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Combined effect of Fe^{2+} ions and the meta-isomer of dihydric phenol on duckweed

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Abstract. The toxic effects of Fe^{2+} ions and resorcinol on *Lemna minor* in their joint presence in the aquatic environment were studied. The test response in the bioassay of solutions of Fe^{2+}, resorcinol, and their mixtures was a violation of the permeability of duckweed membranes. This parameter was estimated from the change in the electrical conductivity of the aquatic medium in which the plant was placed, exposed to the toxicant in the acute experiment (30 min). It was found that the addition of both an equinormal concentration of Fe(II) (0.1n) and a five-fold deficiency (0.02n) to a 0.1n solution of resorcinol reduced the toxicity of resorcinol. Most likely, the effect obtained can be achieved by the formation of a new, less toxic compound (probably of a complex nature). The test used in the work, based on the assessment of the permeability of cell membranes under the action of toxicants, once again proved to be a promising tool for analyzing the combined toxicity of phenolic compounds and metal ions in relation to plant organisms.

1 Introduction

Metal ions play an important role in plant life. They determine the physiological activity of the cell, the most important biochemical processes, the structures of cells and membranes, the state of the cells depends on their ratio in the plant organism. At the same time, at an increased content, metals can exhibit significant toxic effects: they affect the growth of roots and shoots, changing their morphology and anatomy [4]; cause a decrease in the content of chlorophyll and a significant suppression of the rate of photosynthesis; negatively affect photosystems II and I [1]; disturb the water balance of plants [3]. At the cellular level, metals can cause changes in the configuration of the endoplasmic reticulum, increased cell vacuolization, an increase in the size of the cell nucleus, a change in the shape of the Golgi apparatus, as well as a violation of the ultrastructure of chloroplasts and mitochondria [2].

Phenolic compounds also play an important role in the biochemical processes of plant cells. However, just like metals, these compounds at certain concentrations limit the growth and development of plant organisms [5].

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The extremely high reactivity of metal and phenol ions and their simultaneous existence in the environment lead to very different interactions between them and the appearance of various complex compounds. Phenols are able to reduce many metals, dramatically changing their chemical and biological properties, they can contribute to their entry into the cell. On the other hand, metals activate the oxidation of phenolic compounds and the formation of highly reactive products from them. This changes the solubility, bioavailability of metals, their valency, as well as their biological activity and aggressiveness.

Unfortunately, the combined effect of metals and phenols on aquatic plants has been studied extremely insufficiently. In this regard, the aim of the study was to study the combined effect of Fe^{2+} ions and resorcinol on the aquatic plant *Lemna minor*.

2 Materials and methods

The object of study was the aquatic plant *Lemna minor* (order *Alismatáles*, class *Liliopsida*, family *Lemnaceae*, subfamily *Lemnoideae*, genus *Lémna*). Under laboratory conditions, duckweed was cultivated in glass vessels at room temperature (20–24°C) and artificial light (650–850 Lx).

The joint effect of Fe^{2+} ions with the diatomic phenol resorcinol on the yield of electrolytes from shoots of *L. minor* was studied. $FeSO_4 \cdot 7H_2O$ (chemically pure) was used as a source of Fe^{2+}. The concentrations of iron salt solutions in the experiments (in terms of the Fe^{2+} ion) were 0.02n and 0.1n. The concentrations of dihydric phenols were also 0.02n and 0.1n.

The release of electrolytes from the duckweed was recorded by the change in the electrical conductivity of distilled water, in which the test object was placed. To do this, a weighed portion of the *L. minor* plant 0.5 g/50 ml was added to freshly prepared solutions of the tested toxicants (in the control, to distilled water). Pretreatment of duckweed in solutions of toxicants was 30 minutes. After pretreatment, the plant was thoroughly washed with running distilled water. The washed plants were placed in a beaker with distilled water (50 ml) and its electrical conductivity was measured for 90 min using an Expert-002 conductometer with a UEP-P-S submersible sensor.

The experiments were performed in triplicate, statistical processing was performed using Microsoft Office Excel 2010 and Statistica 2007 software. Mean ± error of the mean (M±m) was calculated, and the significance of differences was assessed by Student's t-test. The conclusions are drawn with the probability of an error-free forecast $P \geq 0.95$.

