PRODUCTIVITY AND ACCUMULATION OF HEAVY METALS IN GRAIN OF VARIOUS GENOTYPES OF SPRING DURUM WHEAT UNDER CONDITIONS OF SOIL CONTAMINATION WITH CADMIUM AND ZINC

The developed industry has an adverse effect on the ecological state of the environment, accompanied by the accumulation of harmful substances in the soil, including heavy metals. Therefore, the creation of technogenically resistant varieties of agricultural crops is one of the components of environmentally friendly technologies. This study is aimed at studying various genotypes of spring durum wheat for their resistance to the accumulation of cadmium and zinc in grain, which is a commercial part of the product. The content of the studied heavy metals in the soil of the root zone of various genotypes of spring durum wheat was investigated. The accumulation of the studied elements in seeds was determined, which is the most important studied indicator. The indices of productivity and survival of spring durum wheat genotypes were investigated in the field of natural pollution of the environment with heavy metals. The most stable and sensitive to the action of cadmium and zinc genotypes were revealed. The structure of spring wheat productivity from the collection and the relationship of its elements were analyzed. The identified resistant genotypes are recommended for further study of their productivity and survival in weather conditions of the East Kazakhstan region in field experiments to identify forms promising for agricultural production.

Key words: cadmium, zinc, spring durum wheat.
Урожайность и накопление тяжелых металлов в зерне различных генотипов яровой твердой пшеницы в условиях загрязнения почвы кадмием и цинком

Развитая промышленность оказывает неблагоприятное воздействие на экологическое состояние окружающей среды, сопровождающееся накоплением в почве вредных веществ, в том числе тяжелых металлов. Поэтому создание техногенно-устойчивых сортов сельскохозяйственных культур является одной из составляющих экологически чистых технологий. Данное исследование направлено на изучение различных генотипов яровой твердой пшеницы по их устойчивости к накоплению кадмия и цинка в зерне, которая является товарной частью продукции. Было исследовано содержание изучаемых тяжелых металлов в почве прикорневой зоны различных генотипов яровой твердой пшеницы. Определены накопления изучаемых элементов в семенах, что является наиболее важным исследуемым показателем. Также были изучены показатели урожайности и выживаемости генотипов яровой твердой пшеницы в полевых условиях естественного загрязнения среды тяжелыми металлами. Выявлены наиболее устойчивые и чувствительные к действию кадмия и цинка генотипы. Проведен анализ структуры урожайности яровой пшеницы из коллекции и взаимосвязь ее элементов. Выявленные устойчивые генотипы рекомендованы для дальнейшего изучения их урожайности и выживаемости в погодных условиях Восточно-Казахстанского региона в полевых экспериментах для выявления перспективных для сельскохозяйственного производства форм.

Ключевые слова: кадмий, цинк, яровая твердая пшеница.

Introduction

The mining industry and metallurgy are well developed in Kazakhstan, however, the developed industry has an adverse impact on the ecological state of the environment, accompanied by the accumulation of harmful substances in the soil, including heavy metals. Soils of agrocenoses may also be contaminated. So, for example, it was noted that in regions where ferrous metallurgy is developed, soil pollution with lead is 3, and zinc is 2 times higher than on unpolluted soils, while the accumulation of heavy metals by agricultural plants is 1.5 – 2.0 times higher than their maximum permissible concentration (MPC) for soil. Metal compounds emitted into the air by industrial enterprises in the form of dust settle on the soil, plants at a distance of 10-40 km from pollution sources [1].

The study of lead content in the soil and plants of wheat and potatoes in the zone of influence of enterprises of the West Siberian industrial region showed that chernozems annually accumulate this element in amounts exceeding the MPC by 2.0-5.4 times, and plants – by 1.5-2.8 times. At the same time, in the area of maximum distribution of dust aerosols, an increasing increase in metal occurs both in the soil and in plants. Thus, in the third year of observations, the highest concentration of metal in the soil was 54 mg / kg, in plants – 2.8 mg / kg.

compared with its concentration in the first year of observation – 20 mg / kg and 1 mg / kg 20 mg / kg, respectively [2].

