ARTICLES

EFFECT OF ZINC CONTAMINATED SOIL ON THE SEEDS PROGENY ABOUT BARLEY

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The rapid accumulation of heavy metals in fertile soils leads to a decrease in productivity and a deterioration in the properties of agricultural products and even a deterioration in the microbiological activity of soils. Zinc is both an important trace element, as well as a very toxic substance for plants, which quickly accumulates both in the soil and in the plants themselves. Although the direct effect of elevated soil zinc concentrations on plants is well understood, little is known about its effect on seedlings of plants. This work shows that increased Zn concentrations in soils can have a negative effect on the quality of barley seed progeny – reduce the mitotic activity of cells and increase the frequency of mitotic abnormalities in seedlings, which reduces the quality of the seed. But since zinc is also a biologically important element necessary for the normal growth and development of plants, its microconcentrations in the soil contribute to a significant increase in the germination energy of seeds grown on these soils of plants and thereby increase their quality. The greatest influence of zinc on the quality properties of seeds and the frequency of mitotic anomalies in their seedlings is observed on sod-podzolic soils.

Keywords: zinc, barley, mitotic anomalies, vegetation, seed quality

Soil pollution with HM is a serious and global environmental problem [1, 2], posing a very serious threat to the stability of the yields and the quality of crop products. It is necessary to determine the reliability of plant protection against the harmful effects of heavy metals (HM) not only by the growth characteristics and the process of development of the plants themselves, but also by the quality of their offspring, since this is one of the most significant indicators of the stability of populations. But, unfortunately, now the number of detailed laboratory studies impact research of HMs on plant offspring is very small. This led to the fact that there is no clear understanding of how dangerous heavy metals are for the second generation of plants and for the stability of populations. Of course, there are many field studies of the influence of HM on seed offspring, but in such studies it is difficult to isolate and quantify the influence of one particular factor. Among HMs, Zn is considered one of the most dangerous pollutants for agriculture because of its high rate of accumulation in soils and then in plants [1]. Although Zn is an important microelement for plants, in high toxic concentrations it inhibits plant growth and development and thereby significantly reduces the yield and quality of seeds, which makes the determination of optimal as well as maximum permissible concentrations of zinc in the environment a very urgent agrochemical task. Indicators based on the study of growth processes and mitotic anomalies are widely and effectively used to assess the effect of heavy metals on plant organisms. A decrease in the intensity of plant development processes is considered a very important criterion for assessing the risk of exposure to HM. Methods for analyzing mitotic anomalies in plants are considered to be the most suitable for assessing the mutagenic risk of HM. [3]. They give reliable and well-reproducible results in experiments, and also make it possible to detect unfavorable processes at the early stages of the development of plant reactions to an unfavorable effect. In this regard, the determination of the regularities of the appearance of mitotic anomalies and changes in the intensity of growth and development of plants with soil contamination with heavy metals is a very important stage of research, providing information necessary for substantiating and making decisions on environmental issues and agricultural problems.

The presented work is devoted to the assessment of the qualitative characteristics of seeds obtained from plants grown on soils with different levels of contamination with zinc nitrate.

Materials and research methods

Studied the germination and abnormalities of mitosis in the cells of the apical meristem of seedlings of seed progeny of barley (Hordeum vulgare L., cultivar Zazersky 85) obtained in a vegetation experiment on three types of soils with different degrees of zinc contamination: 1) cultivated sandy loam sod-podzolic soil (25 50 100 150 and 250 mg/kg air dry soil); 2) typical heavy loamy chernozem (50, 100, 250, 500 and 750 mg/kg air dry soil); 3) boggy lowland peat (250, 500 and 1000 mg/kg air dry soil). The seeds were germinated in a thermostat (21 °C) in Petri dishes on filter paper moistened with distilled water.

