Toruń, 10.03.2025

Abstract

Title: Mycogenic silver and zinc oxide nanoparticles: biosynthesis, antimicrobial activity and growth stimulators of maize

The worldwide food security highly depend on agriculture, however the increasing population contributes to the threat of malnutrition or hunger. Maize (*Zea mays*) is one of the most important crop plants in the world, including Poland, however its growth is significantly limited by adverse abiotic and biotic factors.

The main aim of the study was biosynthesis of AgNPs and ZnONPs using fungal strains of the genus *Fusarium* and evaluation of their antimicrobial and growth-stimulating activity in maize.

AgNPs and ZnONPs synthesized from broad set of fungal strains of the genus *Fusarium* showed different activities against bacteria and fungi. Among others, AgNPs 1 from *Fusarium culmorum* JTW1 with the strongest antibacterial activity, AgNPs 2 from *Fusarium solani* IOR 825 with high antifungal activity against phytopathogens, and ZnONPs 1 from *F. solani* IOR 825 with high potential to promote maize growth, were selected for further studies. The AgNPs and ZnONPs showed varied physicochemical properties, such as size, shape and surface properties, depending on the fungal strain used for synthesis (AgNPs) or synthesis conditions (ZnONPs).

AgNPs 1 showed inhibitory and biocidal activity against a broad spectrum of Gram-positive and Gram-negative bacteria, synergistic effect with antibiotics, especially streptomycin against Gram-negative bacteria, and inhibited the formation and hydrolytic activity of bacterial biofilms. AgNPs 1 and AgNPs 2 prevented the growth of mycelia and spore germination of fungal phytopathogens. AgNPs 2 at concentrations $\geq$32 μg mL^{-1} effectively disinfected the surface of maize grains and stimulated seedling dry mass production. In the organs of maize plantlets developed from grains treated with the lowest effectively disinfecting concentration of AgNPs 2, changes in H_2O_2 and ascorbate levels and antioxidant enzymes activity were observed. The highest AgNPs concentration (512 μg mL^{-1}) promoted production of fresh and dry mass of plants, but resulted in reduced chlorophyll content and increased MDA level.

ZnONPs synthesized by two methods (ZnONPs 1 and ZnONPs 2) using *F. solani* IOR 825 showed high antifungal activity, particularly against *Fusarium oxysporum* IOR 342 and *Phoma lingam.* The treatment of maize grains with ZnONPs 1 at the concentrations of 32 and 128 μg mL^{-1} resulted in the most effective increase in plant mass (especially dry mass). The lowest tested concentration of ZnONPs 1 (32 μg mL^{-1}) caused minor changes in H_2O_2 levels and ascorbate peroxidase activity in both leaves and roots. The application of ZnONPs 1 at higher concentrations reduced chlorophyll content and increased glutathione and MDA levels in the leaves.

Selected AgNPs 2 and ZnONPs 1 synthesized from *Fusarium solani* IOR 825, at low concentration of 32 μg mL^{-1}, show potential for safe use in agriculture. AgNPs 2 effectively inhibit the growth of phytopathogens, including these on the maize grain surface. Both AgNPs 2 and ZnONPs 1 stimulate plant growth without causing oxidative stress or affecting chlorophyll content. In addition, the biosynthesis of nanoparticles and the pre-sowing treatment of grains with nanoparticle solutions are simple, cost-effective and environmentally friendly, thereby having the potential for practical application.

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