Application of nanoparticles in the fertilization of crop plants

Mgr Inż. Lidia Mielcarz-Skalska

Supervisor:
dr hab. inż. Beata Smolińska, prof. PŁ

Abstract

Nanofertilizers are fertilizers which consist of nanoparticles or are supported by them. They are a potential solution to the problems of modern world, i.e. increasing the population with simultaneous reduction of agricultural land, environmental pollution, urbanization. Due to the possibility of activating the antioxidant system of plants and, among others, an influence of the uptake of nutrients, blocking the access of heavy metals to the rhizosphere or protection against diseases and parasites, nanoparticles will not only increase yield, but also will reduce the penetration of pesticides and excess of chemicals into the soil. In addition, the use of nanofertilizers increases the bioavailability of nutrients, e.g. nitrogen or phosphorus. Thanks to the possibility of reducing the doses of conventional fertilizers in favor of supplementation with nanoparticles, it will also be possible to reduce the introduction of excessive amounts of macro and microelements, and thus, the risk of groundwater chemization and eutrophication of surface waters.

The aim of this study was to develop a new fertilization method with the use of soil supplementation with nanoparticles. The research was carried out on four plant species: *Lepidium sativum*, *Brassica rapa*, *Raphanus sativus* and *Lolium perenne*. For this purpose, a number of experiments were carried out, leading to the selection of nanoZnO and nZVI nanoparticles to support the fertilization of plants with selected macroelements as efficiently as possible. For this purpose, the effects of nanoparticles themselves in various forms and concentrations on plants were first investigated. Then, variants containing nanoZnO and nZVI, which had the greatest impact on plants, were selected and cultivation was carried out in which they were added to the soil simultaneously. The next and last stage of the work was to investigate the functioning and yielding of plants on soil containing only macronutrients: nitrogen, phosphorus, magnesium and calcium in three different concentrations: low (½ optimal concentration - Makro 1), optimal (Makro 2) and high (1 ½ optimal concentration - Makro 3) (Makro study) and the same macronutrients combined with nanoparticles (Nano study). Cultivation was carried out under controlled conditions and then the plants were harvested, the content of elements in soil and plants was examined, the yield was weighed, the antioxidant system was examined (the content of chlorophyll, anthocyanins, carotenoids, polyphenols, flavonoids, superoxide dismutase activity, catalase and pyrogallol peroxidase).

The analysis of the content of selected elements in the aboveground and underground parts of plants grown on soil with nanoparticle supplementation showed an increased uptake of phosphorus, nitrogen and magnesium in comparison to plants which were fertilized only with macroelements. Also in the soil, positive results were obtained – an addition of nanoparticles resulted in the reduction of macroelement residues in the soil and an increase in bioavailable fractions (in the variant without plants, the effect was probably smaller than in the case of the presence of plants - nZVI causes an increase in the rhizosphere surface and root exudate).

The studies carried out on *Lepidium sativum* with the use of nanoZnO showed that the concentration form <50 nm caused a decrease in biomass and mass of the aboveground part, while concentration form <100 nm improved the yield. Similarly, growth stimulation of the aboveground part of *Lolium perenne* was observed. An addition of nanoZnO to the soil also increased the biomass of *Raphanus sativus* and *Brassica rapa*. In the case of the last two plants, an increase in tuber thickness was also observed when they were fertilized with both types of nanoZnO. The best parameters of the antioxidant system were observed at a concentration of 10 mg / kg DM. nanoZnO soils in the concentration form <100 nm.

All plants which were tested as the part of the doctoral thesis showed an increase in biomass and stimulation of yielding with nZVI nanoFER 25 supplementation (except for white radish biomass, where inhibition was observed). The best effect in the case of the mass of the underground part of turnips and radishes was obtained at the concentration of 10 mg nanoFER25 / kg DM soil. Fertilization of the soil with nanoFER 25S at concentrations of 10 and 100 mg / kg DM soil, caused a complete inhibition of the growth of yellow turnip, and therefore these variants were excluded from further studies. The concentration of 10 mg nanoFER 25 / kg DM soil was considered as the best variant. It caused both an increase in plant yield and an improvement in the functioning of the antioxidant system.

The plants which were harvested from the soil enriched with the combined nano compounds were characterized by a higher biomass compared to the control plants. Better yielding of all species was observed, both in comparison with the control variant and with plants grown on single nanoparticles. An exception was the yellow turnip, in which no significant effect of fertilization on biometric parameters was observed. The analysis of the antioxidant system also showed a positive effect of soil supplementation with combined nanoparticles on its activity.

The highest concentration of macronutrients gave the best results in the cultivation of cress, yellow turnips and white radishes. On the other hand, perennial ryegrass had the best biomass growth in the variant with optimal concentrations (higher concentrations were probably too high and they caused the salt effect). The study of antioxidant systems carried out on cress and white radishes gave the best results when supplementing the soil with the Makro 2 variant, in the remaining species the best parameters were observed in the Makro 3 variant.

In turn, the latest study showed that the addition of nanoparticles to the soil fertilized with specific concentrations of macronutrients causes a comparable or better growth of the tested plants than at lower concentrations. The analysis of the non-enzymatic antioxidant system of cress showed an increase in the concentration of polyphenols and flavonoids in the whole plant and an increase in the content of chlorophyll *a*. No effect of the Nano test on the content of other plant pigments was observed. The cultivation of perennial ryegrass on soil supplemented with nanoparticles resulted in an increase in the content of polyphenols in the whole plant and carotenoids in the above-ground part (a decrease was observed in the underground part at higher concentrations). The other parameters did not change significantly, in comparison to the control plants. White radish responded to the applied conditions by stimulating the production of both chlorophylls in all variants, by increasing the content of carotenoids in the leaves (decrease in the roots) and anthocyanins in the roots (decrease in the aboveground part). The analysis of the turnip antioxidant system showed that it can be clearly indicated that only the Nano 2 variant had a positive effect on the functioning of both the enzymatic and non-enzymatic antioxidant system. In case of other plants, there is no clear answer which cultivation methods are the best to used. The activity of superoxide dismutase increased in the root part of the cress, no effect was observed in the extant variants and in other plant species. The peroxidase activity decreased in the whole *L*. sativum, increased in all parts of the ryegrass and in the above-ground parts of *B. rapa* and *R. sativus*. Catalase activity increased in the aerial part of white radish andin the highest concentration, during the cultivation of perennial ryegrass. An activity decresed in *L. perenne* and *R. sativus* in their underground part.

The obtained results suggest that soil supplementation with nanoparticles is a promising solution (this is also confirmed by the latest literature reports). Plant yield increases, biometric and physiological parameters are improved.

Additionally, the increased activity of the antioxidant system could preparing plants for the onset of potential abiotic stresses and disease.

The method used allowed to reduce the consumption of conventional fertilizer by about half (only in the case of *Brassica rapa* it was a slight difference). At the same time, an increase in yield and improvement in biological functions was observed.