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APPLICATION OF ZINC NANOPARTICLES IN THE AGRICULTURAL INDUSTRY

Introduction. Zinc (Zn) is an essential trace element for plant growth and development, and also plays an important role in animal and human organisms. It is involved in the regulation of the activity and structural stability of various proteins and enzymes, acting as a catalytic, regulatory or structural cofactor for many enzymatic and regulatory proteins. In plants, Zn is required for a wide range of biochemical and physiological processes, including the regulation of gene expression, chlorophyll biosynthesis, photosynthesis, respiration, hormonal regulation, signalling and adaptation to environmental stress factors (Zeng, 2021).

ZnO nanoparticles (ZnNPs) have a wide range of applications due to their semiconducting, piezoelectric and pyroelectric properties. This is due to their large band gap and high binding energy. ZnNPs are one of the most widely used engineered nanomaterials and have significant potential for application in agriculture. They can be

used as nanofertilizers and antimicrobials, helping to stimulate plant growth (Timilsina, 2023).

The aim of this work is to analyze the application of ZnNPs for the agro-industry. Zinc deficiency in agriculture has become a serious problem for arable soils around the world. This is due to the fact that only a small part of the total Zn stock in the soil is available for plant absorption. The main amount of it is contained in structural minerals or is in a bound state with other soil components, which makes it difficult for plants to absorb it. Of course, here is a paraphrased version:

Nanomaterials play a key role in protecting plants from the negative effects of climate change, as they have many beneficial properties. They are more effective than conventional fertilizers, because they precisely deliver nutrients to plants and release them in a controlled manner. This improves the absorption of nutrients by plants and reduces environmental pollution associated with nutrient loss. In addition, nanomaterials contribute to increasing crop yields by providing gradual release and precise dosing of pesticides to control pests and diseases. Due to their antimicrobial properties, nanomaterials can reduce the risk of plant pathogens, which is especially important in a changing climate.

Seed priming with ZnNPs can reduce abiotic and biotic stress in plants, act as a biostimulant, causing an increase in germination rate, seedling and plant growth and total fresh weight, and improve biomass and photosynthetic machinery. pest control (Khan, 2023).

Nanopriming is responsible for inducing the expression of aquaporin genes, which are involved in water consumption and mediate hydrogen peroxide, or reactive oxygen species, dispersed on biological membranes. It activates reactive oxygen species as well as antioxidant mechanisms in seeds, thus stimulating rapid starch hydrolysis. Indian scientists have investigated that nanopriming of seeds with ZnO nanoparticles (ZnNPs) can reduce abiotic and biotic stress of plants, act as a biostimulant, causing an increase in germination rate, seedling and plant growth and total fresh weight, and also improves biomass and photosynthetic mechanism, precisely due to their ability to move through seed coats (Donia, 2023).

Conclusions. Climate change and environmental degradation threaten agriculture and food security, especially for vulnerable groups. Nanopriming with ZnONPs opens up prospects for sustainable agriculture, increasing crop yield and plant resistance to stresses. Studies of physiological and biochemical responses of plants to ZnNPs priming revealed a dose-dependent and nanoparticle-property-dependent effect. For widespread application of this technology, comparative studies of the structure and morphology of ZnNPs and their effects on plant growth are necessary.

An important step is the creation of a database for the selection of optimal ZnNPs depending on the type of crops, soil and climate. Standardization of ZnNPs synthesis will ensure uniformity and environmental friendliness of production. Implementation of these strategies will make nanopriming an effective and affordable tool for sustainable agriculture (Zeng, 2021).

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