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Variable impacts of various nano-ZnO application techniques on selected growth parameters of tomato (*Solanum lycopersicum* L.)

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Introduction

Tomato (*Solanum lycopersicum* L.) is a highly esteemed horticultural crop that is consumed in various forms, including raw and processed. Contemporary agriculture employs both conventional and organic fertilizers to enhance crop yield and optimize efficiency. Conventional fertilizers have been shown to enhance agricultural productivity, but their usage has been linked to negative environmental consequences. Those circumstances provide motivation for the exploration of an alternative resolution.

The purpose of this study was to investigate the effects of nano-ZnO (at conc. 50, 150 and 250 mg/L) administered in two distinct ways (foliar spraying and directly into the soil) along with conventional fertilizer on tomatoes (*Solanum lycopersicum* cv. Maskotka). After cultivation, the plant tissues, including aboveground parts of the plants and fruits were analyzed in detail.

Biometric parameters

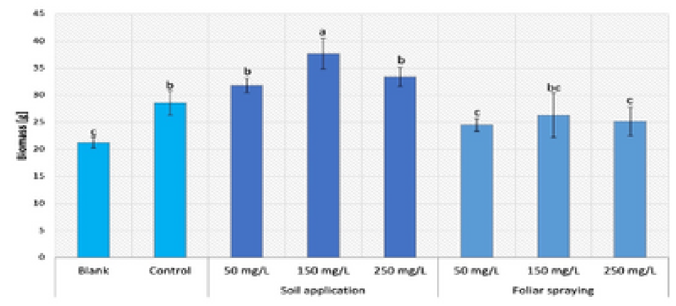

Figure 1. Biomass of the aboveground parts of plant of Maskotka cultivar. Vertical bars are used to display all data, which are the means of 3 replicates (±SD). Different letters indicate the significant differences for p-value ≤ 0.05.

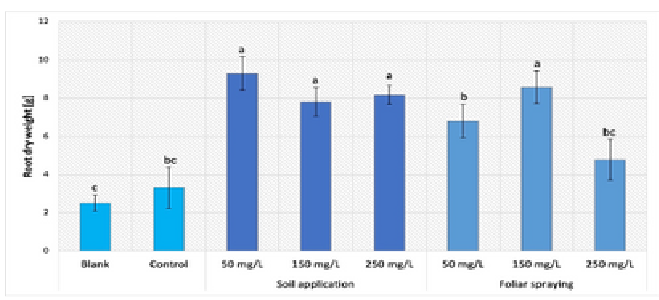

Figure 2. Roots' dry weight of Maskotka cultivar plants. Vertical bars are used to display all data, which are the means of 3 replicates (±SD). Different letters indicate the significant differences for p-value ≤ 0.05.

Figure 3. Pictures of chosen examples of tomato plants (*Solanum lycopersicum* cv. Maskotka) and roots after cultivation. On the picture on the left represents control plants (right)

Antioxidants activity and plants pigments

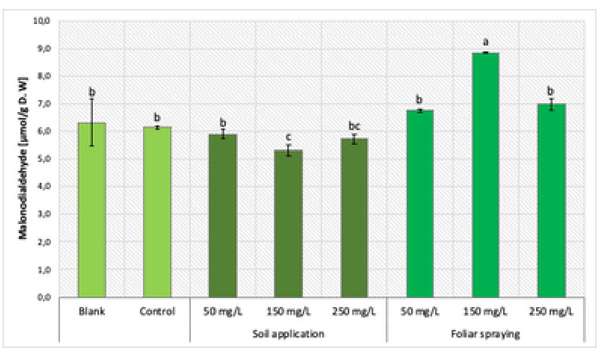

Figure 4. Malondialdehyde (MDA) content in tomato leaves of Maskotka cultivar. Vertical bars are used to display all data, which are the means of 3 replicates (±SD). Different letters indicate the significant differences for p-value ≤ 0.05.

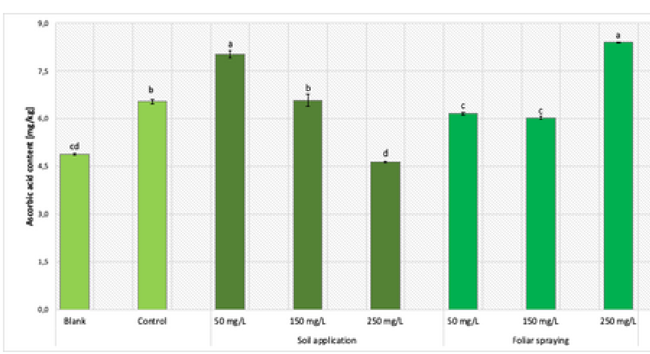

Figure 5. Ascorbic acid content in tomato leaves of Maskotka cultivar. Vertical bars are used to display all data, which are the means of 3 replicates (±SD). Different letters indicate the significant differences for p-value ≤ 0.05.

