The effect of different concentrations of nanometals (Fe and Cu) on the activity of antioxidant protection of Solánnum tuberósum L.

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Abstract. At present, rapid development of nanotechnology requires assessment of their effects on plants, interaction with plant cells and concentration dependence. The degree of toxicity of nanocompounds affecting plants depends on physical properties of nanoparticles (dimension, shape, catalytic activity, concentration). The research objects were Tarasov potato tubers treated in Fe\textsuperscript{o} (90-110 Nm) and Cu\textsuperscript{o} (50-110 Nm) NPs at four concentrations with a geometric progression (0,0125; 0,025; 0.05 and 0.1 M). The aim of the research is to study the effect of iron and copper metals on the activity of Solánnumtuberósum L. antioxidant protection of plants. The Fe\textsuperscript{o} NPs caused oxidative stress and decreased the content of MD (1.3 - 26.7%) and phenolic compounds with a simultaneous increase in peroxidase. After exposure to Cu\textsuperscript{o} nanoparticles, there was a redox imbalance in the roots and sprouts which manifested itself as a decrease in CAT (7.4 - 36.7%) and FS (19.1 - 34.0%) activity with a sharp increase in the content of MD and an increase in peroxidase activity.

1. Introduction

The solution of problems of adaptation of biosystems (plant organisms) to oxidative stress has been one of the topical research directions [1-3]. Under the influence of unfavorable environmental factors, an increase in the concentration of reactive oxygen species (ROS) and the start of oxidative reactions destroyed vital cellular components [4]. Plants are exposed to ROS, especially in the presence of nanomaterials [5]. The most prolonged and harmful effects occur under direct and indirect effects of nanoforms or metal nanoparticles [6]. However, some plant species can adapt to metal NPs using various mechanisms [7, 8]. Plants provide an opportunity to assess nanoparticle effects and dose-dependent effects.

Numerous studies discussed the effect of Ag, TiO\textsubscript{2}, Al\textsubscript{2}O\textsubscript{3}, Fe\textsubscript{3}SO\textsubscript{4}, FeO, ZnO, CeO\textsubscript{2} nanoparticles on plant organisms. However, there is little information about the effect of Fe\textsuperscript{o} and Cu\textsuperscript{o} NPs on growth, development, and physiological and biochemical parameters of plants.

Copper and iron are trace elements essential for the plant growth. They perform several functions in important physiological processes that affect living organisms, participate in the structures of proteins and metabolic enzymes. Among metal trace elements, iron has the maximum share.

The article studies effects of iron and copper NPs on the activity of antioxidant protection of Solánnumtuberósum L. plants.
2. Materials and methods

The studies were carried out in the Center for Collective Use of the BST of the RAS. Biological activity of Fe⁰ (90-110 Nm) and Cu⁰ (50-110 Nm) NPs was tested at four concentrations with a geometric progression (0.0125; 0.025; 0.05 and 0.1 M) and in 3 replications. Catalase (CAT) was determined by the Maehly and Chance (1954) and (Aeby, 1984) methods based on the interaction of H₂O₂ with potassium iodide at a 1:1 ratio. The measurements were carried out using a FEK-56 M photocolorimeter (Russia) at 435-445 nm.

The content of malonogonaldehyde (MD) was determined using the Heath and Packer (1968) method [9]. Measurements were carried out using a spectrophotometer at 532 nm (Sibgatullina, 2011) [10].

The content of phenolic compounds (PS) was determined by the method based on the interaction of the extract with the Folin-Chokalteu reagent (Applichem, Germany) consisting of phosphorus-tungsten and phosphomolybdic acid salts [9]. Optical measurement was carried out using a spectrophotometer at λ = 765 nm. The content of PS in was determined using a calibration curve constructed for dihydroquercetin.

Peroxidase activity was determined by the Boyarkin method [11], guaiacol was used as a substrate. An increase in optical density in a reaction mixture consisting of 0.5 ml of 0.1 M citrate-phosphate buffer (pH 6.2 and 5.4), 0.5 ml of 0.3% hydrogen peroxide and 0.5 ml (0.035%, 0.04%, 0.045%, 0.5%, 0.055%) guaiacol was measured at 580 nm.

