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THE EFFECT OF NANOPARTICLES OF BIOGENIC METAL OXIDES ON SEED GERMINATION CAPABILITY, PHOTOSYNTHETIC PIGMENT CONTENT, ACTIVITIES OF PSII AND SUPEROXIDE DISMUTASE IN WHEAT SEEDLINGS

Aim. The effect of nanoparticles of copper, titanium, iron and aluminum oxides on the germination energy, germination capability, growth and development, the content of photosynthetic pigments, the activity of photosystems and superoxide dismutase of wheat seedlings was studied. ***Methods.*** The objects of the research were bread wheat (*Triticum aestivum* L) seedlings. The seeds of the experimental plants were treated with powders of nanoparticles of CuO, Fe_2O_3, ZnO, Al_2O_3, and TiO_2, then sown in Petri dishes and in the pots with soil. ***Results.*** Nanoparticles were found to express various effects: CuO, and Al_2O_3 decreased the growth of seedlings, whereas TiO_2, ZnO and Fe_2O_3 accelerating the growth of seedlings had a positive effect on the activities of PSII and superoxide dismutase. ***Conclusions***. Nanoparticles of TiO_2, ZnO and Fe_2O_3 had a positive effect on seed germination and accelerated the growth of wheat seedlings. Nanoparticles of ZnO and Fe_2O_3 also positively influenced on the activity of PS II, and the activity of the antioxidant enzyme-superoxide dismutase also increased.

Keywords: wheat, nanoparticles, germination, growth of seedlings, PS II, superoxide dismutase.

Currently, nanoparticles are widely used in many branches of agriculture. It is well-known that when microelements are introduced in the form of their water-soluble salts, most of them are absorbed by the soil colloids and their absorption by plant roots is obstructed. The accumulation of these substances in the soil solution leads to environmental pollution. Nanoparticles are distinguished by unusual physicochemical properties, peculiarities of action on living organisms [1]. Thanks to the microscopic size, nanoparticles can easily pass through biological membranes, accumulate in the internal environment, and accelerate the rate of metabolic processes in cells. However, it should be noted that at high doses, nanoparticles can accumulate in plants and can later be absorbed by the human organism [2–4]. According to some authors, silver nanoparticles at low concentrations can enhance germination energy and seed germination capability, growth and development, respiration intensity and activity of enzyme systems [5–8]. It is noted that silver nanoparticles mainly accumulate in the roots of plants. TiO_2, Al_2O_3, Fe_3O_4 nanoparticles were shown to have different effects depending on their concentrations [9, 10]. In these experiments, iron powders at low concentrations increased the yield and grain quality of cereals. In [11], soaking seeds with titanium, aluminum, and iron nanoparticles did not affect seed germination and plant growth. It is supposed [12] that in the process of growth and development, plants can use the surface energy of nanoparticles coming from outside, which can affect the functions of the molecular structures of the cell. Thus, the results of the researches carried out with nanoparticles are contradictory, and further researches are advisable in this direction.

The purpose of this work was to study the effect of nanoparticles of copper, titanium, iron and aluminum on germination energy, germination capability, growth and development, the content of photosynthetic pigments, the activity of photosystems and antioxidant plant enzymes.

Materials and methods

The objects of the research were bread wheat (*Triticum aestivum* L.) seedlings. The seeds of the experimental plants were treated with powders of nanoparticles of CuO, Fe_2O_3, ZnO, Al_2O_3, and TiO_2, sown in Petri dishes and in the vegetative pots with soil. The germination energy and germination capability of seeds were determined. Then morphometric parameters, the content of chlorophyll a and b, carotenoids, the activity of PS 2 and the enzyme superoxide dismutase were determined in the course of the plant growth. Alcohol extract of leaves was used to determine the content of pigments. The content of pigments was measured using spectrophotometer SP -2000, at 665, 649 and 440 nm. The amount of pigments was calculated using the Vernon method [13]. The activity of PS 2 was determined using the device - PAM (Photosynthesis analyzer, Germany). The activity of the superoxide dismutase enzyme was determined using the method [14]. Static data processing was performed using the program “Statistics for windows”.

Results and discussion

Nanoparticles were found to impact differently on the germination energy and germination capability (Table 1).

As seen in Table 1 nanoparticles of TiO_2, ZnO and Fe_2O_3 positively affected germination energy and germination capability of seeds. These nanoparticles accelerated also growth of wheat seedlings.

Nanoparticles of ZnO and Fe_2O_3 were also found to have a positive effect on the contents of chlorophyll a and b (Table 2).

The activity of PSII, where water photooxidation occurred with the release of hydrogen protons and molecular oxygen, increased under the influence of the nanoparticles of ZnO and Fe_2O_3. Nanoparticles of TiO2, ZnO and Fe_2O_3 increased the activity of superoxide dismutase (Fig.).

