UDC 633.11:504.5-03:581.1 https://doi.org/10.26577/2218-7979-2016-9-1-8-12

[1,2*]Alybayeva R.A., [1]Atabayeva S.D., [1]Asrandina S.Sh.,
[1]Serbaeva A.D., [2]Asylbekova A.A., [2]Sadyrbaeva A.S.

[1]School of Biology and Biotechnology
[2]UNESCO Chair for Sustainable Development al-Farabi
Kazakh National University, Almaty, Kazakhstan
[*]e-mail: raya_aa@mail.ru

Identification of spring wheat germplasm resistant to heavy metals for create clean wheat growing technology

Abstract: The aim of this study was to identify wheat germplasm resistant to heavy metals (zinc, cadmium), which are priority pollutants in eastern Kazakhstan region, and identification donors for breeding and promising forms of wheat that are resistance to heavy metals and destined for agricultural production. The objects of research are different genotypes of spring wheat from the collection of the East Kazakhstan Research Institute of Agriculture. In field experiment plants were grown on scientific test site, under natural environmental pollution, in the suburban area of Ust-Kamenogorsk city, East Kazakhstan region. The content of heavy metals in plants was determined by atomic absorption on the device AAnalyst 300 of "Perkin Elmer". Experiments and determination of physiological parameters were conducted by the method of field experiment. The study of the accumulation of heavy metals in components of different genotypes of winter wheat in conditions of natural pollution has shown the genotypic differences in the accumulation of zinc and cadmium in plant seeds. The study of investigated heavy metals accumulation in the spring wheat seeds of East-Kazakhstan Agricultural Research Institute collection showed, that in terms of cadmium accumulation, the most resistant varieties of spring wheat are Ulbinka, Zaulbinka and Omskaya-18. Upon indicator of accumulation of zinc, the most resistant varieties are Samal and Kutulukskaya. Spring wheat varieties Ulbinka, Zaulbinka and Omskaya-18 can be recommended for further use in breeding for resistance to the accumulation of cadmium in the grain. Samal spring wheat varieties can be recommended for further use in breeding for resistance to the accumulation of zinc in the grain. The most harvest from plots has spring wheat varieties: Ulbinka-25, Glubochanka, Erythrospermum-616 and Altai. It is connected to a large number of grains per ear, high grain weight per ear, high productive tillering and good survival during the spring-summer growing season. Varieties Ulbinka-25 and Omskaya-18 can be recommended for cultivation on soils contaminated with cadmium, as these varieties of spring wheat accumulate least of cadmium in the seeds and at the same time are characterized by high yields and good survival during the spring-summer growing season in a polymetallic contamination of soil.

Key words: heavy metals, wheat, metal resistant germplasm, physiological parameters, promising forms.

Introduction

In Kazakhstan, the development of a powerful industry was based on its rich natural resources. However, the industrial centers are the areas of highest contamination by heavy metals [1].

Sound environmental technologies are crucial to address heavy metal pollution. Development and use of plant varieties characterized by minimal accumulation of heavy metals can provide one such environmental solution.

Plants, grown in contaminated soils, exhibit significant interspecies differences in responses to pollution.

The available literature data showed that a significant positive correlation between the concentration of heavy metals in the grain and genotypes, indicating the possibility of breeding varieties with a low potential for accumulation of heavy metals [2].

Characterization of heavy metal accumulation in wheat and identification of germplasm resistance to influence of heavy metals is an important step towards the creation and use of wheat varieties resistant to heavy metal pollutions in agricultural production systems.

This requires the study of the gene pool of cultivated plants and the selection of donors that accumulate minimum amount of heavy metals and varieties that are promising for cultivation in areas contaminated with heavy metals.

The aim of this study was to identify wheat germplasm resistant to heavy metals (zinc and cadmium), which are important to eastern Kazakhstan region,

 Printed in Kazakhstan

identification of donors for breeding and promising forms destined for agricultural production.

Materials and methods

Different genotypes of wheat specific to East Kazakhstan were studied. Experiments were carried out using spring wheat varieties of East Kazakhstan Agricultural Research Institute collection: Altai, Ulbinka-25, Zaulbinka, Lyazzat, Glubochanka, Nargiz, Omskaya-18, Samal, Eritorospermum-606, Kutulukskaya.

Field studies carried out for the determination of physiological parameters. Plants were grown on scientific test site, under natural environmental pollution, in the suburban area of Ust-Kamenogorsk city, East Kazakhstan region.

