

1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: Nanocarriers with mycogenic iron nanoparticles as new and sustainable nanofertilizers for maize cultivation

1.1. Project goals

In the present project, a sustainable approach to supplementing maize plants with mycogenic iron oxide nanoparticles will be investigated. Mycogenic iron oxide nanoparticles will be encapsulated in casein-loaded calcium carbonate microspheres, which will serve as nanocarriers, enabling the controlled release of iron in soil and nutrient delivery to the maize plant. This novel nanocarrier delivery system will be synthesized via green fungal-mediated routes and characterized for morphology, encapsulation efficiency, and release kinetics under simulated conditions. Maize plants treated with these novel nanocarriers will be evaluated for physiological responses, with a particular focus on redox homeostasis through enzymatic and non-enzymatic antioxidant assays. In addition, the environmental fate of the nanoparticles will be tracked using spectroscopic and imaging techniques to assess their stability, transformation, and bioavailability in the rhizosphere and maize plant. Analysis of the maize rhizosphere microbial communities will be performed to understand broader ecological implications.

1.2. Outline

In recent years, the global agricultural sector, in general, and the Polish agricultural sector, in particular, have faced increasing challenges in enhancing crop productivity while promoting environmental sustainability. The Green Revolution has proved that agriculture has the potential to meet the food demand. Conventional chemical fertilization is efficient, but it often leads to significant nutrient losses through leaching, volatilization, and fixation, resulting in decreased nutrient utilization and contributing to environmental challenges. The advent of nanotechnology and the introduction of nano-fertilizers in agriculture offer a potential solution to these challenges. To understand the nature and environmental implications of nanomaterials, substantial research is being conducted on their effects on plants and associated microbial systems. Nanofertilizers are nano-scale nutrients encapsulated or coated in a material that enables controlled nutrient release and gradual dispersion in the soil (Jithendar et al., 2024). Nano-fertilizers, compared with conventional chemical fertilizers, offer several advantages, including improved nutrient utilization, reduced environmental impact, enhanced agricultural output, and improved product quality. Nano-fertilizers, due to their small size and higher surface area-to-volume ratio, are highly reactive. The controlled release of Nanofertilizers can be a sustainable and efficient solution to addressing challenges in nutrient management, environmental concerns, and economic efficiency.

1.3. Work plan

- Mycosynthesis and characterization of iron nanoparticles and casein-based nanocarriers
- Conducting the experiments on the effect of nanomaterials on plant growth and redox balance

- Analysis of nanoparticle fate in maize and release kinetics from carriers
- Analysis of the microbial communities of the maize rhizosphere after treatment with nanocarriers
- Literature review, data analysis, and contributing to the writing of scientific articles

1.4. Literature (max. 10 listed, as a suggestion for a PhD candidate)

Kekeli, M.A., Wang, Q. and Rui, Y., 2025. The Role of Nano-Fertilizers in Sustainable Agriculture: Boosting Crop Yields and Enhancing Quality. *Plants*, 14(4), p.554.

Jeevanandam, J., Barhoum, A., Chan, Y.S., Dufresne, A. and Danquah, M.K., 2018. Review on nanoparticles and nanostructured materials: history, sources, toxicity and regulations. *Beilstein J Nanotechnol* 9(1), pp.1050-1074.

Jithendar, B., Kumar, R. and Rana, N., 2024. Revolutionizing crop nutrition: exploring nano fertilizers in agriculture. *Int. J. Plant Soil Sci*, 36(6), pp.327-339.

More literature According to candidate own choice

1.5. Required initial knowledge and skills of the PhD candidate

- A Master's degree in Life Sciences, preferably in Biology, Biotechnology or similar
- Experience in microbiology, especially in cultivation and screening for antimicrobial activity of bioactive compounds
- Experience in bionanotechnology, especially in biosynthesis of nanoparticles, nanocomplexes, and their characterization with various techniques
- Experience in plant cultivation
- Ability to work independently on its own initiative and in a team environment.
- Excellent oral and written communication skills in English are expected for effective interaction with our multidisciplinary research team
- Experience in paper writing and conference presentations is welcome.

1.1. Expected development of the PhD candidate's knowledge and skills

The project aims to train doctoral fellows in the fields of microbiology (cultivation, molecular analysis, biodiversity analysis), bionanotechnology (biosynthesis, characterization), and plant physiology (plant growth and development, plant condition, redox balance parameters), both in knowledge and in laboratory skills. The goal of this extensive training program is to complement the day-to-day scientific training with the experiences and tools needed to pursue a future career in any sector of science, both inside and outside academia.