Table 1. Effect of nanoparticles on germination capability, morphological and physiological indices of wheat seedlings

Variants	Germination energy, %	Germination capability, %	Seedling height (cm)		F_v / F_m
			14 days	19 days	
Control	70	90	3.5 ± 0.2	11 ± 0.9	0.8
CuO	70	80	4.5 ± 0.3	12 ± 0.8	0.6
TiO_2	85	90	6.5 ± 0.5	14 ± 0.9	0.7
ZnO	90	100	6.5 ± 0.6	14± 0.8	0.7
$Fe_2 O_3$	85	90	7.0 ± 0.8	15 ± 0.9	0.7
$Al_2 O_3$	60	80	4.5 ± 0.5	7.0 ± 0.7	0.6

Table 2. Effect of nanoparticles on photosynthetic pigment contents in wheat leaves (mg/g fresh mass)

Variants	Chlorophyll a	Chlorophyll b	a + b	a/b	Carotenoids
Control	1.8	0.55	2.35	3.27	2.2
CuO	1.4	0.46	1.86	3.04	2.9
TiO_2	1.9	0.71	2.61	2.67	3.2
ZnO	1.9	0.69	2.59	2.75	3.5
$Fe_2 O_3$	2.1	0.72	2.82	2.92	3.7
$Al_2 O_3$	1.9	0.61	2.51	3.11	3.9

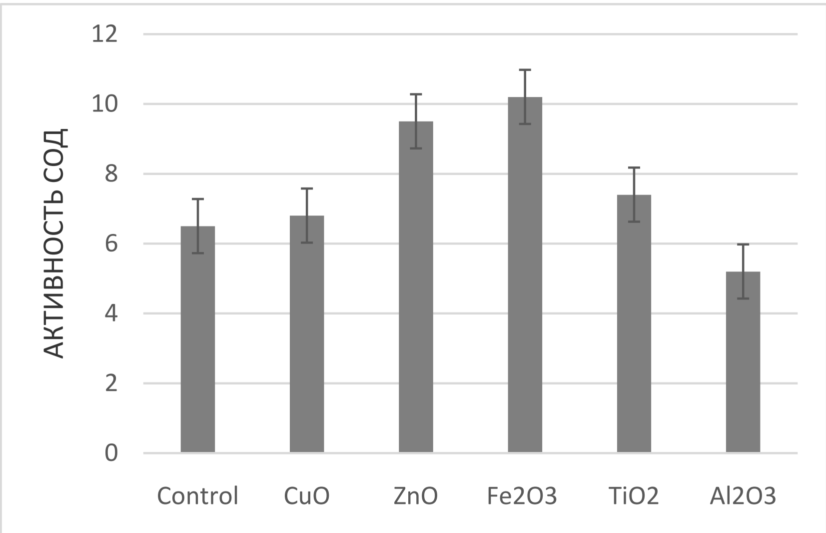

Fig. Influence of nanoparticles on activity of superoxide dismutase. (Enzyme activity is given in arbitrary units). Each bar represents mean ± sd (standart deviation) for average of n=3 independent experiments; P = 0.05.

The results we obtained are consistent with the data obtained by Yegorov et al. [12]. They showed that pre-sowing treatment of plant seeds with low concentrations of iron nanopowder had a positive effect on the germination energy. However, an increase in the concentration by an order of magnitude led to the suppression of their growth.

Nanoparticles of TiO_2 and Al_2O_3 were found to retard the growth of bean, wheat and amaranth [10]. Studies on the effect of iron nanopowder on the growth, development, drought tolerance and productivity of maize, wheat and sunflower showed that the yield of these crops increased on average by 15–20 %. The contents of gluten in the grain, oil in seeds and amino acids in the leafy stalk mass of fodder crops increased. Iron nanoparticles were shown to have different effects on the content of photosynthetic pigments in *Triticum vulgare* [15]. Nanoparticles of Fe_3O_4 had a greater effect on the total amount of photosynthetic pigments compared with those of FeO. The degree of the effect of nanoparticles on the content of photosynthetic pigments was found to depend on their concentrations.

Conclusions

Nanoparticles of TiO_2, ZnO and Fe_2O_3 had a positive effect on the germination capability and accelerated the growth of wheat seedlings. ZnO and Fe_2O_3 nanoparticles also positively influenced on the activity of PS 2, where water photooxidation occurred with the release of hydrogen protons and molecular oxygen, and increased the activity of the antioxidant enzyme superoxide dismutase.

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ВПЛИВ НАНОЧАСТИНОК ОКСИДІВ БІОГЕННИХ МЕТАЛІВ НА СХОЖІСТЬ НАСІННЯ, ВМІСТ ФОТОСИНТЕТИЧНИХ ПІГМЕНТІВ, АКТИВНІСТЬ ФС 2 І СУПЕРОКСИДДИСМУТАЗУ В ПРОРОСТКАХ ПШЕНИЦІ

Мета. Вивчено вплив наночастинок оксидів міді, титану, заліза і алюмінію на енергію проростання, схожість, ріст і розвиток, зміст фотосинтетических пігментів, активність фотосистем і супероксиддисмутазу проростків пшениці. ***Методи***. Об'єктом дослідження були саджанці рослин м'якої пшениці (*Triticum aestivum* L.). Насіння досвідчених рослин обробляли порошками наночастинок CuO, Fe_2O_3, ZnO, Al_2O_3 і TiO_2, потім висівали в чашки Петрі і в горщики з ґрунтом. ***Результати.*** Виявлено, що застосовуються наночастинки діють по-різному: CuO і Al_2O_3 знижують ріст проростків, в той час як TiO_2, ZnO і Fe_2O_3 прискорюють ріст проростків і роблять позитивний вплив на активність фотосистем і супероксиддисмутази***. Висновки***. Наночастки TiO_2, ZnO і Fe_2O_3 позитивно впливали на схожість насіння і прискорювали зростання проростків пшениці. Наночастки ZnO і Fe_2O_3 також позитивно вплинули на активність фотосистеми 2, також збільшилася активність антиоксидантного ферменту супероксиддисмутази.

Ключові слова: пшениця, наночастинки, схожість, ріст проростків, фотосистема 2, супероксиддисмутаза.