There is also information that very high concentrations of Cd, Pb and Zn were found in plants and soils adjacent to smelters [3]. As a result of the activity of the zinc smelting plant, the soils turned out to be heavily contaminated with zinc, lead and cadmium, the gross amount of metals in the soil within a radius of 1.5 km from the enterprise exceeded the MPC: for zinc 4-10 times, for lead 2-4 times, for cadmium – in 4 times. In crop production, the maximum concentrations of zinc and cadmium were detected in almost all crops, which is an environmental hazard and worsens the quality of agricultural products [4].

Excessive amounts of heavy metals in the soil affect the productivity of agricultural plants and the quality of the products obtained. For example, an increase in the level of soil contamination with cadmium led to a decrease in yield by 21-34% compared to the control variant, and to a decrease in the removal of basic nutrients. A.O. Shumilin showed that at background values of the cadmium content in the soil, about 0.1 mg of cadmium per kilogram of dry weight was accumulated in the seeds of spring wheat; with an increase in the cadmium content by 10 mg / kg of soil, its content in the grain increased 23 times, and with the cadmium
content in soil at the level of 50 mg / kg of soil – 55 times [5].

The presence of polluting trace elements can have a huge impact on the state of the biosphere. Violation of mineral metabolism and, as a result, an imbalance of chemical elements in food products, is the main cause and trigger mechanism for the occurrence and development of many diseases of humans and animals [6]. Scientists are of the opinion that the bulk of heavy metals enters the human body with plant food [7]. Zinc and copper are recognized as essential, that is, vital elements, but, as toxicants, they are classified as hazard classes I and II. Lead and cadmium are pollutants that can be toxic to the body [8].

Due to the fact that large areas are contaminated with heavy metals and methods of soil cleaning are ineffective, a promising direction for solving this problem is the search for varieties of agricultural crops with a reduced level of their accumulation in the commercial part of plants in order to grow in contaminated areas or selection in this direction, there is information that a different ability to accumulate cadmium was revealed in varieties of soft and durum wheat [9, 10]. Therefore, the purpose of our work was to study various genotypes of spring durum wheat for their resistance to the accumulation of cadmium and zinc in grain, which is a commercial part of the product.

Materials and methods

The object of research in this work is the genotypes of spring durum wheat from the collection of the East Kazakhstan Research Institute of Agriculture. The experiment studied varieties and genotypes of spring durum wheat: Nauryz, Lan, GVK (East Kazakhstan genotype)-10008, GVK-19005, GVK-5/14.

Growing plants in conditions of natural pollution. Plants were grown in nurseries of primary seed growing of the research site of the East Kazakhstan Research Institute of Agriculture, in conditions of natural 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 triplicate. Sowing is mechanized, plotting, the seeding rate is 5-6 million germinating grains per hectare. 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, widespread in the foothill-steppe zone. The soil of the experimental plot is neutral (pH 7.0). The humus content in the arable horizon averages 2.6%. The soil is moderately supplied with easily assimilable nitrogen (22.6-18.4 mg / kg soil), highly supplied with mobile potassium (390-400 mg / kg soil) and low supplied with mobile phosphorus (16.3-18.5 mg / kg soil).

The predecessor – black fallow after autumn 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 East Kazakhstan. Early spring harrowing, cultivation, pre-sowing cultivation. Plant care (rolling, weeding by hand).

Determination of the content of heavy metals in the soil of the root zone and in the 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 the solutions of the substances used 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 passage of light through a combustible gas flame and its absorption by the atoms of the investigated element is recorded photoelectrically. Samples of grain and soil in the root zone taken in the field of natural soil contamination with heavy metals were ashed in a muffle furnace. The ash material was treated with nitric and hydrochloric acids and water was added. The atomic absorption of the test and control samples was measured using an atomic absorption spectrophotometer [11, 12, 13].

Determination of plant survival. To determine the survival rate of plants, the number of spring durum wheat plants emerging and remaining before harvesting was calculated per unit area. By the difference between these indicators, one can judge the survival rate of plants during the spring-summer growing season.

Determination of vegetative indicators and productivity in conditions of natural environmental pollution.

Phenological observations, field and laboratory assessments, records were carried out according to generally accepted methods [14, 15].

