Reducing Heavy Metal Accumulation in Spring Wheat Grain using Plant Growth Regulators

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Abstract. In the context of increasing anthropogenic impact on the environment, the problem of crop contamination with heavy metals is becoming increasingly important. Heavy metals such as lead, cadmium, mercury and others can accumulate in soil, water and plants, including grain crops. This can lead to a decrease in the quality of products, which can be potentially hazardous to human health. The studies examined the effect of growth regulators on reducing the level of accumulation of heavy metals in spring wheat grain. Experiments have shown that the use of Biodux and organomineral biopreparation can help reduce the content of heavy metals in wheat grain. The results of the study open up new opportunities for agricultural professionals to enhance product quality using growth regulators. These findings suggest that growth regulators can effectively minimize the risk of heavy metal contamination in crops, making them a valuable tool for spring wheat cultivation. By modifying physiological processes and enhancing plant defense mechanisms, this technology contributes to both improved product quality and environmental protection.

1 Introduction

In the modern era, anthropogenic activities have led to significant environmental pollution, which is a major determinant of ecosystem functioning and human well-being. The natural development of ecosystems and changes in their functioning under anthropogenic pressures are influenced by the nature and magnitude of the impacts, as well as their temporal characteristics. [1]

Agricultural production is increasingly vulnerable to anthropogenic stressors, which significantly impact soil properties, plant productivity, and product quality. Heavy metals, in particular, pose a significant threat to environmental sustainability and human health. [2]

Soil contamination by heavy metals can result from various human activities, including mining and mineral processing, fuel combustion, waste disposal, and industrial production. [3]

Heavy metals can accumulate in soil through atmospheric deposition, surface runoff, and industrial emissions, posing a significant threat to environmental sustainability and human health. [4], [5]

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Regions with heavy metal-polluted soils are often located near large industrial facilities, mining and processing plants. In Russia, examples of such regions include industrial centers in the Ural, Siberia, and Far East. Additionally, soil pollution is observed in some agricultural regions where fertilizers and pesticides are applied.[6]

In the face of increasing anthropogenic pollution, it is essential to prioritize the environmental aspects of agricultural production. Developing and implementing novel technologies and methods that mitigate the negative environmental impact and enhance product quality are crucial [7], [8].

One potential solution to the problem of heavy metal toxicity in agricultural crops is the application of growth promoters. Most modern growth promoters are derived from plant or natural sources and can induce significant changes in plant physiology at low concentrations [9].

Purpose of research: The primary objective of this investigation was to elucidate the impact of plant growth regulator application on the heavy metal accumulation in the grain of spring wheat variety Radmira.

2 Materials and Methods

The study focused on soft spring wheat (Triticum aestivum L.) of the Radmira variety, developed at the Federal State Budgetary Institution "Federal Research Center 'Nemchinovka'" using the Zlata and Ester varieties. Two plant growth promoters, Bidux and Organomineral biopreparation, were selected for this study to address the research questions.

Bidux is a preparation containing a complex of polyunsaturated fatty acid (PUFA) derived from the soil fungus Mortierella alpina. This PUFA complex induces non-specific resistance in plants to various pathogens, including fungi, bacteria, and viruses [10-11].

Organomineral biopreparation (OMB) is a liquid humic fertilizer that contains a minimum of nitrogen, potassium, phosphorus, humic acids, and micronutrients vital for plant growth and development [12].

A controlled environment experiment was carried out in a greenhouse at the Department of Agronomic, Biological Chemistry, and Radiology, Russian State Agrarian University named after K.A. Timiryazev, to examine the efficacy of plant growth promoters in enhancing the yield and quality of spring wheat cultivated in heavy metal-contaminated soil.

The experiment simulated different levels of soil contamination with heavy metals by adding chemically pure salts of cadmium, zinc, lead, and copper. Two doses were created: Dose 1 (D1), corresponding to the maximum allowable concentrations of these elements, and Dose 2 (D2), exceeding the maximum allowable concentrations by a factor of 2 [13].

Seeds were treated with the growth regulators Bidux and organomineral preparation by soaking them in a 1% solution for 1 hour.

The findings of this research can inform the creation of recommendations for the use of biostimulants in agricultural areas impacted by heavy metal soil pollution, a critical issue affecting regions situated on contaminated land [14].

Dry seeds were sown at a rate of 30 seeds per vessel, with subsequent thinning to 20 seeds per vessel at the tillering stage.

The experiment was replicated four times to ensure reliability.

The concentration of heavy metals in grain was determined using inductively coupled plasma atomic emission spectroscopy (ICP-AES) according to GOST ISO 22036-2014 [15].

The maximum allowable concentrations (MAC) of heavy metals in soil are as follows: Cd - 0.5 mg/kg; Zn - 23 mg/kg; Cu - 3 mg/kg; Pb - 32 mg/kg.