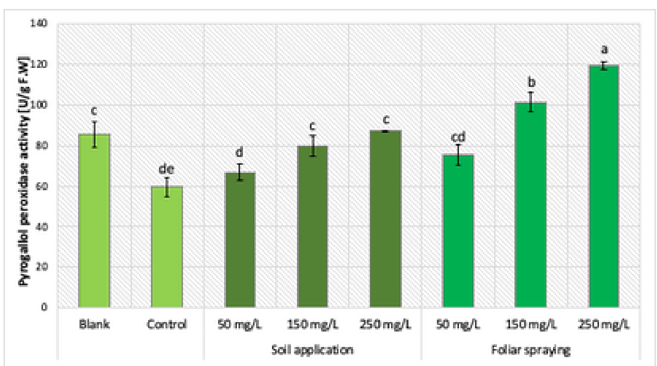

Figure 7. Pyrogallol peroxidase (POX) activity in tomato leaves of Maskotka cultivar. Vertical bars are used to display all data, which are the means of 3 replicates (±SD). Different letters indicate the significant differences for p-value ≤ 0.05.

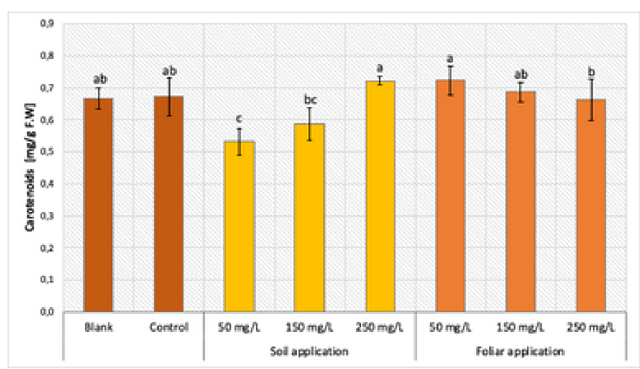

Figure 8. Carotenoids content in tomato leaves of Maskotka cultivar. Vertical bars are used to display all data, which are the means of 3 replicates (±SD). Different letters indicate the significant differences for p-value ≤ 0.05.

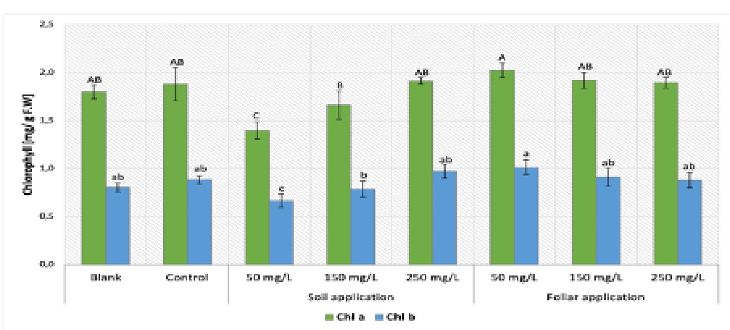

Figure 9. Chlorophyll (chl *a* and chl *b*) content in tomato leaves of Maskotka cultivar. Vertical bars are used to display all data, which are the means of 3 replicates (±SD). Different letters indicate the significant differences for p-value ≤ 0.05.

The research scheme

In the prepared plastic pots containing soil, previously sterilized seeds were sown (each cultivar separately) and then hydrated. After five days of incubation in the dark, the containers were placed on a 12/12 day/night cycle at 25 ± 3°C (air humidity approximately 50%). After a further week of incubation, individual sprouting was transferred to soil in separated container. Next, 50 mL of fertilizer (Biohumus SuperForte, Agrecol J.P., Poland) and 30 mL of ZnO NPs (<50 nm) solution were added. The suspensions of NPs at concentrations of 50 mg/L, 150 mg/L and 250 mg/L were used. In addition, two types of control samples for Maskotka plants were cultivated simultaneously. The blank sample contained neither fertilizer nor nanoparticle solutions, while the control contained only fertilizer. For the Maskotka cultivar, two methods of NPs solution application were utilized: soil treatment and foliar spraying. For plants intended for soil application, NPs solutions of a specific concentration were applied shortly after seeding in new containers. The first foliar application of NP's on Maskotka plants was provided two weeks after transferer to new containers. Selected plants were sprayed with the NPs solution every two weeks, and all plants were fertilized (50 mL) and treated with the NPs solution approximately once per month (30 mL).