Observations were carried out for the following developmental phases – seedlings, tillering, renewal of vegetation, tube emergence, heading, flowering, ripeness.

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

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

\[
\frac{C \times 100}{A} = \frac{B}{2}
\]

where: \(A\) – the number of plants preserved for harvesting, %; \(B\) – the number of plants in the full germination phase, pcs. per \(m^2\); \(C\) – the number of plants to be harvested, pcs. per \(1 m^2\).

The yield was determined by a direct gravimetric method. The grain moisture was determined by the gravimetric method. From each plot, grain samples are taken into 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 the calculation is carried out using the formula:

\[
X = \frac{B}{H}
\]

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

The standard 14% humidity is recalculated according to the formula:

\[
X = \frac{Y \times (100 - b)}{100 - c},
\]

where: \(X\) – yield reduced to standard moisture content; \(Y\) is the yield obtained; \(b\) – moisture content of the crop (%); \(c\) – standard humidity for this object.

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

**Research results and discussion**

First of all, the content of the studied heavy metals in the soil of the root zone of various genotypes of spring durum wheat was investigated. With prolonged intake of heavy metals from emission sources into the atmosphere, a significant amount of them accumulates on the soil surface. The mining and processing of metal ores, coupled with industry, have led many countries to widespread metal contaminants in the soil. During mining, tailings (heavier and larger particles deposited on the bottom of the flotation machine during mining) are directly discharged into natural depressions, including wetlands, resulting in increased concentrations of heavy metals [16]. Most of the heavy metals are emitted into the atmosphere in the form of solid aerosols with particles of 0.1 – 0.5 microns. The bulk of emissions settles near the source of pollution, quickly enters the surface of soil and plants, is carried out and migrates with surface and ground runoff. As a result, technogenic geochemical regions of heavy metals are formed [17].

Soil contamination with cadmium is one of the most dangerous environmental phenomena [17]. In terms of its effect on the natural environment and humans, cadmium is of particular concern due to its potential harm, therefore, in various environmental programs it is classified as a priority pollutant to be controlled [18].

The results of the study of the cadmium content in the soil of the root zone showed that in relation to the MPC of cadmium in the soil, there is an excess of one and a half, two and a half times.

![Cadmium content in the soil](image)

**Figure 1** – The content of cadmium in the soil of the root zone of various wheat genotypes in relation to the MPC
The ratio of the cadmium content in the soil of the root zone to the Regional Clark was also determined. There is an opinion that the content of elements in the topsoil should be compared with the background [19, 20]. Some researchers understand the “background” as proposed by A.P. Vinogradov “clarks” – the average content of elements in the biosphere, others – the average regional content of chemicals in soils that have not experienced anthropogenic impact, that is, unpolluted areas [21]. In East Kazakhstan, all soils are experiencing, to one degree or another, a technogenic impact, taking into account this circumstance, in our studies we compare the content of heavy metals with “clarks.” Studies have shown that in relation to Regional Clark, the excess of the metal content has higher values, than in relation to MPC (approximately 2.5 -3.5 times).

![Cadmium content in the soil](image)

**Figure 2** – The content of cadmium in the soil of the root zone of various wheat genotypes in relation to Regional Clark

The content of zinc in the soil of the root zone of various genotypes of spring wheat was also investigated (Figures 3, 4).

Intensive mining and smelting of lead-zinc ores and zinc leads to soil contamination, which poses a threat to human health and the environment. Many methods of reclamation of these areas are long and expensive and cannot restore soil productivity. The environmental risk of soil heavy metals to humans is associated with their bioavailability [22]. The presence of the mining and metallurgical industry in East Kazakhstan also causes polymetallic soil pollution.

The results of the study of the zinc content showed that in relation to MPC of zinc in the soil, there is an excess of 1.8 -1.9 times (Figure 3).

![Zinc content in the soil](image)

**Figure 3** – The content of zinc in the soil of the root zone of various wheat genotypes in relation to the MPC
The ratio of the zinc content in the soil of the root zone to the Regional Clark was also determined. Studies have shown that in relation to Regional Clark, the excess of zinc content has lower values than in relation to MPC (approximately 1.42 - 1.53 times).