3 Results and Discussion

The results of the conducted research are presented in Figures 1-4. At background levels of heavy metal content, the application of growth regulators Biodyuks and organomineral biopreparation reduced cadmium concentrations in the grain of spring wheat variety Radmira (Figures 1). In the variant with the first level of pollution D1, Biodyuks preparation contributed to a 1.6-fold decrease in cadmium concentrations, while the application of OMP (organomineral biopreparation) resulted in a 1.5-fold decrease. In the variant with high-level pollution D2, Biodyuks preparation influenced cadmium accumulation in the grain of spring wheat, reducing its concentration by 1.7 times; organomineral biopreparation - by 1.5 times.

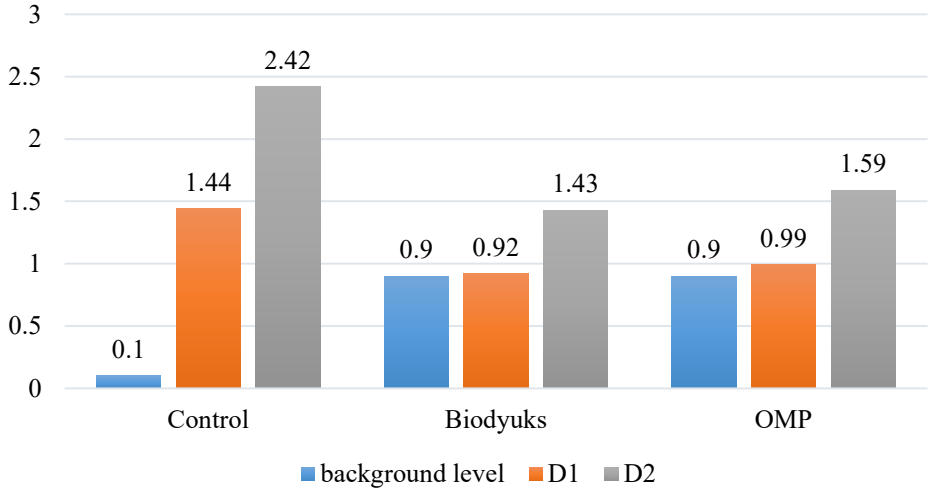

Fig. 1. Cadmium content in the grain of spring wheat variety Radmira, mg/kg.

Notably, at ambient levels of heavy metal content, the treatment with growth regulators Biodyuks and organomineral biopreparation led to a significant decrease in zinc concentrations in the grain of spring wheat variety Radmira, with reductions of 1.2-fold and 1.1-fold, respectively, as illustrated in Figures 2. In the variant with the first level of pollution D1, Biodyuks preparation contributed to a 1.2-fold decrease in zinc concentrations, while the application of OMP (organomineral biopreparation) resulted in a 1.3-fold decrease. In the variant with high-level pollution D2, Biodyuks preparation influenced zinc accumulation in the grain of spring wheat, reducing its concentration by 1.6 times; organomineral biopreparation - by 1.7 times.

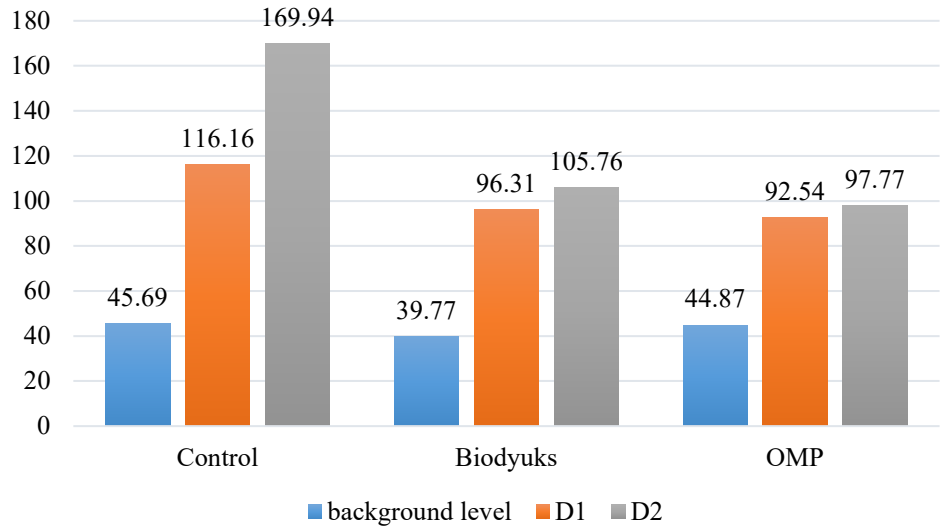

Fig. 2. Zinc content in the grain of spring wheat variety Radmira, mg/kg.

Similarly, at ambient levels of heavy metal content, the application of growth regulators Biodyuks and organomineral biopreparation also resulted in a notable decrease in copper concentrations in the grain of spring wheat variety Radmira, with reductions of 1.2-fold and 1.1-fold, respectively, as shown in Figures 3. In the variant with the first level of pollution D1, Biodyuks preparation contributed to a 1.5-fold decrease in copper concentrations, while the application of OMP (organomineral biopreparation) resulted in a 1.3-fold decrease. In the variant with high-level pollution D2, Biodyuks preparation influenced copper accumulation in the grain of spring wheat, reducing its concentration by 1.4 times; organomineral biopreparation - by 1.2 times.