In the process of germination, their germination energy was determined on the third day after soaking the seeds. Seed shoots 1–1.5 cm long were fixed in acetoalcohol to fix the cells during the first mitoses. The squashed preparations were stained with acetoorcein. In the preparations, the number of dividing cells and the number of cells with mitotic abnormalities were counted (on average, 3-6 thousand anatelophases were analyzed for each variant). When analyzing the spectrum of disorders, chromatid (single), chromosomal (double) bridges and fragments, multipolar mitoses, and chromosome lagging were identified. The preparations were examined using Nicon Eclipse 55i and Nicon Eclipse E200 microscopes. Complex (unrecognizable) anomalies were excluded from the analysis. This is bind to the fact that aberrations formed in the vegetative phase (before flowering) were later lost during meiosis and only symmetrical inversions and translocations could be preserved. The activity of the process of cell division of the embryonic meristem of seeds was assessed by the mitotic index (MI%). For this purpose, the number of mitoses was recorded in all prepared preparations. The mitotic index (MI) is calculated by the formula: $MI = ((T + A + M + P) / (I + T + A + M + P)) * 100$, where: T is the number of dividing cells at the telophase stage; A is the number of dividing cells in anaphase; M is the number of dividing cells at the metaphase stage; P is the number of dividing cells at the prophase stage; I is the number of dividing cells in the interphase. The data obtained in the experiment were statistically analyzed in MS Excel. The method [4] was used to determine the sample size required to obtain statistically significant results. A check was carried out for emissions excluded from further consideration. The significance of differences between the samples was determined using the Student's test.

Research results and discussion

Reducing the viability of offspring is a very important and extremely dangerous consequence of exposure to heavy metals for plant populations reducing. It manifests itself in the morphological and physiological parameters of seeds. One of these indicators is the seed germination energy. It was found that the germination energy of barley seeds obtained from plants grown on soils contaminated with zinc nitrate tends to decrease with an increase in metal concentration in all studied soils ($r = 0.51–0.59$). However, at the same time, a low concentration of metal (25-250 mg / kg of dry air in the soil) is able to increase seed germination (Fig. 1).

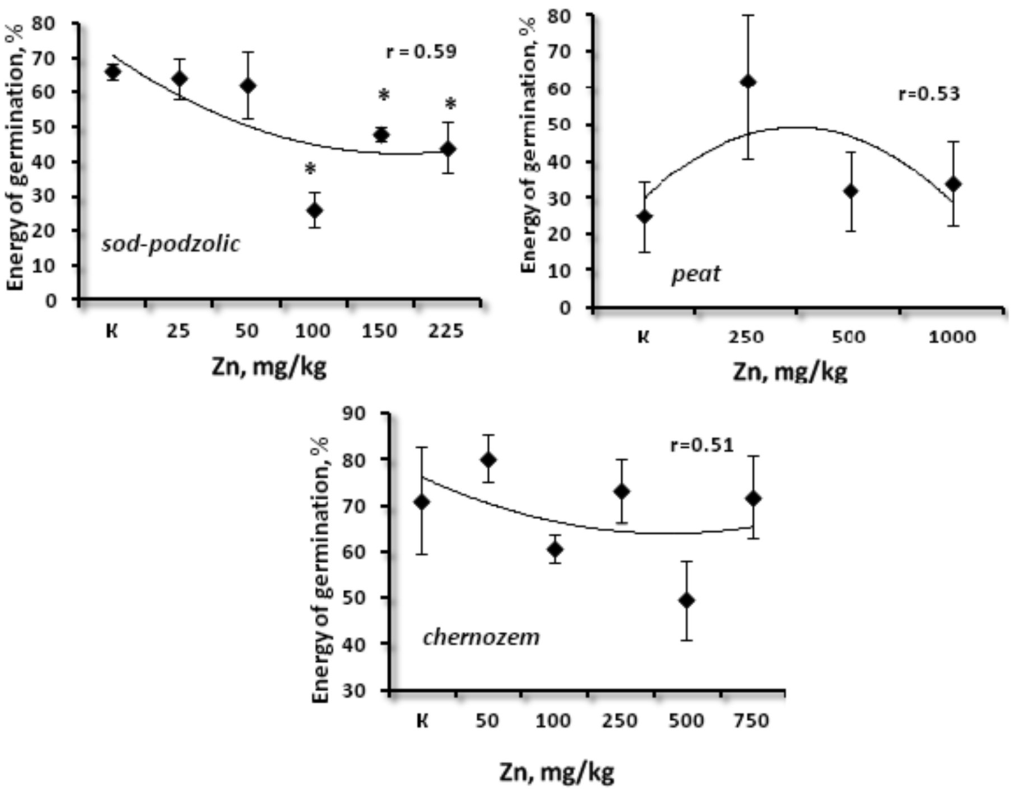

Fig. 1. Energy of germination of barley seeds.
Note. * – the difference is statistically significant from the control

The growth of seed germination is statistically significant on sod-podzolic and peat soils. Since zinc is a trace element necessary for oxidative and metabolic processes, the synthesis of enzymes, proteins, chlorophyll, the functioning of hereditary mechanisms for the formation of generative organs and seeds [5, 6], then insignificant levels of soil contamination can increase the germination of the resulting seed offspring. Only the excess of a certain critical level established for each plant species makes Zn toxic for them. Since the availability of zinc for plants depends on the properties of the soil, due to the high acidity, low volumes of cation exchange and the supply of humus in the seed progeny of barley obtained on sod-podzolic soil, a decrease in germination occurs with a significantly lower content of zinc.