3. The study of the structure of the modified lead-tin-base bronze

Changes in plant metabolism can be determined by the activity or an isoenzyme spectrum of key AO enzymes. Changes in the catalase activity are due to species characteristics: the higher the resistance of a species to pollutants, the less its activity changes. The results of the experiment showed that CAT in SolánumtuberósL sprouts reacts to metal NPs in a different way. The CAT enzyme activity decreased after treatment with Cu⁰ at all concentrations (up to 7.4-36.7% compared with control plants) (Fig. 1).

![Figure 1. Catalase activity (CAT) in SolánumtuberósL sprouts. after exposure to Fe⁰ and Cu⁰ nanoparticles at P <0.05](image)

However, a slight increase in CAT was recorded after Fe⁰ treatment at a concentration of 0.0125 and 0.025 M (from 6.9% to 20.3%) (P <0.05). An increase in CAT may be due to the activation of latent forms and synthesis of new molecules.

It is known that lipid peroxidation causes the most destructive process in every living organism, and membrane damage usually acts as an indicator of lipid damage under all sorts of stresses. Malonic dialdehyde (MD), one of the end products of unsaturated fatty acid peroxidation in phospholipids,
damages the cell membrane. The content of MD in sprouts and roots of control plants was 0.86 ± 0.09 and 0.92 ± 0.08 μmol/g of wet weight (Figure 2).

![Figure 2. Malondialdehyde activity in SOLÁNUM TUBERÓSUM sprouts and roots after exposure to Fe° and Cu° nNPs at P <0.05](image)

In the presence of Cu NPs, the MD index changed both in sprouts and roots and exceeded the control one by 8.0-45.9% and 27-46.7%, respectively (P <0.05). At the same time, there is a decrease in MD in sprouts at all concentrations of Fe° NPs (by 9.2 - 26.7%) and in roots at concentrations varying from 0.0125 to 0.05 M (by 1.3-9.6%) in comparison with the control option.

Some researchers believe that phenolic compounds protect metabolism from ROS more effectively than antioxidant enzymes [12]. The data obtained indicate that there was a sharp decrease in FS, (1.5 times) in sprouts and roots at all concentrations of Fe° NPs, and in sprouts with Cu° NPs increased by 19.1-34.0% compared to the control option (Fig. 3) Thus, the results can be explained either by the low rate of synthesis, or by weak manifestation of oxidative stress in seedlings, by the lack of demand for FS as elements of AOC.

![Figure 3. The content of phenolic compounds in SOLÁNUM TUBERÓSUM sprouts and roots after exposure to Fe° and Cu° NPs at P<0.05](image)

The use of peroxidase as a marker of the stress state allows you to characterize protective moves for the diagnosis of resistance to stress factors. When processing potato tubers with Fe° and Cu° NPs,
activity of the peroxidase intensified 2-3 times in comparison with the control group, and amounted to 415.3 ... 531.5 and 713.6 ... 603.8 r.u./g wet weight, respectively (Fig. 4).

Figure 4. Peroxidase content in SOLÁNUM TUBERÓSUM sprouts after exposure to Fe\textsuperscript{o} and Cu\textsuperscript{o} NPs at P<0.05

The sensitivity of sprouts to Cu\textsuperscript{o} NPs turned out to be much higher than to FeO NPs. In addition, the experimental results indicate that an increasing intensity of oxidative stress experienced by SOLÁNUM TUBERÓSUM plants decreases resistance to Cu\textsuperscript{o} NPs.

4. Conclusion

Thus, the research results contribute to the idea about the effect of metal NPs on physiological processes of sprouts and roots of potato plants. The study of physiological processes has shown that in SOLÁNUM TUBERÓSUM plants, metabolic changes depended on the chemical nature of metals and concentration of the nano-preparation. The effect of FeO NPs caused oxidative stress and a decrease in the content of MDA and phenolic compounds with a simultaneous increase in peroxidase. After the exposure to Cu\textsuperscript{o} NPs, a redox imbalance was observed in roots and sprouts manifesting itself as a decrease in CAT and PS activity, with a sharp increase in the MD content and an increase in peroxidase activity. The results serve as additional evidence of selectivity of metabolic reactions determined by properties of the nanomaterial.

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