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«Development of a methodological approach for determining phytotolerance to the toxic effects of pollutants using hydroponics as a model environment»

Abstract

The dissertation is devoted to the development and experimental substantiation of a methodology for assessing phytotolerance of higher plants to pollutants (heavy metals, anionic surfactants, high-molecular hydrocarbons) using hydroponics as a standardized model environment.

The purpose of the work is to develop and justify a methodology for assessing phytotolerance using hydroponics as a model environment to establish tolerance limits for plants to pollutants characteristic of soils in the areas affected by mining and oil and gas enterprises.

Work objectives:

1. Analysis of existing approaches to assessing phytotolerance and justification of the advantages of using hydroponics as a model environment.
2. Development and testing of a methodology for obtaining phytotolerance limits using hydroponics as a model environment.
3. Establishment of phytotolerance limits ($LimP_H$) of higher plants to pollutants (heavy metals, anionic surfactants, high-molecular hydrocarbons) and determination of recalculation coefficients between hydroponic and soil environments.
4. Investigation of the effect of EDTA on changes in phytotolerance of higher plants.
5. Development of a software package and practical recommendations for the selection of higher plants for bioindication monitoring and the biological stage of disturbed land reclamation.

As a result of the research, a standardized methodology for hydroponic experiments has been developed, tested, and implemented, including the assessment of tolerance through the phytotolerance limit ($LimP_H$) and the transfer of results to field conditions through the recalculation coefficient «k». For the first time, quantitative values of phytotolerance limits ($LimP_H$) for eight plant species to six types of pollutants characteristic of soils in the zones of influence of mining and oil and gas enterprises have been obtained. The highest tolerance was shown by *Brassica juncea*: $LimP_H$ (Cd) = 60 mg/L, $LimP_H$ (Ni) = 40 mg/L, $LimP_H$ (Zn) = 690 mg/L, $LimP_H$ (Hg) = 105 mg/L. A statistically significant correlation ($r = 0.89$, $p < 0.01$) was revealed between phytotolerance limits in hydroponic and soil environments. The recalculation coefficient «k» (0.66–4 L/kg) allows predicting field $LimP_S$ values with an accuracy of $\pm 25\%$, ensuring the transfer of laboratory data to the practice of environmental monitoring. The positive effect of EDTA on shifting the phytotolerance limit ($LimP_H$ shifts by 35–40% on average)

has been established. The software package «*PhytoRemediator*» (registration certificate No. 2026615895) has been developed and registered, containing a database of more than 150 plant species, covering 11 regions of the Russian Federation, 11 soil types, and 10 classes of pollutants.

The following provisions are put forward for protection:

1. Justification of the use of hydroponics as a model environment that eliminates the influence of soil environment factors and provides a more accurate determination of phytotolerance limits to the effects of pollutants.
2. For the first time, phytotolerance limits ($LimP_H$) have been obtained for eight plant species to six types of pollutants characteristic of soils in the zones of influence of mining and oil and gas enterprises, and a recalculation coefficient «k» has been established, allowing laboratory data to be transferred to the soil environment with an accuracy of about 75%.
3. The positive effect of the chelating agent EDTA (by 35–40%) has been established, shifting the phytotolerance limit of higher plants to heavy metals.
4. The software package «*PhytoRemediator*» has been developed, providing automated selection of plant species for specific pollution conditions, taking into account soil type and natural-climatic region in 11 constituent entities of the Russian Federation, and forming a tool for systematic environmental monitoring and planning of biological reclamation of disturbed lands.

The obtained results are of both applied and fundamental significance. The applied significance of the work is confirmed by an implementation certificate from the production cooperative «Module», a certificate of registration of the software package «*PhytoRemediator*», and developed methodological recommendations. The research materials have been used in educational lectures and courses. Further research in this area may be related to expanding the database of the software package with new species of phytoremediants, as well as developing a methodology for objects with multicomponent pollution.