizes low molecular weight solutes, including soluble carbohydrates for better absorption of water during salinity. Genotypes with a powerful genetic apparatus cope with this task and grow well in salt conditions. In the process of evolution, protective mechanisms against environmental stressors are formed in all organisms, including plants. Therefore, when assessing tolerance to stress factors, it is necessary to consider the individual characteristics of each plant genotype [7,8].

Conclusions

Among the wheat varieties, the most tolerant was the bread wheat variety Mirbashir-128, among the maize varieties, the hybrid Belaya x Gurur.

References

1. Khan Syeed S., Masood A., Nazar R., Iqbal N. Application of salicylic acid increases contents of nutrients and antioxidative metabolism in mungbean and alleviates adverse effects of salinity stress. *Int. J. Plant Biology*. 2010. Vol. 1, No. 1. P. 1–8.
2. Azizov Q. Z. Classification of saline soils of Azerbaijan according to degree and types of salinity. Baku, 2002. 29 p.
3. Garratt L. C., Janagoundar B. S., Lowe K. C., Anthony P., Power J. B., Davey M. R. Salinity tolerance and antioxidant status in cotton cultures. *Free Radicle Biol. and Medicine*. 2002. Vol. 33. P. 502–511.
4. Munns R., James R. A., Läuchli A. Approaches to increasing the salt tolerance of wheat and other cereals. J. Exp. Bot. 2006. Vol. 57. P. 1025–1043.
5. Huseynova I. M., Suleymanov S. Yu., Azizov I. V., Rustamova S. M., Magerramova E. G., Aliev J. A. Effects of high concentrations of sodium chloride on photosynthetic membranes of wheat genotypes. *Scientific works of the Institute of Botany of ANAS*. 2008. Vol. XXYIII. P. 230–238.
6. Wintermans J. E. G., De Mots A. Spectrophotometric characteristics of chlorophyll a and b and their phaeophytins in ethanol. *BBA*. 1965. Vol. 109. P. 448–453.
7. Lu C. M., Qin N. W., Wang B. S., Kuang T. Y. Does salt stress lead to increased susceptibility of photosystem II, to photoinhibition and changes in photosynthetic pigment composition in halophyte Suaeda Salsa grown out doors. *Plant Sci*. 2002. P. 1063–1068.
8. Wang Wen-Yuan, Yan Xiao-Feng, Jiang Ying, Qu Bo, Xu Yu-Feng Effects of salt stress on water content and photosynthetic characteristics in *Iris lactera* var. *Chinessis* seedlings. *Middle – East Journal of scientific research*. 2012. 1. P. 70–74.

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ВПЛИВ НАТРІЮ ХЛОРИДУ НА МОРФО-ФІЗІОЛОГІЧНІ ХАРАКТЕРИСТИКИ РОСЛИН ПШЕНИЦІ ТА КУКУРУДЗИ

Мета. Вивчено вплив хлориду натрію на фізіолого-біохімічні показники генотипів пшениці та кукурудзи, виявлено стійкі до засолення сорти. Рослини пшениці та кукурудзи вирощували в горщиках у ґрунті з додаванням 0,5 % розчину натрію хлориду. Для створення нових солестійких сортів пшениці та кукурудзи проведено порівняльний аналіз морфо-фізіологічних показників рослин. ***Методи***. Морфо-фізіологічні параметри, такі як ріст, вміст хлорофілу та каротиноїдів, фотохімічна активність хлоропластів та активність ФСІІ, були вивчені на рослинах пшениці та кукурудзи. ***Результати***. Вплив солі на кількість хлорофілу *a*, хлорофілу *b* і каротиноїдів, які є основними фізіологічними показниками, проявляється в обох рослинах по-різному. При вивченні солестійкості рослин виявлено відмінності у відносних кількостях хлорофілу (a+b), каротиноїдів, а також фотохімічної активності хлоропластів і ефективності ФС 2. ***Висновки***. Серед сортів за всіма морфо-фізіологічними показниками найбільш толерантними до дії солі виявилися сорт м’якої пшениці Мірбашир-128 та гібрид кукурудзи Біла х Гурур.

Ключові слова: пшениця, кукурудза, сіль, хлорофіл, хлоропласт, фотосистема 2, толерантність.