In the field experiment the following physiological parameters were determined: phenological observations, yield, yield structure, the content of cadmium and zinc in seeds. Conducting the experiments and determination of physiological parameters were done by the method of field experiment [3].

Heavy metals (zinc and cadmium) in soil and plant samples were determined by atomic absorption with atomization in flame and graphite furnace on the device AAnalyst 300 of "Perkin Elmer" firm.

Sample preparation was carried out using a heating unit "Hot Block" with the addition of concentrated nitric acid and hydrochloric acid at a temperature of 90 ± 5°C, in accordance with standard operating procedures.

Weighed portion of sample was placed in disposable sample cups; 5 mL of 50% nitric acid and 0.5 mL of concentrated hydrochloric acid were added. Samples were mixed well to liquid clay condition, covered with a watch glass and placed in a heating block.

The sample was heated to a temperature of 90 ± 5°C, and evaporated for 10-15 minutes without boiling. Then the sample was cooled, 5 mL concentrated HNO_3 were added and heated again for 30 minutes.

Content of capacitances were evaporated without boiling at a temperature of 90 ± 5°C for approximately up to 5mL during 2 hours, avoiding foaming. After that the sample was cooled and the volume was adjusted to 50 mL with deionized water.

To calibrate of the device calibration blank have been used, consisting of deionized water and 1% HNO_3 solution and standard samples of the company "High Purity".

After calibration of devise readings of analyzed samples were taken. Accuracy of analysis performance was checked by the screening standard of the company "Merck".

The content of heavy metal in the sample was calculated according to the formula:

$$Cmg/kg = \frac{C_{device} \times V_{samp} \times FD}{M}$$

where C_{device} – devise reading (mg/L); $V_{samp.}$ – final volume of samples (mL); FD – dilution factor; M – weighed sample (g).

Results and their discussion

The genotypes of spring wheat were studied in the field of natural soil contamination with heavy metals.

Our studies of the accumulation of heavy metals in the soil of root zone of different genotypes of winter wheat collection of East Kazakhstan Agricultural Research Institute under natural pollution showed that the content of heavy metals is different.

Zinc content exceeds the maximum permissible concentration of the metal only in the root zone soil of varieties Nargis and Samal, in the zones of other varieties such excess is not observed (Figure 1).

Thus, the wheat plants are not under stress from increased concentrations of zinc in the soil, except for varieties Samal and Nargiz, but in this case the excess is insignificant.

Investigation of cadmium in the soil of the roots zone of different genotypes of winter wheat showed that the amount of the metal exceeds the maximum permissible concentration in nearly all varieties, except variety Nargiz (Figure 2).

The scope of excess of MPC is from 1.5 to 4.5 times. The highest excess recorded in the root zone soil of variety Omskaya-18. Thus, the wheat plants are stressed by high concentrations of cadmium in the soil, and this stress is significant. It should be noted also that the study of soil contamination has polymetallic character. The excess of the MPC also observed for metals such as copper and lead.

In this connection, it was of interest to study the parameters of growth and development of these varieties to identify the tolerance to abiotic stress and agronomic resistance of varieties in the conditions of polymetallic stress. This may facilitate the identification of varieties that retain good productivity and at the same time little accumulates heavy metals in the grain.

Investigation of zinc and cadmium in the seeds of winter wheat genotypes is the most important as a grain of wheat is used in the food industry. Ac-

cording to some researchers, the level of heavy metal cadmium in products is the problem of food security. Reduction of cadmium in the grain is one of the priorities of breeding programs [4].

Our research of accumulation of zinc in plant seeds of genotypes of East-Kazakhstan Agricultural Research Institute collection in a polymetallic soil contamination have shown that this metal accumulates in small quantities, and its content does not exceed the maximum permissible concentration in the seeds of almost all genotypes, except varieties Nargis, Altai and Glubochanka (Figure 3).

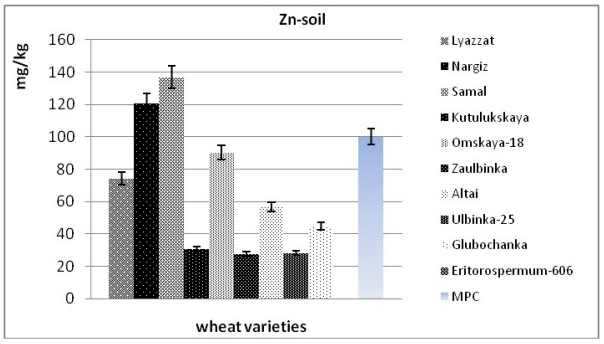

Figure 1 – Content of zinc in the root zone soil of studied genotypes (mg/kg) in relation to the maximum permissible concentration (MPC).

