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БАЯНДАМАЛАРЫ

ДОКЛАДЫ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН

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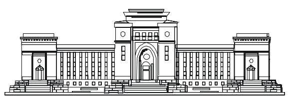

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ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ
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PRODUCTIVITY AND ACCUMULATION OF HEAVY METALSIN THE GRAIN OF VARIOUS GENOTYPES OF SPRING BARLEY UNDER CONDITIONS OF SOIL CONTAMINATION WITH COPPER AND LEAD

Abstract. Environmental pollution, especially by chemical substances, is one of the most powerful factors in disrupting components of the biosphere. Currently, the biosphere receives a lot of pollutants. Among them are significant heavy metals. Among the chemical elements, heavy metals are the most toxic. The danger of increasing the content of heavy metals in the soil and heavy metals in the atmosphere is associated with active absorption and accumulation of plants, which not only negatively affect their active actions, but also threaten human and animal health. The danger of metals is that they have a cumulative effect and retain these toxic properties for a long time. In connection with the task of studying the gene pool of cultivated plants in the conditions of technogenic pollution, the study of metal resistance of barley varieties was carried out in order to identify promising forms for growing in the East Kazakhstan region, as well as breeding donors that collect the minimum amount of pollutants. The results obtained allow us to suggest donors resistant to heavy metals that can be used in breeding and genetic research. Barley is a concentrated product for animals, as the composition is rich in starch and protein. Barley seeds, along with amino acids, protein, lysine and tryptophan, which cannot be replaced by another substance, are preserved better than in other crops. Barley in Kazakhstan ranks second after wheat. The East Kazakhstan region is favorable and in demand for growing barley. However, the damage to the vessels by heavy metal affected the commissioning of the product. The most effective way out of this is to prevent the genetic and physiological effects of the genes of these tolerant (hardy) species. Genotype identification is a new and unexplored area of invention for products that grow against heavy metals in plants.

Keyword: heavy metal, barley grain, phytostabilization, genotype.

Introduction. Currently, the problem of soil contamination of industrial and agricultural territories with heavy metals is relevant. Heavy metals occupy one of the leading places among all environmental pollutants. Many representatives of this group of substances, such as lead, copper, zinc, and cadmium, even in very small amounts, can cause immunological, oncological, and other types of diseases. As a result of research conducted by scientists from different countries, it is proved that about 70% of heavy metals enter the human body with food [1]. The maximum soil pollution is observed near industrial centers, megacities, and major highways [2]. Anthropogenic activities pollute the environment with the following types of heavy metals: mining and metallurgy-As, Cd, Pb and Hg; industry - As, Cd, Cr, Co, Cu, Hg, Ni and Zn; atmospheric deposition - As, Cd, Cr, Cu, Pb, Hg and U; agriculture - As, Cd, Cu, Pb, Se, U and Zn; and waste disposal - As, Cd, Cr, Cu, Pb, Hg , and Zn [3].

The main sources of anthropogenic input of heavy metals into the environment are metallurgical enterprises, thermal power plants, quarries and mines for the extraction of polymetallic ores, transport, chemical means of protecting crops from diseases and pests, burning oil and various wastes, etc. [4. 5]. The most powerful halos of heavy metals occur around ferrous and especially non-ferrous metallurgy enterprises as a result of atmospheric emissions. The effect of pollutants extends for tens of kilometers from the source of elements entering the atmosphere. The size of human anthropogenic activity can be estimated from the following data: the contribution of technogenic lead is 94-97% (the rest is natural sources), cadmium - 84-89%, copper - 56-87%, Nickel 66-75%, mercury – 58%. Most of the heavy metals contained in industrial dust and gas emissions are usually more soluble than natural compounds [6].

Soil cover is a mandatory component of any ecosystem that is actively exposed to negative factors that disrupt its state [7]. Crop products grown in such areas accumulate heavy metals in concentrations above the maximum permissible concentrations. Thus, the analysis of soil and plant samples taken from the territories of key areas of the agricultural zone of Stavropol revealed the maximum value of Zn contamination indicators and an increased copper content exceeding the MPC by 2-2. 5 times [8]. Zinc, lead, and cadmium are relatively easily accessible to plants, so these elements have the highest risks of accumulation in dangerous concentrations.

