Abstract

Copper as one of the micronutrients is essential for proper plant growth. Cereals, including spring barley (*Hordeum vulgare* L.), are particularly sensitive to both deficiency and excess of Cu. Cu deficiency, especially during tillering and anthesis stages, may result in e.g. pollen abortion or a decrease in their nutritional value. Due to the unsatisfactory efficiency of conventional fertilizers, more attention is being focused on the use of nano-fertilizers. Due to their small size (1- 100 nm), engineered nanoparticles (ENPs) exhibit more effective physico-chemical properties than their bulk counterparts. In the context of fertilization, the ability of ENPs to gradually release metal ions, among other things, can be used to provide plants with long-term source of micronutrients.

The goal of the doctoral dissertation was to verify the advantages of copper nanoparticles over conventional copper fertilizers. Accordingly, 2 experiments (laboratory and pot experiments) were set up, which were preceded by a literature review on the application of nanotechnology in crop production [**PI**]. The laboratory experiment aimed to evaluate the response of barley plants suffering from Cu deficiency to foliar application of nano-Cu versus $CuSO_4$ at two concentrations of 100 and 1000 mg Cu L^{-1} [**PII**, **PIII**]. Cu compounds-plant leaves interactions were analyzed with spectroscopic and microscopic methods (ICP-OES, FTIR/ATR, SEM-EDS). Patterns of pigment content, lipid peroxidation, enzymatic antioxidant activity and non-enzymatic content along with gene expression analysis of Cu transporters, aquaporins, and enzymatic antioxidants in plants after 1 and 7 days of exposure were used to evaluate the efficiency of plant supplementation with nanoparticle and ionic form of Cu, including cellular Cu status. The second stage of the study (pot experiment) involved quantitative and qualitative assessment of spring barley grains after foliar application of nano/microparticles (nano-Cu, nano-CuO, micro Cu) and ionic Cu compounds ($CuSO_4$, Cu-EDTA) [**PIV**]. The yield, mineral composition, nutrient content, antioxidant content, and bioactivity of the grains were evaluated.

The study showed that the application of nano-Cu at a dose of 100 mg L^{-1} had a positive effect on plant health, increasing the content of low-molecular antioxidants and a milder molecular response than $CuSO_4$, which enlarged the plant stress response. On the other hand, the analyses of the grains of the seeds showed that although nano-Cu provided a similar level of Cu accumulation as $CuSO_4$ or Cu-EDTA, their effects on individual biochemical parameters

(nutritional value, antioxidant content and activity) were different, but the advantage of nano-Cu over used conventional fertilizers was inconclusive.

Key words: *Hordeum vulgare*, Cu nanoparticles, foliar application, biofortification, antioxidants