3 Results and discussion

In the resorcinol–Fe^{2+} system, equinormal solutions were used in relatively high (0.1n) and low (0.02n) concentrations, as well as a fivefold excess of dihydric phenol and Fe(II).

In solutions with relatively high equinormal concentrations (0.1n) of the studied compounds, the toxicity of resorcinol is higher than that of Fe(II) (figure 1).

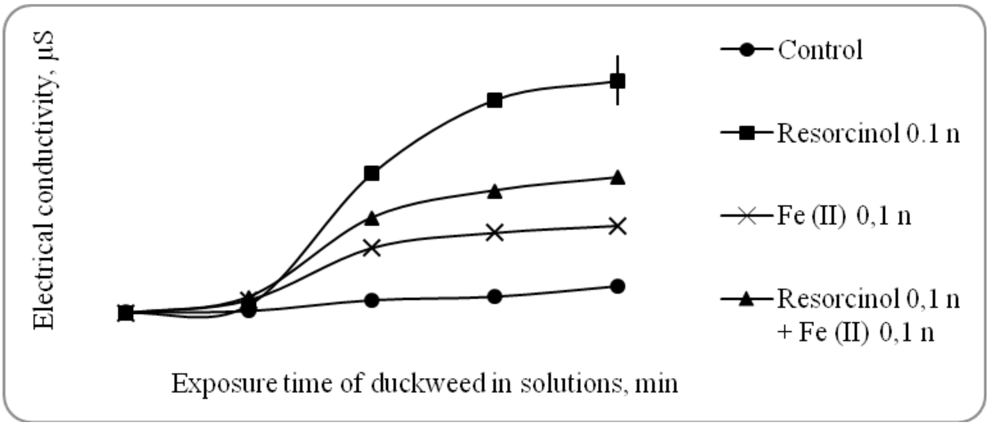

Fig. 1. Effect of mixtures of 0.1n resorcinol with 0.1n Fe(II) on the yield of electrolytes from duckweed.

In solutions with relatively low concentrations of both substances (0.02n) at the same normality ratio (1:1), the toxicity of the Fe(II) solution is more pronounced than that of resorcinol (figure 2).

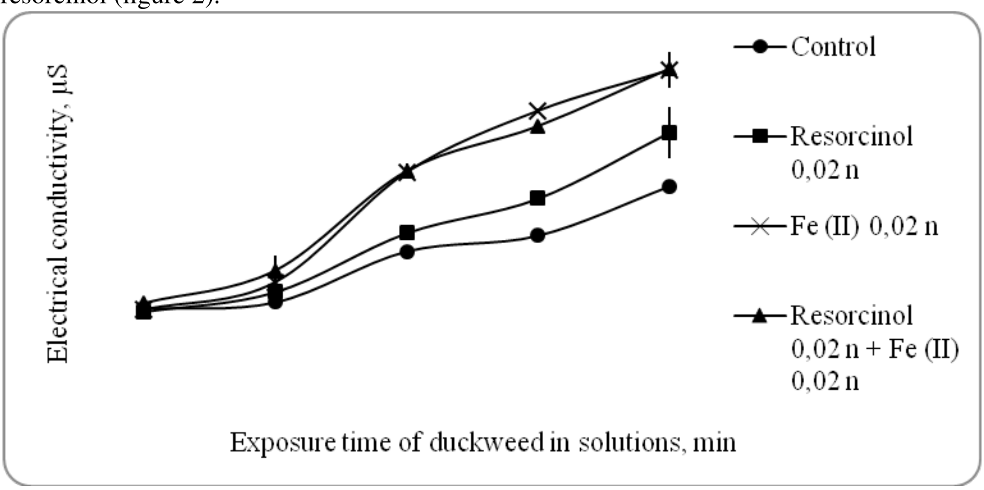

Fig. 2. Effect of mixtures of 0.02n resorcinol with 0.02n Fe(II) on the yield of electrolytes from duckweed.

The addition of both an equinormal concentration of Fe(II) (figure 1) and a fivefold deficiency of it (figure 3) to a 0.1n solution of resorcinol reduced the toxicity of resorcinol. Moreover, the toxicity of the mixture (Fe(II) + resorcinol) decreased approximately equally, regardless of the concentration of Fe(II) in the range used. However, the toxicity of the mixture remained higher than that of the solution containing only the Fe(II) salt (figures 1 and 3).