Knowledge of the biological characteristics of agricultural crops helps to solve the problem of rational use of soils with different levels of heavy metal pollution. This should take into account: the culture, variety, and parts of the plant used. Taking all this into account, on soils with a low level of pollution, it is possible to obtain a fairly clean crop of grain crops without much risk. It is shown that there are significant genotypic differences in the accumulation of cadmium in maize leaves and grains, which may be based on genetic factors. Now, when contamination of cultivated soils has become relatively common and is likely to continue, the identification and creation of varieties with the ability not to accumulate heavy metals for polluted territories is almost the only real solution to emerging environmental problems. To do this, it is necessary to study the plant gene pool and identify forms that accumulate the minimum amount of ecotoxicants in the commercial part of the crop [9].

Objects and methods of research. The object of research in this work is the genotypes of spring barley from the collection of the East Kazakhstan research Institute of agriculture. The experiment studied varieties and genotypes of spring barley: Despina, L-202, genotype 488-A, genotype 120-A, L-201.

Growing plants in conditions of natural pollution. The plants were grown in the primary seed nurseries of the research and testing site of the VKNIISKH, in the conditions of natural environmental pollution, in the suburban area of Ust-Kamenogorsk, East Kazakhstan region, North-East direction, 3 km from the city border. The area of the experimental plot is 5 m2 in three-fold repetition. Seeding is mechanized, divided, the seeding rate is 5 - 6 million germinating grains per 1 ha. The width of the aisles is 15 cm, the space between the rows is 50 cm.

The soil cover of the experimental site is represented by ordinary heavy loamy Chernozem, widely distributed in the foothill-steppe zone. The soil of the experimental site has a neutral reaction (pH 7.0). The average humus content in the arable horizon is 2.6 %. The soil is moderately provided with easily digestible nitrogen (22.6-18.4 mg/kg of soil), highly provided with mobile potassium (390-400 mg/kg of soil) and low provided with mobile phosphorus (16.3-18.5 mg/kg of soil).

Predecessor – black steam after winter plowing – 23-25 cm. When laying the experiments, soil preparation, sowing and plant care were carried out according to the accepted technology of barley cultivation in the foothill steppe zone of Eastern Kazakhstan. Early spring harrowing, cultivation, pre-sowing cultivation. Care of plants (rolling, weeding by hand).

Determination of the content of heavy metals in the soil of the root zone and in grain. The concentration of heavy metals (zinc and cadmium) was determined using an atomic absorption spectrophotometer. The method of atomic absorption spectrophotometry (AAS) is based on the property of atoms of chemical elements formed when solutions of used substances are sprayed in a "cold" flame (acetylene-air, propane-air, etc.) to absorb light of a certain wavelength. The radiation intensity of low-pressure gas-discharge lamps after the light passes through the flame of the combustible gas and its absorption by the atoms of the element under study is recorded photoelectrically. Samples of grain and soil of the root zone taken in the field of natural soil contamination with heavy metals were salted in a muffle furnace. The exposed material was treated with nitric and hydrochloric acids and water was added. The atomic absorption of experimental and control samples was measured using an atomic absorption spectrophotometer.

Determination of the coefficient of biological accumulation of metals. One of the characteristics that reflects the level of accumulation of heavy metals by crops is the coefficient of biological accumulation. We calculated bioaccumulation (coefficient of biological accumulation) as the ratio of the average content of heavy metals in plants to their average content in soils,

$$Кc = \frac{Ct}{Cav}$$

where KC is the coefficient of biological accumulation; CT is the metal content in the plant, mg/kg; SSR. is the metal content in the soil cover, mg/kg [10].

Determination of plant survival. To determine the survival rate of plants, the number of spring durum wheat plants per unit area that rose and remained before harvesting was calculated. The difference between these indicators can be used to judge the survival rate of plants during the spring-summer vegetation period.

Determination of vegetative indicators and productivity under conditions of natural pollution

Phenological observations, field and laboratory assessments, and records were carried out according to generally accepted methods [11].

