Advanced Studies in Biology, Vol. 15, 2023, no. 1, 157 - 162
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https://doi.org/10.12988/asb.2023.91751

Influence of Ti, Zn and Fe Oxide Nanoparticles on Seed Germination Capability, Photosynthetic Pigment Content and Activity of Photosystem II Triticum Aestivum L.

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Abstract

The effect of nanoparticles of Ti,Fe and Zn oxides on the germination energy, germination capability, growth and development, the content of photosynthetic pigments, the activity of photosystems was studied. **.** 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 Fe_2O_3, ZnO,, and TiO_2, then sown in Petri dishes and in the pots with soil. TiO2, ZnO, and Fe2O3 nanoparticles had a positive effect on seed germination, wheat seedling growth, photosynthetic pigment biosynthesis, and *photosystem 2(*PSII) activity.

Key**words:** wheat, nanoparticles, germination, growth of seedlings, photosynthesis pigments, photosystem 2 (PS II)

Introduction

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.

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.

Nanoparticles are classified as a material in which at least one dimension is <100 nm in diameter [Auffan et al., 2009]. Nanoparticles are not new to the environment and occur naturally in the form of minerals, clays and bacterial waste products. It has been used since ancient times as dye for metals, but the systematic design and development of nanoparticles for various purposes only started in the last few decades [Maurer-Jones et al., 2013]. Engineering nanoparticles designed in such a way as to have properties that bulk samples of the same materials do not have. [Auffan et al., 2009]. Engineering nanoparticles are composed of various materials and are found different sizes and shapes with a set of synthetic surface molecules, making them different from naturally occurring materials [Radad et al., 2012; Maurer-Jones et al., 2013]. TiO2, Al2O3, Fe3O4 nanoparticles were shown to have different effects depending on their concentrations [Salama, 2012]. In these experiments, iron nanopowders at low concentrations increased the yield and grain quality of cereals. It is supposed 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.

Metal and nanoparticles of metal oxides exhibit different physicochemical properties and differ from their native bulk compounds in several respects including its surface, optical, thermal and electrical properties. Several factors are responsible for the reactivity of nanoparticles with biomolecules, including: nanoparticle size, core composition, shape, surface properties, purity, stability and method production [Teske and Detweiler, 2015; Wang P. et al., 2016]. Nanoparticles can retain the main characteristics of their volume material, so it is necessary to take into account the influence bulk material when studying the interaction of nanoparticles in environment, e.g. heavy metals are toxic to plants while silicon as a metalloid has been seen to be useful for plants [Yadav, 2010; Tubana et al., 2016; Helaly et al., 2017]. In recent years, nanoparticles of metals and metal oxides have been used in various industries, including agriculture.

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,and the activity of photosystems.

The object of the study was seedlings and plants of the soft wheat variety (Triticum aestivum L) Mirbashir-128. The seeds of experimental plants were treated with powders of Fe2O3, ZnO, and TiO2 nanoparticles, then sown in Petri dishes and pots with soil. Plants were also grown in the experimental plot under field experimental conditions. The drought was created by stopping watering in the booting phase. The germination energy and seed germination, morphometric parameters, the content of chlorophylls a and b, carotenoids, and plant productivity were determined. The alcoholic extract of the leaves was used to determine the content of pigments. The pigment content was measured on an SP-

2000 spectrophotometer at 665, 649, and 440 nm. The amount of pigments was calculated according to the method [Wintermans J.E.G., De Mots A. 1965] .PS2 activity was determined using a PAM device (photosynthesis analyzer, Germany).The efficiency of photosystem 2 was determined based on the determination of fluorescence parameters in the slits of plants growing in normal and saline environments, according to the Fv / Fm- ratio. Fv = Fm - F0 ; F0 - fluorescence of leaves kept in the dark, Fm - fluorescence of leaves saturated with light.

