Growth, antioxidant and allergenic potential of tomato (*Solanum lycopersicum* L.) exposed to nano-ZnO during fertilization

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Abstract

The rapid growth of the world's population over the past few decades is forcing the agricultural sector to increase crop yields to meet the needs of billions of people. Modern agriculture faces many problems, such as stagnant yields, decline in soil organic matter or water availability, reduction in agricultural area, etc. The widespread use of conventional fertilizers is a solution with many disadvantages, such as the low efficiency with which plants can uptake nutritional compounds, such as nitrogen and phosphorus, necessary for growth and development. Nanotechnology can offer a potential solution to crop problems. The use of nanoparticles in plant fertilization can, as indicated by several studies, improve plant's antioxidant system, increase the bioavailability of specific nutrients, improve the biometric parameters of plants and, above all, lead to a reduction of usage of conventional fertilizers as well as pesticides.

The purpose of this study was to determine the effect of zinc oxide nanoparticles (nano-ZnO) on the growth, antioxidant potential of tomato (*Solanum lycopersicum* L.) and quantitative content of selected allergens in the fruit of this plant. An additional aspect of the research conducted was to combine the application of nano-ZnO with the use of a standard fertilizer (biohummus) to support the fertilization of plants by increasing the uptake of micro- and macronutrients.

In the preliminary stage of the study, the effect of selected concentrations of ZnO nanoparticles (<100 nm or <50 nm) on tomato seed germination was analyzed during direct application of these nanoparticles to seeds. The results of the abovementioned analysis allowed to determine and compare parameters such as seed germination percentage, average germination time, germination index, germination rate index and seed vigor index. The obtained results allowed to select the appropriate plant cultivation parameters for the next stage of the research. In a further stage of the work, selected tomato varieties were grown in the presence of organic fertilizer (biohummus) and nano-ZnO (<50 nm) solutions at concentrations of 50 mg/L, 150 mg/L and 250 mg/L, respectively. The nanoparticle solutions were applied by foliar spraying method or directly into the soil, which allowed to compare the performance and effectiveness of the two nanoparticle application methods. The subjects of the study were three selected varieties of cherry tomatoes (Maskotka, Granit and Malinowy Bossman). After cultivation, detailed analysis was carried out on the plants' tissues, i.e. shoots and fruits, and soil, which was the growth medium. Quantitative analysis of the content of selected elements and the activity of individual antioxidants, including, polyphenols, flavonoids, carotenoids, catalase (CAT), peroxidase (POX), superoxide dismutase (SOD) or malondialdehyde (MDA) were performed on the green parts of the plants. The examination of fruits included the determination of the total content of antioxidants (DPPH), as well as individual ones, such as lycopene or beta-carotene, but most importantly, the quantification of selected allergens (profilin and bet v 1) was performed. As part of the analyses of the growth medium, the quantitative content of selected elements was determined.

The results showed that the application of nano-ZnO in tomato plants affected the biometric parameters of the plant, its antioxidant potential, and the content of selected allergens. The results of the conducted analyses depended on the nano-ZnO concentrations used, the method of their application and the tomato variety. The application of nano-ZnO solutions increased the uptake and accumulation of selected nutrients in plant shoots (Zn, Fe, K and P). In addition, the application of nano-ZnO had a significant effect on selected biometric parameters of the plant, i.e. root length and weight and biomass of aboveground parts. However, the effect of nanoparticles on plants depended

on the varieties of *Solanum lycopersicum* L. utilized in this study. Subsequent analyses showed that the application of nano ZnO increased the concentration of malondialdehyde (MDA) and total antioxidant activity (DPPH) in plant shoots. The increased concentration or activity of selected antioxidants (polyphenols, flavonoids, vitamin C, CAT, POX, SOD) may have contributed to the plants' resistance to oxidative stress. No inhibition of plant growth or development was observed. The study showed that the application of nano-ZnO caused a minor decrease in chlorophyll and carotenoid content in selected plants, as well as in the amount and weight of obtained fruits. Nevertheless, despite the decrease in fruit weight, an increase in lycopene and β-carotene concentrations in the fruit of selected plants was observed after the nano-ZnO treatment (depending on the utilized nanoparticle doses and the chosen method of application), as well as a significant effect on the content of selected allergens. While the concentration of profilin in the fruit of plants did not change significantly under the treatment of chosen nanoparticles, the analysis of Bet v 1 concentration in tomato fruit showed that the application of a certain concentration of nano-ZnO can reduce the concentration of this allergen.

The results obtained from the conducted analyses indicate that nano-ZnO nanoparticles at size of <50 nm may be a promising compound for enhancing the growth and development of *Solanum lycopersicum* L. The increased concentration of selected elements in the studied plants indicates that the use of nano-ZnO together with fertilizer in plant cultivation may increase uptake of nutrients, which, consequently, may contribute to a reduction in the amount of utilized fertilizers. In addition, the analysis of the antioxidant potential of plants indicates the beneficial effect of nano-ZnO on the activity of selected antioxidants. Depending on the concentration of nanoparticles used or the method of their application, the use of nano-ZnO resulted in an increase of the activity of selected antioxidants and, consequently, enhanced defense potential of plants against external factors (biotic and abiotic stressors). However, it should be noted that the effect of nano-ZnO on the plant depended not only on the nanoparticle concentration used, the application method, but also on the plant species and cultivar. The obtained results differed significantly between the varieties studied, indicating that the presence of nanoparticles in fertilization and plant cultivation requires an individual approach.

The studies presented in this paper and the obtained results often displayed a beneficial effect of nano-ZnO nanoparticles at size of <50nm on the cultivation of *Solanum lycopersicum* L. Nevertheless, there is a need for further detailed analysis of selected parameters in order to apply nanoparticles in agricultural practice.