Observations were made for the following phases of development - seedlings, tillering, vegetation renewal, exit into the tube, earing, flowering, ripeness.

Productive bushiness was determined in plants. Plants were dug out on each variant and the actual number of stems per plant (total, including productive ones) is calculated. The arithmetic mean, obtained by dividing the total number and number of productive stems by the number of plants, characterizes the total or productive bushiness, respectively, depending on the variety.

Plant survival was determined. Plants were counted during the full germination phase and before harvesting. The number of preserved plants (%) is calculated by the formula:

$$B = \frac{(Cx100)}{B_n}$$

where: B – the number of plants preserved for harvesting, %; B_n – the number of plants in the full germination phase, PCs. per m^2; C – the number of plants to harvest, PCs. per 1 m^2.

The yield was determined by direct weight method. Grain moisture was determined by weight method. Grain samples are taken from each plot in aluminum cups with a tight lid, weighed and dried at a temperature of 100° – 105° C to a constant weight of about 4 - 6 hours, then calculate the formula:

$$X = B : H$$

where: X – grain moisture, % ; B – mass of evaporated water, g; H – raw weight, g.

The standard 14 % humidity is recalculated using the formula:

$$X = Yx(100\text{-}b) / 100\text{-}s,$$

where: X is the yield reduced to standard humidity; Y is the yield obtained; b is the yield humidity (%); C is the standard humidity for this object.

When analyzing plants by elements of the structure of the grain crop yield, 10 plants were selected from each plot of all repetitions of the experiment.

The results of research and their discussion. First of all, the content of the studied heavy metals in the soil of the root zone of various genotypes of spring barley was studied, since East Kazakhstan is an industrial center with a developed mining and non-ferrous metallurgy and the soil can be contaminated with heavy metals.

Atmospheric technogenic load changes the soil profile and leads to the formation of contrasting technogeochemical anomalies in the upper soil layer [12]. A polyelement technogeochemical anomaly of heavy metals with one center and a large peripheral zone is formed around metallurgical enterprises, which are characterized by a high content of heavy metals in the soil, and an unfavorable sanitary and environmental situation.

Research results and discussion. The results of the study of the lead content in the soil of the root zone of various genotypes of spring barley showed that in relation to the MPC of lead for soils, there is an excess of one and a half to 1.9 times (figure 1).

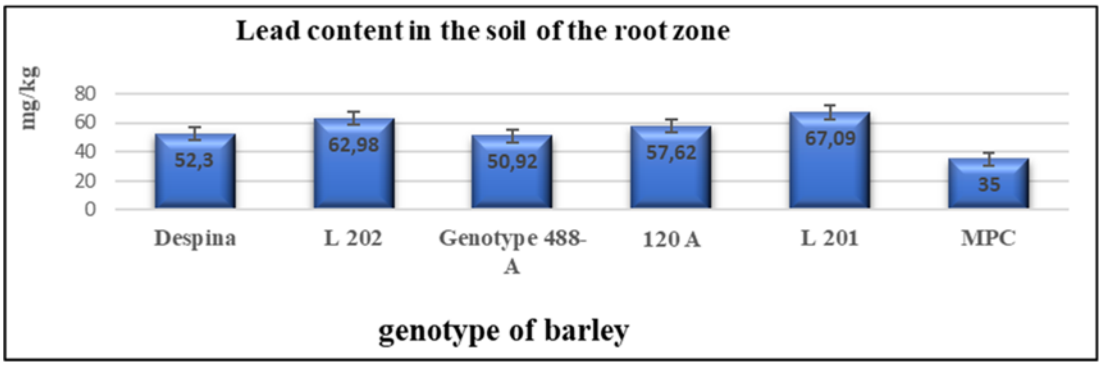

Figure 1 - lead content in the soil of the root zone of various genotypes of spring barley in relation to the MPC

The ratio of the lead content in the soil of the root zone to the regional Clark was also determined. Regional Clark took over the background content of element in soil and compared them with the obtained value of the amount of metal in the soil in accordance with the view that the content of elements in the topsoil should be compared with the background, under the background of the element content mean or srednerynochnoj the content of chemical substances in the soil, not podvergalsya technogenic impact, or "clarky" - the average content of chemical elements in the earth's crust [13].

