

IMPACT OF A GREEN-SYNTHEZED NANOBIOCOMPLEX ON PHYSIOLOGICAL AND BIOCHEMICAL PARAMETERS OF JUVENILE WHEAT PLANTS

Hanna HULIAIEVA* 

Laboratory of Innovation and Technology Transfer, Danilo Zabolotny Institute of Microbiology and Virology, NAS of Ukraine, Kyiv, Ukraine

*Corresponding author: huliaieva_a@imv.org.ua

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Background: Nanotechnology is increasingly applied in agriculture due to the unique properties of nanoparticles and nanomaterials, while green synthesis has emerged as an environmentally friendly approach for obtaining plant-active nanoformulations. However, further research is needed to better understand the physicochemical organization of these systems and their biological effects in plants.

Aim of the study: To synthesize a multicomponent nanobiocomplex (NBC) containing Ag, Cu, Mn, Zn, Fe, Mg, Mo, Se, and I, using *Cucumis sativus* and *Aloe vera* extracts as reducing and stabilizing agents, and to evaluate its physicochemical properties and physiological effects on juvenile wheat plants.

Materials and Methods: The NBC was produced by green synthesis using plant extracts of *Cucumis sativus* and *Aloe vera*. Physicochemical characterization was performed by UV–Vis spectroscopy, transmission electron microscopy (TEM), and morphometric analysis. Physiological effects were assessed on wheat through seed priming and foliar application using biochemical, biophysical, biometric, morphometric, and statistical methods. Parameters analyzed included growth indices, electrolyte leakage, pigment content, antioxidant enzyme activity, and chlorophyll fluorescence.

Results: The NBC supernatant showed a broad UV band at ~270–300 nm, indicating that its optical properties were mainly determined by plant-derived chromophores and metal–organic interactions. TEM and morphometric analysis revealed a hierarchical nanostructure composed of two primary-particle fractions and a heterogeneous aggregate fraction: ultrasmall primary particles of 1.88–5.64 nm (3.70 ± 1.12 nm, median 3.59 nm; $n = 21$), dominant primary particles of 6.06–13.13 nm (10.06 ± 2.23 nm, median 10.42 nm; $n = 41$), aggregates mainly ranging from 20.05 to 81.82 nm (39.33 ± 16.03 nm, median 33.47 nm; $n = 115$) and larger aggregates ranged from 84.38 to 125.12 nm (107.64 ± 12.83 nm, median 107.77 nm; $n = 8$). In wheat, NBC produced positive physiological effects. Seed priming with 0.75–1.25% NBC stimulated early seedling growth, increasing seedling length and fresh biomass. Treatment with 1.25% NBC improved the VI_1 index, while 2.0% NBC increased the integrated viability index VI_2 . The strongest reduction in electrolyte leakage was observed at 1.5% NBC, indicating membrane-protective effects. Foliar application of 0.75% NBC increased chlorophyll a, carotenoids, and total chlorophyll content at the 5–6 leaf stage. NBC also induced dose-dependent increases in POD and CAT activities and favorable chlorophyll fluorescence responses without marked photoinhibition.

Conclusions: The green-synthesized NBC based on *Cucumis sativus* and *Aloe vera* extracts is a plant-active nanobiocomplex composed of ultrasmall and small particles assembled mainly into medium-sized aggregates. Its application improved growth and physiological performance of juvenile wheat plants through coordinated effects on early development, membrane stability, pigment accumulation, antioxidant activity, and photosynthetic function.

Keywords: *Triticum aestivum* L., *Apium graveolens* L., green synthesis, seed priming, nanoparticles.