The very first biological effects of soil contamination with HM can be found at the cellular level of organization. This was confirmed by the results of this study. The use of the method of cytogenetic analysis made it possible to reveal a statistically significant increase in the number of cytogenetic anomalies in seedlings obtained on soddy podzolic soil and chernozem. Seeds obtained on peat soils showed a tendency to an increase in the frequency of cytogenetic anomalies (Fig. 2). An increase in the frequency of anomalies in the cells of barley seedlings obtained on soddy-podzolic soils begins at significantly lower zinc concentrations than in peatlands or chernozems, since zinc is more available for plants [5].

Despite the fact that for toxicants, as a rule, there are no specific abnormalities of mitosis, which would not have been observed and without their influence in control, it is still generally accepted that heavy metals, including Zn, are able to induce genomic disorders to a greater extent [5]. The results obtained in this study confirm this opinion. In support of this, analysis of the spectrum of mitotic anomalies detected in the course of the study showed a tendency towards an increase in the frequency of genomic disorders [7].

Therefore the increased Zn concentration in soils and its high accumulation in plant seeds promote the growth of mutations in the resulting barley progeny.

TM, and especially zinc, also has the can reduce the rate of cell division; due to this, the degree of their toxicity can also be assessed by determining the mitotic index. Therefore, in barley seedlings during the study, the activity of mitotic cell division was assessed. A decrease in the frequency of mitotic cell division was statistically significant in barley seedlings obtained on sod-podzolic soil containing 225 mg of zinc nitrate per 1 kg (Fig. 3). In seedlings of seeds obtained on other soils, the mitotic activity of cells did not depend on the concentration of zinc.

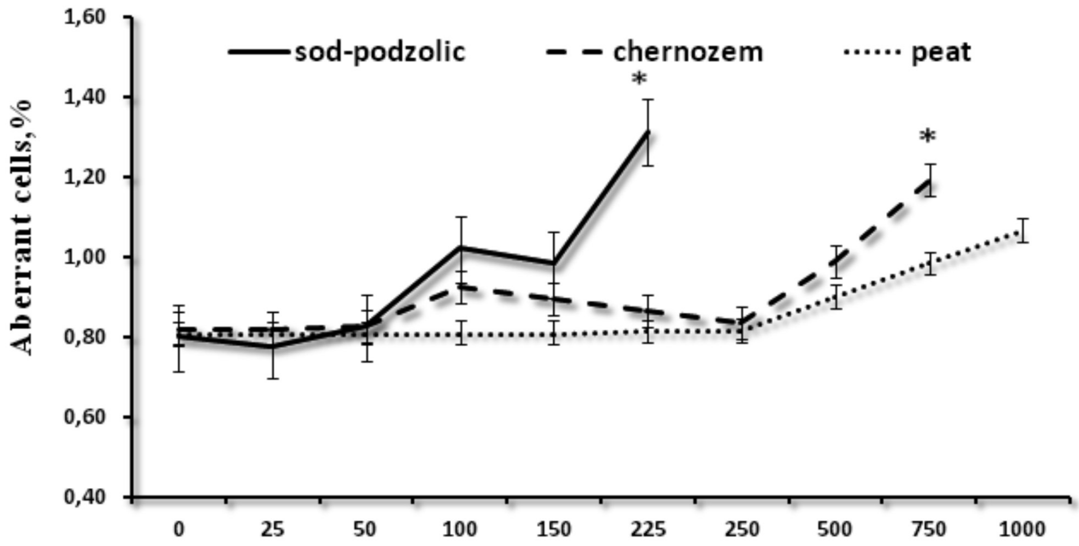

Fig. 2. Frequency of occurrence of mitotic anomalies in the cells of the root meristem of barley seedlings. * – the difference is statistically significant from the control