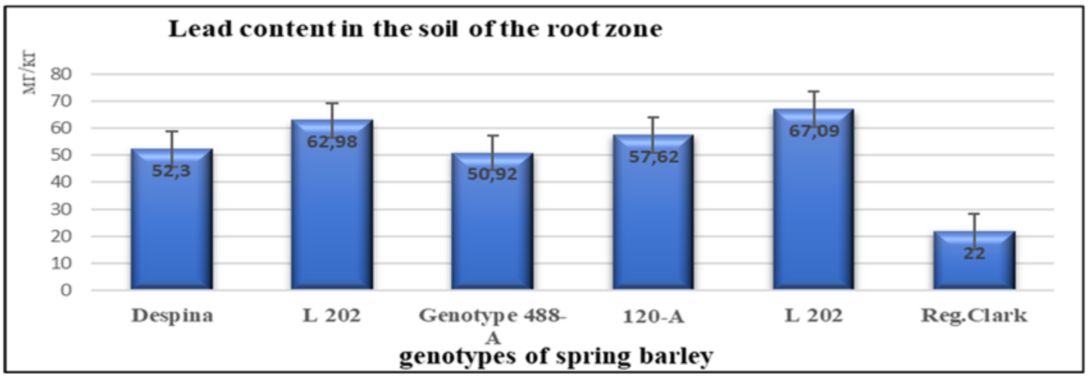

Figure 2 – lead content in the soil of the root zone of various genotypes of spring barley in relation to the regional Clark

The content of copper in the soil of the root zone of various genotypes of spring barley was also studied (figure 3,4).

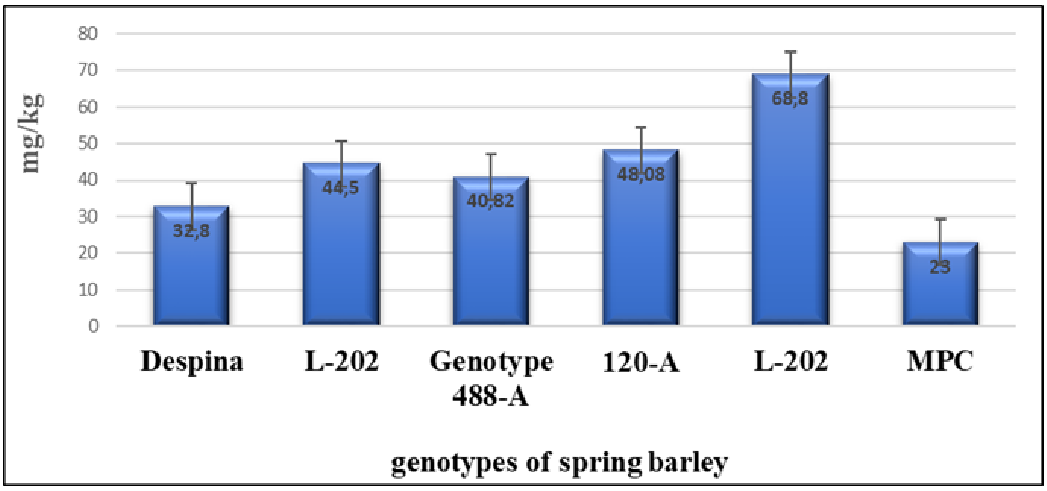

Figure 3 – Copper content in the soil of the root zone of various genotypes of spring barley in relation to the MPC

The results of the study of the copper content showed that in relation to the MPC of copper in the soil, there is an excess of 1.4 -3.0 times (figure 3).

The ratio of the copper content in the soil of the root zone to the regional Clark was also determined. Studies have shown that in Relation to the regional Clark, the excess of copper content is observed only in the soil of the root zone of the L-201 genotype, while in other variants, the excess of Clark is not observed.