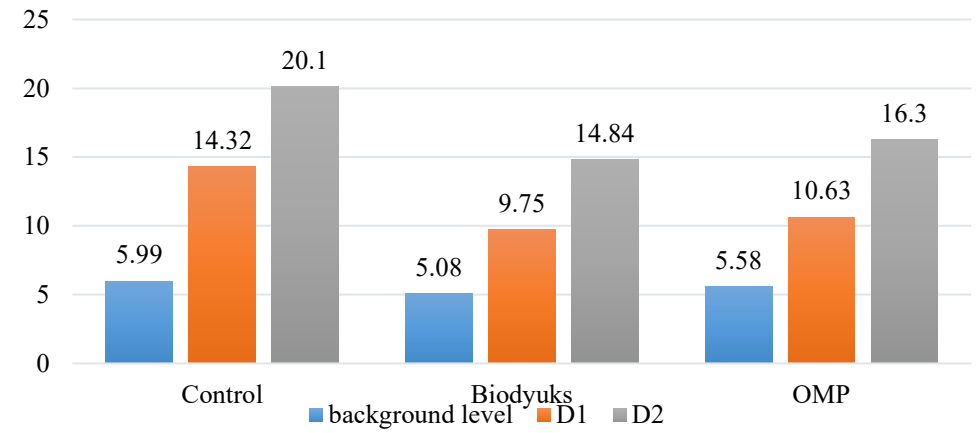

Fig. 3. Copper content in the grain of spring wheat variety Radmira, mg/kg.

Furthermore, at ambient levels of heavy metal content, the treatment with organomineral biopreparation led to a significant reduction in lead concentrations in the

grain of spring wheat variety Radmira, with a decrease of 1.5-fold, as illustrated in Figures 4. In the variant with the first level of pollution D1, Biodyuks preparation contributed to a 1.3-fold decrease in lead concentrations, while the application of OMP (organomineral biopreparation) resulted in a 1.9-fold decrease. In the variant with high-level pollution D2, Biodyuks preparation influenced lead accumulation in the grain of spring wheat, reducing its concentration by 1.6 times; organomineral biopreparation - by 2.3

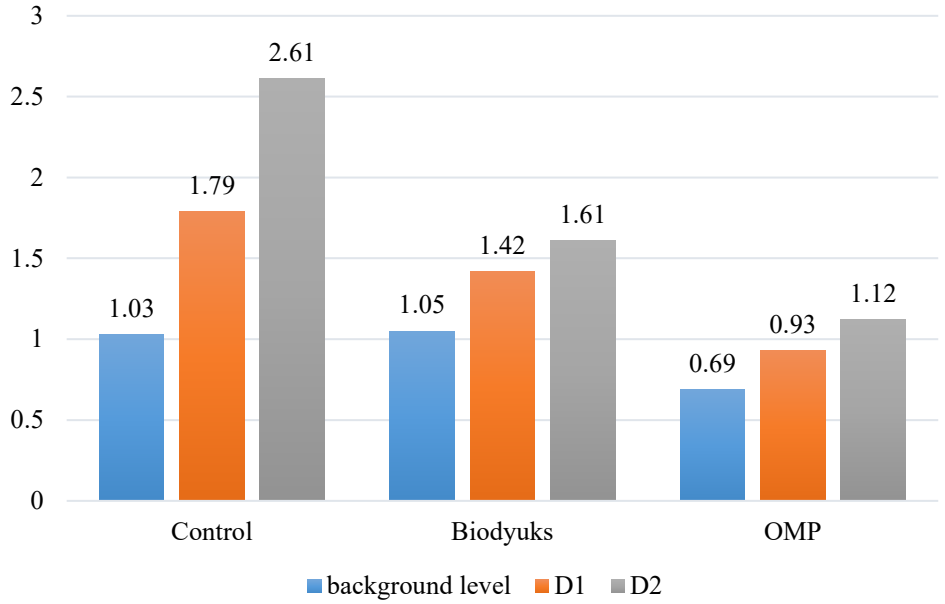

Fig. 4. Lead content in the grain of spring wheat variety Radmira, mg/kg.

The findings of this study clearly indicate that the application of growth regulators Biodyuks and organomineral biopreparation can be a highly effective strategy for minimizing the accumulation of heavy metals in the grain of spring wheat variety Radmira. Consequently, the utilization of biopreparations can be proposed as a promising approach for alleviating the detrimental impacts of heavy metals on agricultural crops.

4 Conclusion

This study examined the effectiveness of biopreparations in mitigating heavy metal accumulation in wheat grain under conditions of mild and moderate soil pollution.

The use of growth regulators resulted in a significant decrease in the concentrations of cadmium, zinc, lead, and copper in the grain of spring wheat variety Radmira, even when heavy metal soil pollution was present.

Notably, Biodyuks preparation was more effective in reducing cadmium and copper content, while organomineral biopreparation was more effective in reducing lead and zinc content, regardless of the pollution level (D1 or D2).

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