Thus, all studied genotypes are stressed by the increased content of cadmium and zinc in the soil. At the same time, the content of cadmium makes a greater contribution to stress, since compared to its natural content in the region, the excess is 2.5-3.5 times, while zinc is about 1.5 times.

Determination of the accumulation of the studied elements in seeds is the most important studied indicator, since wheat grain is used in the food industry.

Our studies have shown that zinc ions accumulate in seeds of all genotypes of spring durum wheat and their amount exceeds the MPC for grain by about two and a half times. Less, in comparison with other genotypes, accumulates zinc ions of the Lan genotype, most of all – the GVK-19005 genotype, the other genotypes of spring durum wheat show average values of the content of this element (Figure 5).

The study of the content of cadmium ions in seeds of spring durum wheat showed that this metal accumulates and its amount exceeds the MPC for grain for all studied genotypes, except for the GVK-10008 genotype. At the same time, there are significant differences between the genotypes of spring durum wheat in terms of cadmium content in seeds (Figure 6).
According to the number of cadmium ions accumulated in seeds of plants of various genotypes of spring durum wheat, they can be arranged in the following order as they decrease: GVK-19005 > Lan > GVK-5/14 > Nauryz > GVK 10008. The smallest amount of cadmium in seeds contains genotype GVK-10008, the largest – genotype GVK-19005.

The same data were obtained in other studies, for example, cadmium in quantities significantly exceeding the MPC established for cereals (0.2 mg/kg dry weight) was found in grain of wheat, rice and barley when growing these species on soils containing metal [23, 24, 25]. When the soil was contaminated with 50 mg/kg of cadmium, the weight and grain size of grain decreased by 20%, and with an increase in the content of cadmium to 100 mg/kg of soil, the resulting grain was feeble [26, 27]. Most organisms do not have a defense mechanism specific for heavy metals, however, there are several systems for controlling the intake of toxic elements in plants [28]. The first barrier to the entry of heavy metals from the soil into the aboveground part is the cover tissue of the roots, which has a significant selective adsorption capacity [29]. When toxic elements penetrate into the cytoplasm of plant cells, chelate compounds are formed with almost 90% of the metals entering the cell [30]. An important role in the resistance to cadmium accumulation in plants is played by vacuolar compartment or the binding of toxicants by cell walls in leaves; phytochelatins, metal-binding peptides, are part of the system for detoxification of heavy metals [31, 32, 33]. Apparently, similar mechanisms are present in the GVK-10008 genotype. In plants, reproductive organs are especially well protected. However, this rule is not always true for cadmium; there is evidence of a greater accumulation of the element in the grain of winter wheat compared to the stems [34].

Tolerance to heavy metals in plants is genetically controlled and has a certain capacity. When the ability of the roots to retain toxic elements is exhausted, metals enter the leaves and fruits. The accumulation of lead, cadmium, zinc, copper above a certain threshold level causes serious disturbances in the metabolic process and leads to a noticeable decrease in yield and product quality. Heavy metals cause numerous changes in plants at different levels: molecular, subcellular, cellular, tissue and organismal [35]. The toxicity of these elements is manifested in a decrease in the activity of enzymes, mainly alkaline phosphatase, catalase, oxidase, ribonuclease, nitrate reductase [36, 37]. When interacting with phosphate-sulfate ions, lead and cadmium form precipitates, with metabolic products enter into a complexation reaction, reduce the intake of potassium and iron into the plant, causing chlorosis and wilting. The ability of lead and cadmium to replace some metals in metal-protein complexes of enzymes is noted, disrupting their most important functional roles [38, 39]. Cadmium is especially dangerous for plants, because, having chemical properties close to those of zinc, it can play its role in many biochemical processes, causing their disruption [40].

Entering plants and accumulating in large quantities in organs that are used for food, they pose a potential risk to human health [41]. Industrial gaseous emissions are one of the main reasons for the high cadmium content in food, and cadmium is also extremely easily transferred from soil to plants. Cadmium is excreted for a very long time from the
body, displaces calcium from the bones, provoking the development of osteoporosis, bone deformation and curvature of the spine. Has a pronounced toxic effect on the sex glands, affects the nervous system. It accumulates in the liver and kidneys. The carcinogenic effect of cadmium compounds increases the risk of developing cancer [35].