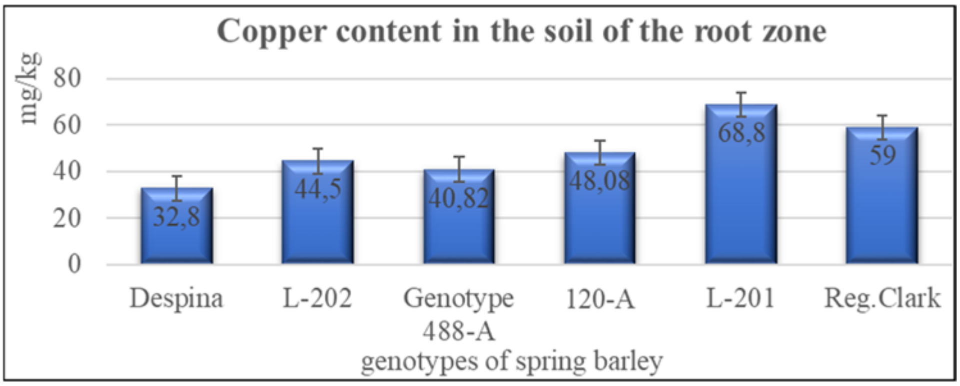

Figure 4 – copper content in the soil of the root zone of various genotypes of spring barley in relation to The regional Clark

Thus, the study of the content of copper and lead in the soil of the spring barley root habitat zone showed an increased content of the studied elements, both in comparison with their MPC for the soil, and lead in comparison with the regional Clark. Thus, all the studied genotypes are stressed by the increased content of lead and copper in the soil. At the same time, the lead content makes a greater contribution to stress, since in comparison with its natural content in the region, the excess is 2.4-3.0 times.

Similar data were obtained in other studies. M. V. Pasypanova found that the permissible level of Pb, Cd, Cu and Zn was exceeded at the foundry dump near the metallurgical plant, which affected the state of vegetation. In Chernozem soils and in wheat and potato plants in the zone of enterprises of the West Siberian region, there is an annual accumulation of lead with an excess of MPC in soils by 2.0-5.4 times, in plants by 1.5 - 2.8 times [14].

Determining the accumulation of the studied elements in seeds is the most important indicator studied, since barley grain is used in the production of feed.

Our research has shown that lead ions accumulate in the seeds of all genotypes of spring barley and their amount exceeds the MAC for grain by about 14 -25 times. According to the number of lead ions accumulated in the seeds of plants of various genotypes of spring barley, they can be arranged in the following order as they decrease: Despina > L-202 > genotype 120-A > L-201 > genotype 488-A.

The 488-A genotype accumulates lead ions less than other genotypes, the Despina variety accumulates the most, while the other genotypes of spring barley show intermediate values of this element content (figure 5).

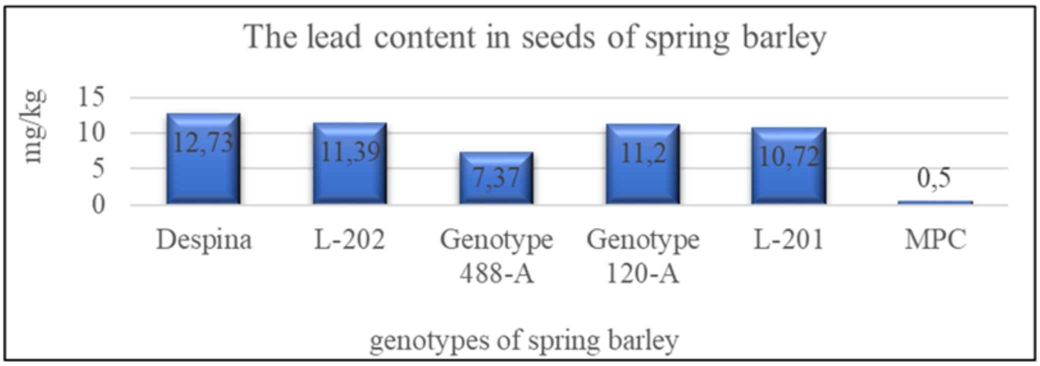

Figure 5 – Lead content in seeds of various genotypes of spring barley in relation to MPC.