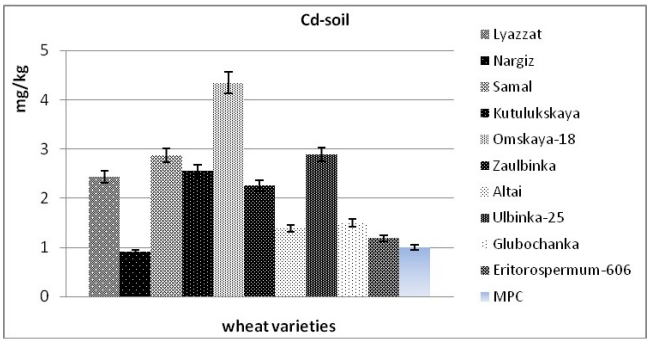

Figure 2 – Content of cadmium in the root zone soil of studied genotypes (mg/kg) in relation to the maximum permissible concentration (MPC).

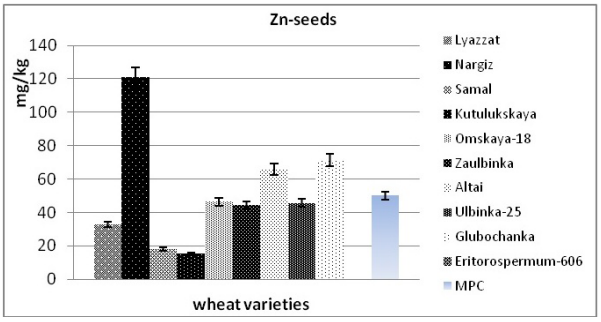

Figure 3 – Zinc content in the seeds of different spring wheat genotypes of East-Kazakhstan Agricultural Research Institute collection

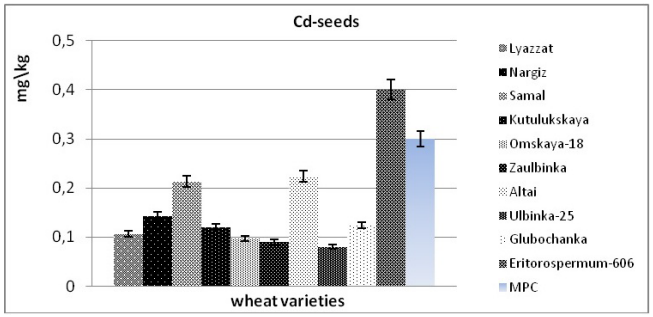

Figure 4 – Cadmium content in seeds of different genotypes of East-Kazakhstan Agricultural Research Institute spring wheat collection

This may be due to the fact that the content of the element in soil does not exceed MPC for soil or slightly exceeded. Despite this, in plant seeds of varieties Glubochanka and Altai accumulated amount of zinc is slightly above the MPC for wheat. The amount of zinc for 1.3 – 1.4 times higher than the maximum permissible concentration for grain in the seeds of varieties Altai and Zaulbinka and for 2.4 times greater than maximum permissible concentration in the seeds of variety Nargis..

The study of cadmium accumulation in plant seeds of genotypes of East-Kazakhstan Agricultural Research Institute collection in a polymetallic soil contamination have shown that this metal accumulates in small quantities, and its content is slightly higher than the MPC for the grain in case of spring wheat variety Erythrospermum (Figure 4).

It should be noted that in the root zone soil content of cadmium is significant and exceeds MPC almost in all genotypes, except varieties Nargiz and Altay (Figure 6). Despite this, spring wheat seeds do not accumulate significant amounts of cadmium. The greatest amounts of cadmium accumulate seeds of variety Erythrospermum. Thus, the study of investigated heavy metals accumulation in the spring wheat seeds of East-Kazakhstan Agricultural Research Institute collection showed, that in terms of cadmium accumulation, the most resistant varieties of spring wheat are Ulbinka, Zaulbinka and Omskaya-18.

In terms of accumulation of zinc, the most resistant varieties are Samal and Kutulukskaya. In respect to varieties Kutulukskaya, this fact can be seen as a disadvantage, since zinc content in soil, where the roots of this variety plants inhabit, is slight. Seeds of this wheat variety depleted of necessary for nutrition element. For variety Samal, this fact can be considered as an advantage, since the soil layer, where this variety roots inhabit, the zinc content heightened and in spite of this seeds does not accumulate significant amounts of zinc.