Fruits analysis

Sample	*Fresh weight[g]*
Blank	76.2
Control	114.0
SA 50	63.7
SA 150	36.8
SA 250	53.8
FS 50	49.1
FS 150	49.2
FS 250	54.3

SA - soil application, FS - foliar spraying
50, 150, 250 - the concentration of NPs suspension [mg/L]

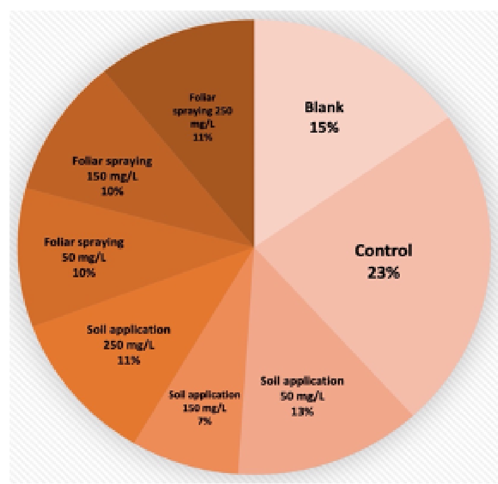

Figure 10. The percentage representation of certain fruits weight from all harvested fruits

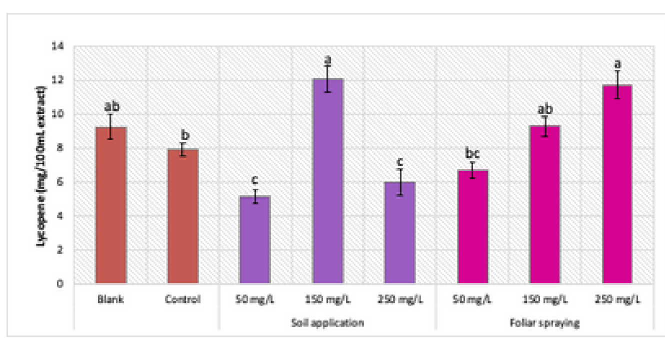

Figure 11. Lycopene content in tomato fruits of Maskotka cultivar. Vertical bars are used to display all data, which are the means of 3 replicates (±SD). Different letters indicate the significant differences for p-value ≤ 0.05.

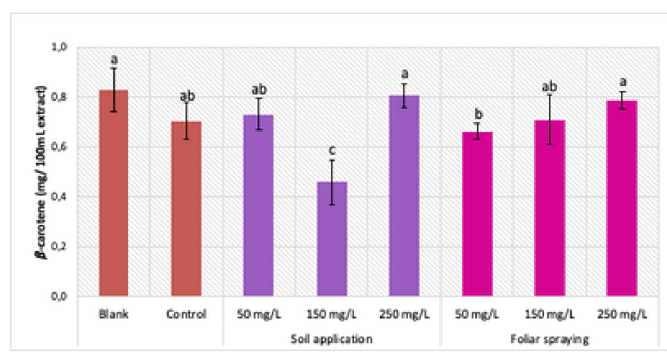

Figure 12. Beta-carotene content in tomato leaves of Maskotka cultivar. Vertical bars are used to display all data, which are the means of 3 replicates (±SD). Different letters indicate the significant differences for p-value ≤ 0.05.

Conclusions

The results demonstrated that applying nano-ZnO to tomato plants altered the plant's biometric parameters and its antioxidant capacity. The outcomes of the conducted analyses were dependent on the nano-ZnO concentrations employed and their application method. The administration of nano-ZnO had a significant effect on particular biometric parameters of the plant, namely root mass and aboveground biomass. In addition, the analyses revealed that the application of nano ZnO increased the concentration of malondialdehyde (MDA) in foliar-sprayed NP-treated plant branches. It is possible that the increased concentration or activity of particular antioxidants (vitamin C) contributed to the plants' resistance to oxidative stress. No inhibition of plant development or growth was observed. The study revealed that the application of nano-ZnO reduced the chlorophyll and carotenoid content of certain plants, as well as the quantity and weight of the crops produced. Nevertheless, despite the decrease in fruit weight, an increase in lycopene and b-carotene concentrations was observed in the fruit of selected plants following nano-ZnO treatment (depending on the doses of nanoparticles used and the application technique chosen). The results of the performed analyses suggest that nano-ZnO nanoparticles with a dimension of 50 nm may be a promising substance for promoting the growth and development of Solanum lycopersicum L. In addition, the analysis of the antioxidant potential of plants reveals that nano-ZnO has a positive influence on the activity of specific antioxidants. Depending on the concentration of nanoparticles used or the manner of their application, the use of nano-ZnO led to an increase in the activity of selected antioxidants and, as a result, an increase in the resistance of plants to external factors (biotic and abiotic stressors).

Chaired by PROF. BIN GAO
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