Determination of the biological accumulation coefficient showed that the 488-A genotype accumulates the least lead, and the Despina spring barley variety accumulates the most.

Table 1 – CBA of lead of various genotypes of spring barley
in conditions of soil contamination with heavy metals

Lead	Despina	Genotype L-202	Genotype 488-A	Genotype 120-A	GenotypeL-201
CBA	0,24	0,18	0,15	0,19	0,16

By the number of copper ions accumulated in the seeds of plants of various genotypes of spring barley, they can be arranged in the following order as they decrease: genotype 120-A > L-202 > Despina > genotype 488-A > L-201. The smallest amount of copper in seeds contains genotypes L-201 and 488-A, the largest – genotype 120-A.

Table 2 – CBA of copper of various genotypes of spring barley
in conditions of soil contamination with heavy metals

Copper	Despina	L-202	Genotype 488-A	Genotype 120-A	L-201
CBA	0,15	0,13	0,12	0,15	0,07

Determination of the coefficient of biological accumulation (table 2) showed that the L-201 genotype accumulates the least copper, although the soil of the root zone of this genotype has the highest content of this metal, compared to the soil of the root zone of other genotypes of spring barley. Most of all, the seeds of the Despina spring barley variety accumulate copper.

When plants are grown on metal-contaminated soils, heavy metals negatively affect the photosynthesis process. The interaction between toxic metals and the photosynthetic apparatus can lead to changes in the functional activity of chloroplasts [15], and the interaction of metals with cytosolic enzymes and organic substances.

In particular, copper (Cu), being a toxic heavy metal, in plants is a part of plastocyanin involved in photosynthesis, and some other copper-containing proteins, and oxidative enzymes. However, even double the optimal concentrations of copper can cause a negative effect. Thus, the adverse effect of copper with its increased content was reflected in the form of a decrease in the accumulation of phytomass, tissue hydration, absorption of ions of some other metals and their translocation through the plant, and the content of chlorophyll in rapeseed [44]. Mechanisms of plant adaptation to the toxic effects of copper are based on the functioning of low-molecular organic stress-protective compounds, protective macromolecules and antioxidant systems, chelation, sequesterization and compartmentalization of heavy metals. [45, 46].

Conclusions:

1. Under conditions of soil contamination with lead and copper ions in seeds of various genotypes of spring barley, the lead content exceeds, and the copper content does not exceed the MPC for grain.
2. The L-201 genotype of spring barley can be recommended for use in breeding and genetic studies as a donor of copper resistance.
3. The main role in the formation of yield under conditions of polymetallic soil contamination is played not only by the mass of the main ear and side shoots, but also by sufficient plant survival during the spring-summer vegetation period.
4. The L-201 Genotype can be recommended for cultivation in conditions of soil contamination with copper ions, since it shows the lowest coefficient of biological accumulation of copper and is characterized by high yield.

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ТОПЫРАҚТЫҢ МЫС ЖӘНЕ ҚОРҒАСЫНМЕН ЛАСТАНУ ЖАҒДАЙЫНДА ЖАЗДЫҚ АРПАНЫҢ ТҮРЛІ ГЕНОТИПІНДЕГІ АСТЫҚТА АУЫР МЕТАЛДАРДЫҢ ӨНІМДІЛІГІ МЕН ЖИНАҚТАЛУЫ