In areas experiencing an intense technogenic impact on soil and plants, it is necessary to improve the specialization of agriculture, to conduct a careful selection of crops and varieties with increased resistance to polluting heavy metals [42, 1]. Soils containing toxic elements in concentrations (mg / kg): zinc – 200, lead – 20, chromium – 100, nickel – 50, vanadium – 50, cadmium – 3, cobalt – 50, copper – 100, molybdenum – 5 should be removed for industrial crops and cereal crops resistant to toxic effects [1]. The possibility of selecting crops and varieties with increased resistance to polluting heavy metals is confirmed by studies, so the study of soft wheat varieties according to the level of accumulation of heavy metals in grain revealed 5 varieties with a reduced level of accumulation of Cd in grain, 11 – Pb, 7 – Ni and 7 – Cr (VI). Among them, Karavajj and Legenda from Belarus, Korund and Altos from Germany were characterized by a reduced level of accumulation of both Cd, Pb, and Ni, variety Zavet (Belarus) – Pb, Ni, and Cr, and variety Shhara (Belarus) – all four studied heavy metals. Some varieties from Sweden, Belarus, and Russia accumulated a low amount of Cr (VI) [43]. Thus, zinc ions are contained in seeds of spring durum wheat in quantities exceeding the maximum permissible concentration of zinc for grain and there are no large differences between genotypes for this parameter. The cadmium content in seeds of spring durum wheat also exceeds the MPC for grain, with the exception of the GVK-10008 genotype. This genotype of spring durum wheat can be recommended for use in breeding and genetic research as a donor of cadmium resistance.

Metal-resistant varieties and genotypes should also be characterized by high resistance to unfavorable weather conditions of spring and summer vegetation, in particular to drought, as well as the ability to maintain a high yield in conditions of soil contamination with heavy metals. For this purpose, the indicators of productivity and survival of spring durum wheat genotypes were studied in field conditions of natural pollution of the environment with heavy metals.

To determine the survival rate of plants, the number of spring durum wheat plants emerging and remaining before harvesting was calculated per unit area. By the difference between these indicators, one can judge the survival rate of plants during the spring-summer growing season.

Studies have shown that the number of plants in the period before harvesting decreases in all genotypes of spring durum wheat, compared to their number in the period before tillering (Figure 7).

Analysis of the data (Figure 8) allows us to conclude that the largest number of dead plants during the spring-summer growing season is observed in the Nauryz variety (10.8%), which indicates their low adaptive ability to the effects of external environmental factors. An average reduction in the number of plants was found in the GVK-10008 genotypes and the Lan variety (7.6...
and 8.6%, respectively). The smallest losses in relation to the number of surviving plants during the spring-summer growing season belong to the genotypes of durum wheat GVK-5/14 and GVK-19005, the seedlings of which decreased only by 5.4 and 6.0%.

![Plant survival during the growing season](image)

**Figure 8** – Survival of plants of various genotypes of spring durum wheat during the growing season

The next stage of our research was to analyze the structure of the yield of spring wheat from the collection of the East Kazakhstan Research Institute of Agriculture and the relationship of its elements. Productivity is the most important and complex quantitative trait, the sum total of the result of plant development during the growing season. By the structure of the harvest, it is possible to identify the main factors in the formation of the harvest and to judge the nature of their influence. In the course of our study, important economically valuable traits associated with the yield of wheat genotypes were analyzed. Optimal parameters of the main elements of the yield structure correspond to a high level of yield. Elements of the spring wheat yield structure are formed in certain phenological phases.