Statistical analysis

The experiments were carried out in triplicate biological replication and each was eproduced independently 3 times. Statistical processing of the results was carried out using the licensed software package IBM SPSS Statistics. The assessment of the reliability of differences in arithmetic means was carried out on the basis of the Student's coefficient. Differences between groups were considered significant at a two-sided significance level $p \leq 0.05$.

Results and discussion

Table 1. Effect of nanoparticles on seed germination and morphophysiological parameters of wheat plants

Options	Energy of seed germination %	Germination %	seedling height, (sm)		PS II F_v / F_m
			14 days	19 days	
Control	70	90	3.5 ± 0,2	11 ± 0,9	0.8
TiO_2	85	90	6.5 ± 0,5	14 ± 0,9	0.85
ZnO	90	100	6.5 ± 0,6	14± 0.8	0.85
$Fe_2 O_3$	85	90	7.0 ± 0,8	15 ± 0,9	0.85

*Differences between the control and experimental series are significant at $p \leq 0.05$ significance levels

As can be seen from the table, TiO2, ZnO, and Fe2O3 nanoparticles stimulated seed germination and plant growth.

Table 2. Effect of nanoparticles on photosynthetic pigments in wheat seedlings (mg/g wet weight)

Options	Chl. a	Chl.b	Chl. a +b	Chl. a/b	Carotenoids
Control	**1,5** ± 0,03	**0,6** ± 0,02	**2,1**± 0,02	2,5	**0,3** ± 0,02
TiO_2	**1,8** ± 0,02	**0,7** ± 0,02	**2,5**± 0,02	2,6	**0,5** ± 0,01
ZnO	**1,9** ± 0,02	**0,8** ± 0,01	**2,7** ± 0,03	2,4	**0,6** ± 0,01
Fe_2O_3	**1,7** ± 0,01	**0,5** ± 0,02	**2,2**± 0,01	3,4	**0,7** ± 0,03

*Differences between the control and experimental series are significant at p≤ 0.05 significance levels.

As can be seen from table 2,TiO2, ZnO and Fe2O3 nanoparticles had a positive effect on the content of photosynthetic pigments in wheat seedlings.

Table 3. Influence of nanoparticles on yield indicators of wheat under drought conditions.

Options	Stem lengh, sm.	Spike lengh, sm.	Number of grain in one spike, pcs.
Control	30±1	6±1	30±2
TiO_2	36±2	9±1	51±3
ZnO	44±2	10±1	63±4
Fe_2O_3	41±1	8±1	52±2

Possible mechanisms of the influence of metal nanoparticles on plant PSA are the subject of active discussion. Research in this area is relatively recent and the available evidence is often conflicting. However, we tried to analyze the main points of view, according to which nanoparticles can change the activity and structure of PSA. The stimulating effect of nanoparticles on the photochemical

reactions of the light phase of photosynthesis is most often associated with their ability to enhance the absorption of light by chlorophyll molecules [Das et al., 2017, p. 247] and quench excess excitation, taking on energy excited electrons. This kind of plasmon resonance effect was shown for gold and titanium oxide nanoparticles, which most often had a stimulating effect on plant PSA. Thus, nanoparticles of these metals are able to prevent the accumulation of ROS, acting as a kind of protectors of oxidative stress. This hypothesis is consistent with the information published earlier. For example, it has been shown in spinach plants that titanium oxide nanoparticles stabilize photosynthetic membranes, protecting chloroplasts from intense aging under conditions of oxidative stress in the light, and also reduce the accumulation of superoxide radicals under the influence of ultraviolet radiation [Lei et al., 2008, pp. 69-79].

Conclusions

Nanoparticles of TiO_2, ZnO and Fe_2O_3 had a positive effect on the germination capability , accelerated the growth of wheat seedlings,and biosynthesis of photosynthesis pigments.These nanoparticles also positively influenced on the activity of PS 2 in normal and drought conditons .

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Received: August 25, 2023; Published: September 8, 2023