Аннотация. Ортаның химиялық заттармен ластануы – биосфера компоненттері бұзылысының күшті факторларының бірі. Қазіргі уақытта биосфераға көптеген ластайтын заттар жиналуда. Олардың ішінде ауыр металдар едәуір орын алады. Химиялық элементтер арасында ауыр металдар аса улы болып саналады. Топырақта ауыр металл және атмосферадағы ауыр металл мөлшерін жоғарылату қаупі өсімдіктің белсенді әрекетіне теріс әсерін тигізумен қатар, адам мен жануарлар денсаулығына қатер төндіретін өсімдіктердің белсенді сіңірілуіне, жиналуына байланысты болып келеді. Металдар қауіптілігіне олардың кумулятивті әсері бар және ұзақ уақыт бойы сол улы қасиеттерді бойында сақтап қалуы жатады. Техногенді ластану жағдайында мәдени өсімдіктердің гендік қорын зерттеу міндетіне байланысты Шығыс Қазақстан өңірінде өсіру үшін перспективалы формаларды, сондай-ақ ластайтын аз санды зат жинайтын селекциялық донорларды анықтау мақсатында жаздық арпа сорттарының металға төзімділігін зерттеу негізге алынды. Алынған нәтижелер асылтұқымды және генетикалық зерттеулерде пайдаланылуы ықтимал ауыр металдарға төзімді донорларды ұсынуға мүмкіндік береді. Арпа – жануарларға арналған концентрацияланған өнім болып саналады, себебі құрамы крахмалға және белокқа бай. Арпаның дәні аминқышқылдарымен қоса белок, басқа затпен алмастыруға болмайтын лизин мен триптофан, басқа дақылдарға қарағанда жақсы сақталған. Арпа Қазақстан бойынша өсірілуі жағынан бидайдан кейін екінші орында тұр. Шығыс Қазақстан өңірі арпа дәнін өсіруге қолайлы және сұранысқа ие. Алайда тамырлары ауыр металмен зақымданғандықтан, өнімнің қолданысқа енуіне әсер тигізді. Бұдан шығудың тиімді жолдары толерантты (шыдамдылық) түрді аталған дақыл генін генетикалық және физиологиялық тұрғыда сыртқы әсерден сақтап қалу. Генотипті идентификациялау – өсімдіктердің ауыр металдарға қарсы өсетін, өнертабыстың жаңа, ғылыми зерттелмеген бағыты.

Түйін сөздер: ауыр металл, арпа дәні, фитотұрақтылық, генотип.

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УРОЖАЙНОСТЬ И АККУМУЛЯЦИЯ ТЯЖЕЛЫХ МЕТАЛЛОВ В ЗЕРНЕ РАЗЛИЧНЫХ ГЕНОТИПОВ ЯРОВОГО ЯЧМЕНЯ В УСЛОВИЯХ ЗАГРЯЗНЕНИЯ ПОЧВЫ МЕДЬЮ И СВИНЦОМ

Аннотация. Загрязнение среды, особенно химическими веществами, является одним из самых сильных факторов нарушения компонентов биосферы. В настоящее время в биосферу поступает множество загрязнителей. Среди них – значительные тяжелые металлы. Среди химических элементов наиболее токсичными являются тяжелые металлы. Опасность повышения содержания тяжелых металлов в почве и тяжелых металлов в атмосфере связана с активными всасываниями и скоплением растений, которые не только отрицательно влияют на их активные действия, но и угрожают здоровью человека и животных. Опасность металлов заключается в том, что они обладают кумулятивным действием и сохраняют эти токсичные свойства в течение длительного времени. В связи с задачей изучения генофонда культурных растений в условиях техногенного загрязнения было исследование металлостойкости сортов ячменя с целью выявления перспективных форм для выращивания в Восточно-Казахстанском регионе, а также селекционных доноров, собирающих минимальное количество загрязнителей. Полученные результаты позволяют предложить устойчивых к тяжелым металлам доноров, которые могут быть использованы в племенных и генетических исследованиях. Ячмень является концентрированным продуктом для животных, так как состав богат крахмалом и белком. Семена ячменя, наряду с аминокислотами, белок, лизин и триптофан, которые не могут быть заменены другим веществом, сохранены лучше, чем в других культурах. Ячмень по Казахстану занимает второе место после пшеницы. Восточно-Казахстанский регион благоприятен и востребован для выращивания ячменя. Однако поражение сосудов тяжелым металлом повлияло на ввод продукции в действие. Наиболее эффективными путями выхода из этого являются предотвращение генетического и

физиологического воздействия генов этих культур толерантного (выносливого) вида. Идентификация генотипов является новым, научно неизученным направлением изобретений таких продуктов, которые растут против тяжелых металлов растений.

Ключевые слова: тяжелый металл, зерно ячменя, фитостабилизация, генотип.

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