Spring wheat varieties Ulbinka, Zaulbinka and Omskaya-18 can be recommended for further use in breeding for resistance to the accumulation of cadmium in the grain.

Samal spring wheat varieties can be recommended for further use in breeding for resistance to the accumulation of zinc in the grain.

The number of plants before the harvest, in comparison with their number before tillering shows the survival rate during the spring and summer growing season, that is why this indicator was also determined.

The study of plants number before tillering showed that the greatest plants number observed in variety Glubochanka (Figure 5). The average number of plants, in comparison with other varieties, is observed in Zaulbinka, Omskaya 18, Altai, Ulbinka, Kutulukskaya, Samal. Smallest number of plants is in varieties – Erythrospermum 606, Lyazzat, Nargis.

Determination of the number of plants before the harvest showed the greatest number of plants observed in variety Glubochanka (Figure 5).

The average number of plants, in comparison with other varieties, observed at the varieties Zaulbinka, Omskaya 18, Altai, Ulbinka, Kutulukskaya, Samal. The smallest number of plants is in the varieties – Erythrospermum 606, Lyazzat and Nargis.

Determination of the number of plants before the harvest showed that the greatest number of plants observed at variety Glubochanka (Figure 5).

As already mentioned above, the number of plants before the harvest, relative to their number before tillering shows survival during the spring-summer growing season. Counting of the survival rate showed that the highest survival has variety Glubochanka. Varieties of spring wheat: Zaulbinka, Omskaya 18, Ulbinka 25, Kutulukskaya, Lyazzat, Nargiz and Altai demonstrated the average survival. The lowest survival rates show the varieties Erythrospermum 606 and Samal (Figure 6).

Very important indicator is productive tillering, which shows the ability of plants to form a productive lateral shoots, which make a considerable contribution to the overall productivity of the variety. The number of stems, formed on wheat plant is called coefficient of tillering. General tillering is distinguished, i.e. the number of shoots per plant, and productive tillering, by which is meant the number of shoots bearing the ear per plant. Usually productive tillering is two to three times less then general, but under favorable conditions the coefficients of general and productive tillering come closer.

For this indicator, the most productive tillering have plants of variety Glubochanka, the average among the studied genotypes – Omskaya 18, Zaulbinka, Altai, Ulbinka 25, Kutulukskaya, lower – gen-

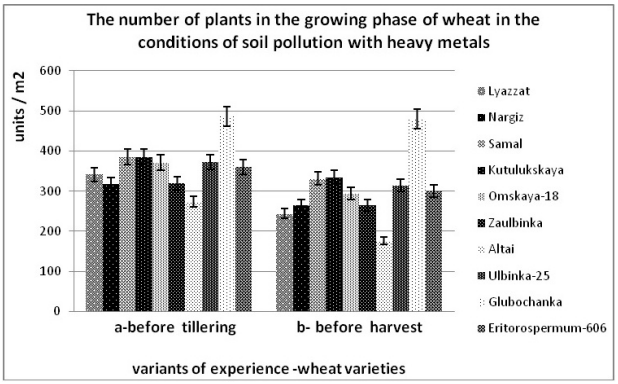

Figure 5 – The number of plants at different genotypes of spring wheat per phases of vegetation, when grown in the natural environment pollution

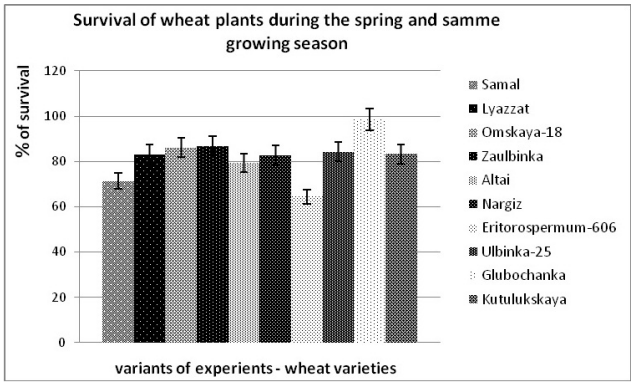

Figure 6 – Percentage of the surviving before harvesting plants of different spring wheat genotypes, when grown in the natural environment pollution

otypes Nargis, Samal, Lyazzat, the lowest – Eritrospetmum 606 (Figure 7).