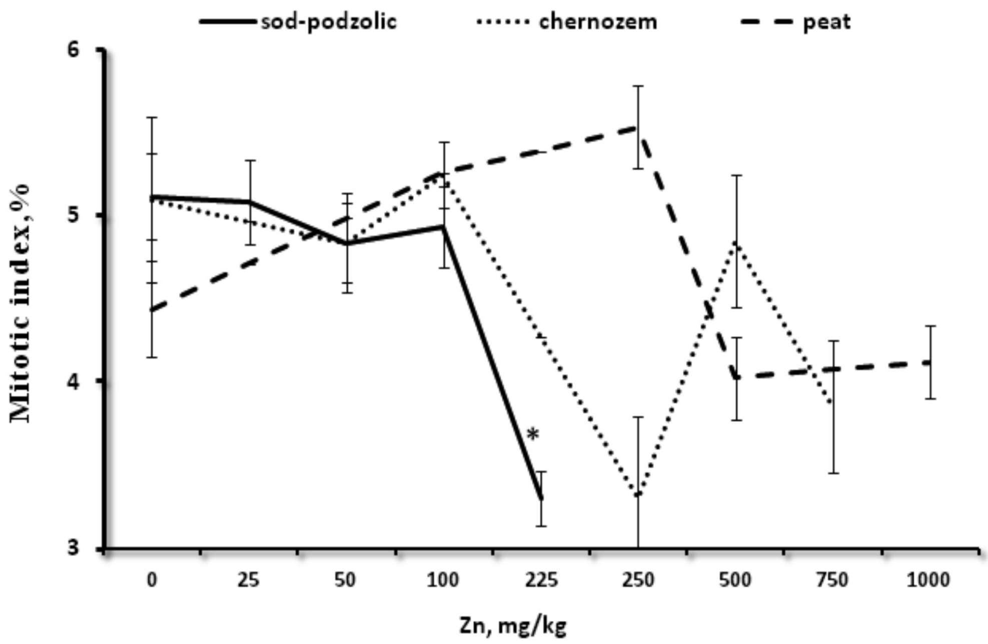

Fig. 3. Activity of mitotic division of cells of the root meristem of barley seedlings.
* – the difference is statistically significant from the control

Conclusion

Based on the results obtained, it can be said that small concentrations of zinc in the soils on which the barley crop was obtained have a positive effect on the germination of the seeds obtained. High concentrations can reduce seed germination, have a mutagenic effect on seed progeny, and reduce the mitotic activity of the cells of the root meristem. The toxic effect of zinc on barley seedlings depends on the type and agrochemical properties of the soil on which the crop was obtained.

References

1. Ilyin V.B. Heavy metals in the soil – plant system. Novosibirsk: Science. Sib. branch, 1991. 151 p.

2. Villiers F., Ducruix C., Hugouvieux V. et al. Investigating the plant response to cadmium exposure by proteomic and metabolomic approaches // Proteomics. 2011. V. 11. P. 1650–1663. DOI: 10.1002/pmic.201000645.

3. Evseeva T.I., Geraskin S.A., Vakhrusheva O.M. Assessment of the contribution of radiation and chemical factors to the formation of biological effects in the mouse pea population from the territory of storage of radium production wastes (Vodny settlement, Komi Republic) // Radiation biology. Radioecology. 2014. T. 54. No. 1. P. 85-96. DOI: 10.7868/s0869803114010068.

4. Lemeshko B.Yu., Gorbunova A.A., Lemeshko S.B., Postovalov S.N., Rogozhnikov A.P., Chimitova E.V. Computer modeling and investigation of probabilistic laws. // Bulletin of the Tomsk State University. 2013. No. 1 (22). P. 74-85. DOI: 10.18799/24131830/2020/9/2806.

5. Micieta K., Murin G. Three species of genus Pinus suitable as bioindicators of polluted environment // Water, Air, Soil Pollution. 1998. V. 104. P. 413-422.

6. Titov A.F., Kaznina N.M., Talanova V.V. Heavy metals and plants. Petrozavodsk: Karelian Scientific Center of RAS, 2014. 194 p. DOI: 10.31857/s0044459620020086.

7. Vasiliev D.V., Anisimov V.S., Anisimova L.N., Frigidova L.M. Zinc delivery into barley plants on different types of soils and its influence on the quality of harvest seeds. Trends in the development of science and education. 2019. No. 50-3. P. 51-57. DOI: 10.18411/lj-05-2019-53.