

**EXPERIMENTAL BOTANY**

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**PIGMENT SYSTEM OF SUBMERGED MACROPHYTE  
CERATOPHYLLUM DEMERSUM L. AT INCREASE OF COPPER  
(II) IONS CONCENTRATION IN THE AQUATIC ENVIRONMENT**

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Pollution of natural reservoirs with heavy metals is due to discharges of insufficiently treated wastewater by industrial enterprises, as well as a result of numerous constructions, road washes and domestic sewage. Copper belongs to the "biometals", which are involved in the implementation of almost all basic vital processes of plants, as they are necessary components of many enzyme systems, ensure their structural organization and functioning. Copper ions in microquantities are necessary for normal functioning of the pigment system of the plant organism and implementation of photochemical reactions [3]. At the same time, with increasing concentration of  $\text{Cu}^{2+}$  in the environment, the functioning of pigment systems is disrupted, the qualitative and quantitative composition of pigments changes [2, 7]. This fact determines the importance of the problem of the impact of elevated concentrations of  $\text{Cu}^{2+}$  on aquatic ecosystems, the production basis of which are photosynthetic organisms. Among them, a significant role belongs to submerged macrophytes.

Therefore, in our research the effect of  $\text{Cu}^{2+}$  ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) at concentrations of 0.002; 0.005; 0.01; 0.02; 0.05; 0.1; 0.5; 1 and 2  $\text{mg}/\text{dm}^3$  on the pigment system (content of chlorophyll *a*, chlorophyll *b* and carotenoids) of submerged macrophyte *Ceratophyllum demersum* L. during 7 days was studied. The range of studied concentrations changed from those actually detected in the reservoirs of Kyiv (0.002-0.05  $\text{mg}/\text{dm}^3$ ) [6] to those that exist in places of discharge of insufficiently treated wastewater by industrial enterprises (0.1–2  $\text{mg}/\text{dm}^3$ ). Chlorophylls and carotenoids from plant tissues were extracted with 80% acetone; the concentration of pigments was determined by spectrophotometric method and calculated according to the formulas [4] in milligrams per 1 g of dry weight. The part of dry weight in the raw plant material was determined after drying at 105<sup>0</sup>C to constant weight.

As a result of such researches it was established that after 7 days of exposure to 0.002–0.005  $\text{mg}/\text{dm}^3$  of copper ions there was an increase in the content of pigments in *Ceratophyllum demersum* compared to control. Therefore, copper in such concentrations acts as a trace element and not as a toxicant. The effect of 0.002  $\text{mg}/\text{dm}^3$   $\text{Cu}^{2+}$  leads to the greatest increase in content of chlorophyll *a* (by 32% compared to control), and the action of 0.005  $\text{mg}/\text{dm}^3$   $\text{Cu}^{2+}$  – to the greatest increase in content of carotenoids (by 44% compared to control).

When exposed 0.01–0.02  $\text{mg}/\text{dm}^3$   $\text{Cu}^{2+}$  on *Ceratophyllum demersum* there is a decrease in the content of the studied photosynthetic pigments, and there is an increase in the relative content of carotenoids, which, according to [1], may be a protective reaction that prevents photodamage and peroxidation of chlorophyll. That is, at these concentrations of copper ions in the aquatic environment there are adaptive changes in the pigment system of higher aquatic plants aimed at stabilizing the content of chlorophyll.

It is established that at influence of  $\text{Cu}^{2+}$  in concentration from 0.05 to 0.5  $\text{mg}/\text{dm}^3$  there is a significant decrease in the content of all investigated photosynthetic pigments of *Ceratophyllum demersum*, and the content of chlorophyll *a* is the most reduced (by 35–79% in comparison with chlorophyll *a* in control plants). The content of chlorophyll *b* decreased by 29–66% compared to the control, and carotenoids – by 23–68% compared to the control.

Visual toxicosis (signs of chlorosis) in *Ceratophyllum demersum* is observed when exposed to  $\text{Cu}^{2+}$  at a concentration of 0.5–2  $\text{mg}/\text{dm}^3$ . At the same time, under actions of copper ions at concentrations of 1 and 2  $\text{mg}/\text{dm}^3$  in plant organisms there are such visual signs of toxic effects of copper as dropping shoots to the bottom, leaf fall, fragmentation of the stem – such

changes can lead to complete destruction of the pigment system and death of plant organism.

As a result of conducted researches, it was found that copper ions in concentrations  $0.01 \text{ mg/dm}^3$  and more lead to a decrease in the content of photosynthetic pigments in *Ceratophyllum demersum*. It is believed that the destruction of pigments is preceded by changes in plastids, namely the increase in free radical oxidation of lipids in chloroplast membranes, which leads to a violation of the hydrophobic bond of chlorophyll with plastid membranes [5]. The decrease in the total chlorophyll content of *Ceratophyllum demersum* when exposed to Cu is also accompanied by a change in the activity of antioxidant enzymes, in particular an increase in the activity superoxide dismutase, catalase, and ascorbate peroxidase [8].

It was found that the indicator of the toxic effect of copper ions on the pigment system of *Ceratophyllum demersum* is a decrease in the ratio of chlorophyll *a*/chlorophyll *b* and (chlorophyll *a* + chlorophyll *b*)/carotenoids compared to control plants that are not affected by copper ions.

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