Study of effects of metallic nanoparticles when introduced into soil on plant *Triticum vulgare*

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**Abstract.** We studied the effect of metal nanoparticles (Fe, Mo and SiO\(_2\), and also Fe and Mo together) at concentration of 10, 25 and 50 mg/kg dry weight of soil on the morphological and biochemical parameters of soft wheat (*Triticum vulgare* Vill). We found that morphometric parameters of test samples were generally superior to control samples. In course of assessing the viability of plant cells, we recorded that experimental groups had viability values of at least 90%. Thus, it allowed us to conclude that the concentrations of nanoparticles used by us did not have a toxic effect on the viability of the roots. When evaluating the enzymatic antioxidant system of plants and the degree of lipid peroxidation, we noted the absence of oxidative stress, while increasing the protective potential of plants. Thus, our studies are the basis for studying the possibility of using nanoparticles in agriculture for intensifying plant growth and increasing their yield.

1. **Introduction**

Nanoparticles in recent decades are among the most closely studied objects in all fields of science. In many ways, this is due to the fact that they have completely unique physicochemical characteristics [1]. It should be noted that soil in future will be main absorber of nanoparticles entering environment, so positive and negative effects on soil biocenoses need to be studied in more detail. Biotesting of nanomaterials is becoming increasingly important and includes a variety of biological models: bacteria (*Photobacterium phosphoreum*), plants (*Lemna minor, Lipidium sativum*), protozoa (*Tetrahimena pyriformis*) and etc. As soon as nanoparticles are released into the environment, they are exposed to possible interactions with the above components of the agroecosystem [2,3]. Therefore, researchers make every effort to understand and analyze the scale of these key interactions in order to gain functional knowledge of toxicity and likely effects of released nanoparticles on environment and agriculture. Moreover, such studies will primarily contribute to the determination of the permissible level of nanoparticles within the permissible safety limits.

Thus, the purpose of our work was to conduct set of studies aimed at assessing effect of promising nanoparticles on physiological and biochemical parameters of plants.

2. **Materials and methods**

In the study, we used drugs from commercially available nanoparticles of Fe, Mo and SiO\(_2\) (50-110 nm, 40-120 nm и 15-25 nm, respectively).
The following concentrations were used in our study: 10; 25 and 50 mg/kg of dry soil, which was due to the results of previous studies. Next, the prepared liozoli NP for each repetition and concentration were mixed with moist artificial soil (moisture 45-50%) and mixed using a mixer.

The study used the following doses and combinations of nanoparticles: NP Fe, Mo and SiO$_2$ in concentration 10; 25 and 50 mg/kg of dry soil (designated as NP 10, NP 25 and NP 50), as well as a combination of NP Fe and Mo (denoted as Fe+Mo 10, Fe+Mo 25, Fe+Mo 50).

Wheat seeds Triticum vulgare Vill (henry variety) were used as an object of study. Wheat plants were planted with 15 seeds in a pot of 15×10×15 cm, in which 350 g of dry soil were placed. The pots were placed in a climatic chamber at $t=22\pm2$ °C and humidity 50%.

The soil for the study was taken 40 km from Orenburg. Soils were represented by textural-carbonate black soil.

On day 3, the germination energy was estimated (GOST 12038-84). On day 7, the percentage of germination was determined. We also measured 10 seedlings - the length of the first leaf (from the base to the leaf apex) and the main root (from the root collar to the tip of the main root), their number. Also determined the mass of leaves and roots.

Catalase (CAT) was determined by the method of Maehly and Chance [4] and [5], based on the interaction of hydrogen peroxide with potassium iodide.

The amount of lipid peroxidation products (LPP) was determined by the content of malondialdehyde (MDA) according to Heath and Packer [6]. The level of lipid peroxidation was expressed as a percentage, the number of TBA-reacted products contained in the cells of the initial roots was taken as 100%.

To assess cell death, Evans Blue was used, which is reliable dye for determining dead cells with damaged cell membranes. Microdrugs were visualized under the light of microscope (Micromed-3, Russia) and number of living cells was counted by number of unstained cells.

Differences were considered significant when the error probability was $P\leq0.05$. The results were processed using the computer software Statistica for Windows 10.0 and Microsoft Office Excel 2010.

3. The study of morphometric and biochemical parameters *Triticum vulgare*

In the experiment on day 3, we estimated the germination energy (Fig. 1). The best indicators were recorded in the control variant of experiment and with the addition of NP SiO$_2$ 10 (90 and 93%, respectively). In variants of the experiment with NP Fe 25 and NP Fe 50, germination energy was 80 and 83%. In all other variants of experiment, germination energy was less than 80%. On day 7, germination rate when introducing Fe 25 (90%) and SiO$_2$ 10 (93%) NPs were higher than the control, the germination rate of which was 83%. Values below control were recorded for Mo NP at all concentrations, NP Fe 10 and NP Fe 50.