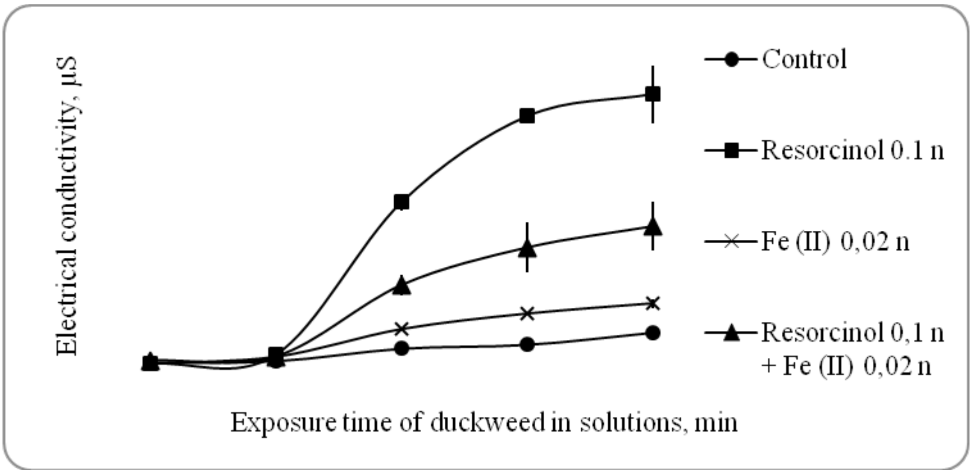

Fig. 3. Effect of mixtures of 0.1n resorcinol with 0.02n Fe(II) on the yield of electrolytes from duckweed.

The addition of a 0.02n solution of resorcinol to an equinormal solution of Fe(II) of equal normality does not reduce the toxicity of Fe(II) (figure 2). A similar situation was observed in a resorcinol solution with a fivefold excess of Fe(II) (figure 4). That is, under conditions of low concentration of resorcinol (0.02n), Fe(II) binding does not occur.

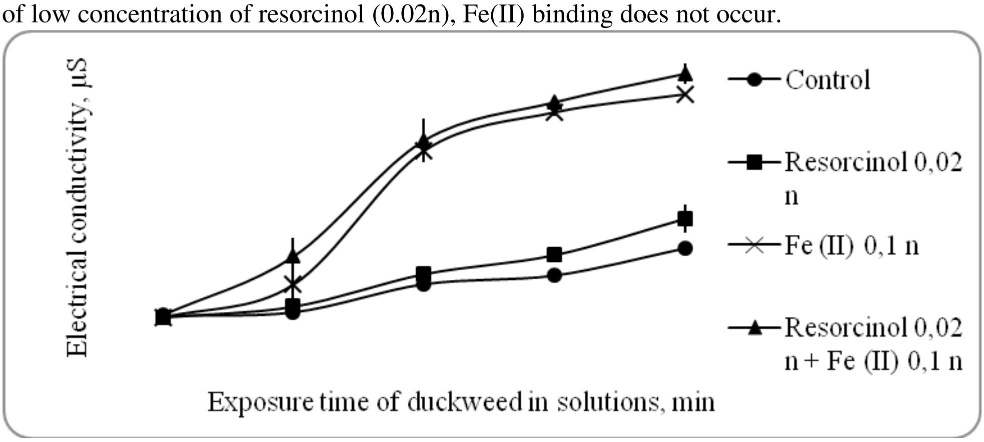

Fig. 4. Effect of mixtures of 0.02n resorcinol with 0.1n Fe(II) on the yield of electrolytes from duckweed.

4 Conclusion

Thus, as a result of the study of systems containing Fe^{2+} ions and diatomic phenol - resorcinol, it was found that adding to a 0.1n solution of resorcinol both an equinormal concentration of Fe(II) (0.1n) and its five-fold deficiency (0.02n), reduced the toxicity of resorcinol. Most likely, the effect obtained can be achieved by the formation of a new, less toxic compound (probably having a complex character). The test used in the work, based on the assessment of the permeability of cell membranes under the action of toxicants, once again proved to be a promising tool for analyzing the combined toxicity of phenolic compounds and metal ions in relation to plant organisms.

The revealed decrease in the toxicity of a 0.1n solution of resorcinol upon addition of both an equinormal concentration of Fe(II) (0.1n) and a five-fold deficiency (0.02n) may indicate the formation of a new, less toxic, most likely, complex compound.

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