Metal-resistant wheat varieties should be characterized not only survival during the spring and summer growing season, but also a good productivity in conditions of soil contamination with heavy metals. So is determined such an important valuable economic feature as yield of wheat plants. Among the varieties of spring wheat of East-Kazakhstan Agricultural Research Institute collection the harvest from the plots is largest at spring wheat Ulbinka-25, Glubochanka, Erythrospermum-606 and Altay (Figure 8).

In the case of the variety Ulbinka-25 together with high yield, this variety is also characterized

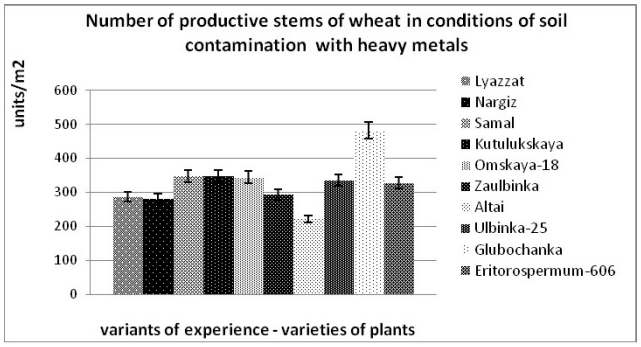

Figure 7 – The productive tillering of plants of different genotypes of winter wheat of world collection, when grown in the natural environment pollution.

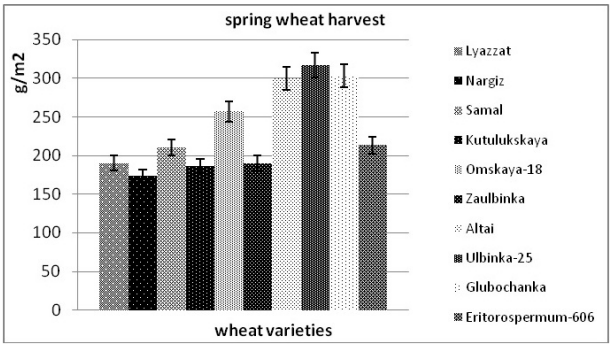

Figure 8 – The harvest of different spring wheat genotypes of the East Kazakhstan Agricultural Research Institute collection, when grown in natural conditions of environmental pollution

by high indicators, as grain weight of main ear and as well as grain weight of lateral stems. In varieties Erythrospermum 606 and Altai, along with high yields also the highest values of grain weight of main ear and average indicators weight of grain of lateral stems revealed.

Variety Glubochanka, although has an average the grain mass of the main ear and lateral stems, however, characterized by the highest rates of productive tillering, i.e. the number of productive lateral stems is big and probably therefore this variety has a higher overall crop yields.

The lowest yields in conditions of soil contamination with heavy metals demonstrate varieties: Lyazzat, Zaulbinka, Samal, Nargiz. The average yield compared with other spring wheat genotypes detected in varieties Kutulukskaya and Omskaya-18 (Figure 7).

Thus, the most harvest from plots was obtained from spring wheat varieties: Ulbinka-25, Glubochanka, Erythrospermum-606 and Altai.

It is connected probably to a large number of grains per ear, high grain weight per ear, high productive tillering and good survival during the spring-summer growing season.

Varieties Ulbinka-25 and Omskaya-18 can be recommended for cultivation on soils contaminated with cadmium, as these varieties of spring wheat accumulate least of all cadmium in the seeds and at the same time are characterized by high yields and good survival during the spring-summer growing season in a polymetallic contamination of soil.

References

1. Alybayeva R.A. Evaluation of the ecological status of soils in Ust-Kamenogorsk // KazNU Bulletin: Environmental Series. – 2007. – No. 2 (21). – pp. 40-44.

2. Wu Feibo, Zhang Guoping Genotypic variation in kernel heavy metal concentrations in barley and affected by soil factors // Journal of Plant Nutrition. – 2002. – No. 25 (6). – pp. 1163-1173.

3. Dospekhov B.A. Methodology of field experience – Moscow: Agro-industrial Publishing, 1985. – P.351.

4. Knox R.E., Pozniak C.J., Clarke F.R., Clarke J.M., Houshmand S., Singh R.E. Chromosomal location of the cadmium uptake gene (*Cdu1*) in durum wheat // Genome. – 2009. – No. 52 (9). – pp. 741-747.