![Figure 1. The germination energy and germination for *T. vulgare*](image-url)
Higher germination of prototypes may be due to the fact that NPs are able to improve germination, as they have the ability to accumulate in plant organs and act as growth promoters.

We found out that the length of the sheet was significantly higher than the control for the experiment variants with NP Mo 25 and Mo 50, NP Fe 10, NP SiO$_2$ 10 and NP SiO$_2$ 25.

At the same time, all the variants of the experiment with the combination of nanoparticles showed the greatest length of the sheet compared with the control (Table 1). The root length increased in the variants with Fe 10 and Fe 50 NPs, as well as SiO$_2$ 10 and SiO$_2$ 25, all variants of the experiment with a combination of iron and molybdenum nanoparticles. Leaf mass increased with the addition of Mo 25 and Fe 10, Fe 25, SiO$_2$ 50, and also with a combination of iron and molybdenum nanoparticles.

When studying the parameters of the antioxidant system of plants, we found that the activity of catalase was higher than the control in all variants of the experiment except Mo 10 and Fe 10. At the same time, the content of malonic dialdehyde did not exceed the control values in all experimental groups. This allowed us to suggest that nanoparticles can increase the antioxidant activity of plants, which are prerequisites for the use of the latter in crop production.

We analyzed the viability of plant roots (Fig. 2). In all test samples, the viability values were not less than 90% for wheat, which allows us to state that the nanoparticle concentrations used by us did not have a toxic effect on the viability of the roots.

Table 1. Morphological parameters of plants when introducing nanoparticles

|               | sheet length, cm | root length, cm | number of leaves, pcs | number of roots, pcs | leaf mass, g | root mass, g |
|---------------|------------------|-----------------|-----------------------|----------------------|--------------|--------------|
| Control       | 13.9±1.1         | 14.01±0.5       | 2.2±0.2               | 3.5±0.5              | 0.047±0.004  | 0.045±0.002  |
| Mo10          | 13.77±0.9        | 16.67±0.7       | 2.2±0.2               | 3.8±0.2              | 0.054±0.004  | 0.019±0.001* |
| Mo25          | 20.54±1.4*       | 14.24±0.5       | 2.6±0.4               | 3.8±0.2              | 0.139±0.011* | 0.060±0.003* |
| Mo50          | 19.36±1.5*       | 15.68±0.8       | 2.2±0.2               | 4.3±0.3              | 0.060±0.005  | 0.051±0.002  |
| Fe 10         | 16.82±0.8*       | 18.44±0.7*      | 2.15±0.15             | 3.4±0.4              | 0.130±0.010* | 0.131±0.010* |
| Fe 25         | 15.13±1.2        | 15.12±0.3       | 2.1±0.1               | 4.05±0.1             | 0.110±0.011* | 0.100±0.010* |
| Fe 50         | 15.39±0.7        | 10.57±0.2*      | 1.9±0.1               | 4±0.5                | 0.075±0.006  | 0.029±0.001  |
| SiO$_2$ 10    | 22.86±1.9*       | 24.74±1.2*      | 2.5±0.5               | 3.7±0.3              | 0.164±0.020* | 0.163±0.011* |
| SiO$_2$ 25    | 19.24±1.3*       | 14.74±0.4       | 3.1±0.1*              | 3.7±0.3              | 0.041±0.003  | 0.084±0.003* |
| SiO$_2$ 50    | 15.04±0.5        | 13.95±0.2       | 2.4±0.4               | 3.9±0.1              | 0.101±0.010* | 0.030±0.002  |
| Fe+Mo 10      | 26.21±1.8*       | 26.89±1.5*      | 3±0.2*                | 4.6±0.4              | 0.180±0.012* | 0.171±0.011* |
| Fe+Mo 25      | 26.41±1.3*       | 22.54±0.1*      | 3±0.2*                | 4.2±0.2              | 0.185±0.011* | 0.183±0.010* |
| Fe+Mo 50      | 22.77±1.1*       | 22.22±1.0*      | 3±0.2*                | 5±1                  | 0.192±0.014* | 0.178±0.012* |
4. Conclusion

Thus, we made the following conclusions:

1. When assessing the viability of plant cells, we found that in all test samples, the viability values were not less than 90%, which allows us to state that the concentrations of nanoparticles used by us did not have a toxic effect on the viability of the roots;

2. When assessing the antioxidant status of plants, we observed the absence of oxidative stress, while increasing the protective potential of plants.

It is known that the effect of stimulants, including NP, on plants, according to some researchers [7], is that all these substances affect primarily the colloid-chemical properties of protoplasm (permeability, viscosity) and increase the flow of water and solutes in plant cells. They also note that, unlike salts, NPs are less toxic and have a prolonged effect [8,9].

The obtained results of morphophysiological and biochemical studies showed the presence of a positive effect of NP Fe, Mo and SiO$_2$, as well as the joint introduction of NP Fe and Mo. This puts them in the category of substances that can be used in agriculture, and in particular in crop production as fertilizers, which increase crop yields.

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