It is known from the literature that when the soil was contaminated with 50 mg / kg of cadmium, the weight and grain size of grain decreased by 20%, and when the content of cadmium increased to 100 mg / kg of soil, the resulting grain was shriveled [44, 45]. Under the influence of cadmium, the number of seeds per ear decreased in winter barley, and in the presence of zinc, in spring barley [41]. Conducted by N.M. Kaznina’s experiments showed that with an increase in the concentration of cadmium in the substrate in spring barley, the length and biomass of an ear, as well as the number of spikelets in an ear, decrease, which affects the potential and real seed productivity of plants [46]. It was revealed that under the influence of cadmium, the processes of formation and development of the reproductive sphere of plants are inhibited due to a decrease in the number of rudimentary flowers as a result of a decrease in the intensity of cell division, as well as the processes of realization of flowers into grain [47]. The study of the effect of cadmium on wheat yield showed that against the background of 10 mg / kg of cadmium in the soil, the processes of formation of generative organs are more disturbed, with a dose of cadmium of 50 mg / kg of soil – the intensity of the accumulation of vegetative mass. This leads to a decrease in the share of grain in the structure of the crop [5].

A very important indicator is productive tillering, it shows the ability of plants to form productive side shoots, which make a significant contribution to the overall yield of the variety (Figure 9).

According to our research, the GVK-5/14 genotypes have the highest productive tillering among the studied spring wheat genotypes (Figure 9). Among the studied genotypes, GVK-19005 and GVK-10008 have an average productive tillering, while Nauryz and Lan durum wheat varieties have a lower level.

One of the tasks of our study was to determine the mass of 1000 grains of the studied genotypes of spring durum wheat from the collection of the East Kazakhstan Research Institute of Agriculture, to determine their productivity. The mass of 1000 grains characterizes the amount of substances contained in
the grain, this indicator is closely related to the size and completeness of the grain. The grain size, an important agronomic trait, is given great attention in breeding and genetic research. The degree of development of a trait of the mass of 1000 grains is largely determined by the genotype in combination with external conditions during the period of grain formation [48].

According to our research, the genotypes of spring durum wheat GVK-5/14 and GVK-19005 (42.3 and 41.7 g, respectively) are characterized by the largest mass of 1000 grains. The genotypes GVK-10008 and the Lan durum wheat variety (40.2 g) are characterized by an average weight of 1000 grains. The durum wheat variety Nauryz is characterized by the smallest mass of 1000 grains.

Productivity, as well as morphometric indicators, is the most important indicator of the productivity and adaptive capabilities of the variety. In this regard, in the course of our research, it has been assigned one of the key places. In the course of our study, the yield was calculated (Figure 11), which is the largest in the genotype of spring durum wheat GVK-5/14. This is most likely due to the highest mass of lateral stems and 1000 grains, and the highest productivity and survival during the spring-summer vegetation period among the studied durum wheat genotypes.

In terms of yield, the genotype of spring durum wheat GVK-19005 ranks second after GVK-5/14.
The high yield of this genotype can be associated with good productive tillering and survival, as well as a rather high weight of the main spike, side shoots and 1000 grains. For all these indicators, the GVK-19005 genotype ranks second among the studied genotypes.

The third place in terms of productivity is occupied by the spring durum wheat variety Lan, which is characterized by the highest mass of the main spike and the number of grains per ear, but at the same time has an average weight of 1000 grains, low productive bushiness, the weight of grains of lateral shoots and survival during the spring-summer growing season.

The genotype GVK-10008 shows an average yield, it is characterized by an average survival rate during the growing season, an average productive tillering and an average number of grains per ear, but has a low grain weight of the main spike and side shoots (Figure 8, 10).

The lowest yield was found by the spring durum wheat variety Nauryz, it has average grain mass of the main spike and side shoots, but a small mass of 1000 grains and the lowest survival rate during the spring-summer growing season.

Thus, it can be concluded that the main role in the formation of yield is played not only by the mass of the main spike and side shoots, but also by the sufficient survival of plants during the spring-summer growing season.

**Conclusion**

1. Under conditions of soil contamination with zinc and cadmium ions, their content in seeds of various genotypes of spring durum wheat exceeds the MPC for grain, except for the content of cadmium in seeds of the GVK-10008 genotype.

2. Genotype GVK-10008 of spring durum wheat can be recommended for use in selection and genetic research as a donor of cadmium resistance.

3. The main role in the formation of productivity under conditions of polycyclic soil contamination is played not only by the mass of the main spike and side shoots, but also by the sufficient survival of plants during the spring-summer growing season.

**Conflict of interest**

All authors have read and are familiar with the content of the article and have no conflicts of interest.

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