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Micronutrient enhancement in the seed of cereal crops through nanotechnology: A new paradigm of biofortification

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ABSTRACT

In the era of malnutrition and the global pandemic, food nutrients play a key role in the fight against the hidden hunger of the human population on the globe. This will give significant requirement of alternative scientific approach for biofortification in cereals like major staple and main course food of more than half of the population on earth. On the other side, Nanotechnology can have the potential to increase nutritional uptake and translocation of those imported and key nutrition in the grain of cereal crops. Among the different nanomaterials, the key important are nanoparticles of different essential macro and micronutrients in this technology. It will also facilitate the physiological development of plants during growth. In this short review cum communication article, the researched based evidence of those studies was framed to understand the nano biofortification phenomenon and other parameters of nutritional enhancement in cereals.

Key words: *Micronutrient, Biofortification, Nanotechnology, Nano fertilizer, Accumulation, Cereal grains*

Introduction

Micronutrient deficiencies causing various nutritional disorders have become a global issue and have gained significant attention from scientists. These deficiencies are prevalent due to regular inadequacies in diets or dependence of people on a single staple food crop, especially on cereals. The food insecurities are more challenging in developing and under-developed countries mainly due to poor lifestyle and diets. Thus, micronutrient deficiency affects so many people that it's now widely recognized as a public health epidemic. Globally, approximately 149 million children under-five suffer from stunting. In 2018, over 49 million children under-five were wasted and nearly 17 million were severely wasted (Annon., 2019). India is one among the many countries where child malnutrition is severe. Therefore, enhancing of micronutrients in the food crops is a promising solution and it is also strongly related to the improvement in food production systems.

Biofortification through nanotechnology offers opportunities for boosting agricultural productivity and enhancing food quality as well as nutritional value in an eco-friendly manner. The formulation of nanofertilizers (depends on the morphology of nanomaterials) has a strong impact on the bioavailability of micronutrients. The nanoscale materials are defined as a set of substances where at least one dimension is less than approximately 100 nanometers. It can be synthesized known as ENM.

On the contrary, there are different types of barriers for accumulation of micronutrients in plants. In which, the transport pathway of metal ions from soil to grain have key importance (Palmgren *et al*., 2008).

Agri-nanotechniques can support an increase in crop yield by facilitate plant nutrient delivery. Meanwhile, nanoparticles for agricultural purposes can be classified with their application in the fields of fertilization and crop nutrition in three types, *i.e.* metallic, ceramic and polymeric (Liu and Lal, 2017). A comparison between the performances given from traditional bulk fertilizers and their "nano" counterpart indicate a better alternative. Because of nanostructures might increase fertilizer efficiency and uptake ratio of the soil nutrients in crop yield and save fertilizer resources. It helps to enhance micronutrient accumulations in the grain of cereal crops.

Case Studies

Sundaria *et al.* (2019) studied seed priming with iron oxide (Fe_2O_3) nanoparticles which triggers iron acquisition and biofortification in wheat (*Triticum aestivum* L.) grains of two genotypes: IITR26 (high-iron) and WL711 (low-iron). They imposed eight different concentrations of IO NPs (12 h seed priming, followed by sowing in the pot under greenhouse condition) with control (DIW). SEM and DLS analysis revealed the engineered nanoparticle size was 80 nm with unaltered hydrodynamic diameter. A pronounced increase was observed in primed seed's germination percentage (16.67%, 41.6%) and shoot length (48.7%, 64%) at 400 and 200 ppm treatment concentrations in IITR26 and WL711 genotypes, respectively. AAS and SEM-EDX results affirmed the treatment concentration of 25 ppm demonstrated higher accumulation with a significant increase in harvested seeds, iron contents to 45.7% in IITR26 (in nucellar projection region of pigment strand of crease) and 26.8% in WL711 genotypes.

Subbaiah *et al.* (2016) prepared and characterized ZnO-nanoparticles (mean diameter 25 nm). Various nine NP's concentration were foliar sprayed at two stages *viz.*, during tasseling stage (48 DAS) and milking stage of grains (100 DAS) to reveal their effects in maize (*Zea mays* L.) var. DHM-117 and translocation of zinc along with bulk $ZnSO_4$ and control (DW). At 400 ppm concentration (T4) showed significant increases in plant height, leaf area, number of leaves and dry weight at 60 and 90 DAS, similar positive effect were depicted in yield attributing characters. The highest germination percentage (80%) was at 1500 ppm (T8) of ZnO NP. Higher accumulation of zinc (35.96 ppm) in grains was recorded with application of 100 ppm followed by 400 ppm (31.05 ppm) of ZnO NPs, endorsed by SEM analysis. These results indicated that ZnO NPs have significant effects on growth, yield and zinc content of maize grains.

Rico *et al.* (2015) performed soil microcosm study to examine the impacts of cerium oxide NPs (8±1 nm) *viz.*, control, $nCeO_2$-L, $nCeO_2$-M, and $nCeO_2$-H: 0, 125, 250, and 500 mg/kg, respectively on the physiology, productivity and nutrient composition of barley (*Hordeum vulgare* L.) var. Millennium. The $nCeO_2$-H treated soil depicted greatly improved (48 DAT) the plant height (34%), shoot biomass (331%) and chlorophyll content (47%) but $nCeO_2$-M reduced the spike production (52%). The ICP-MS analysis depicted $nCeO_2$-M enhanced grain Ce accumulation by as much as 294% which was accompanied by remarkable increase in important micronutrients Fe (45%), Zn (60%) and Cu (41%). Likewise, it enhanced the methionine, aspartic acid, threonine, tyrosine and arginine amino acids in the grains by up to 617%, 31%, 58%, 141% and 378%, respectively. Therefore, the findings illustrated the beneficial effects of nanoceria in barley.

Tarafdar *et al*. (2014) carried out biosynthesis of Zn NPs and used as nanofertilizer (Ordinary size zinc oxide and nano Zinc were foliar sprayed with 16 L/ha after fortnight of germination at a concentration of 10 mg/l, control without any treatment) in pearl millet (*Pennisetum americanum* L.) cv. HHB 67. The synthesized Zn NPs were characterized by DLS (av. size 18.5 nm, PDI- 0.219), while TEM and EDX confirmed spherical shape and size ranged between 15-25 nm and metal Zn purity, respectively. A significant improvement (6-week old plant) was observed in shoot length (15.1%), root length (4.2%), root area (24.2%), chlorophyll content (24.4%), total soluble leaf protein (38.7%), plant dry biomass (12.5%) and enzyme activities of acid phosphatase (76.9%), alkaline phosphatase (61.7%), phytase (322.2%) and dehydrogenase (21%). The grain yield at crop maturity and zinc concentration in grain was improved by 37.7% and 14.1%, respectively.

Ghafari and Razmjoo (2013) investigated the effects of foliar application (50% sprayed at stem elongation and, the rest at flowering stage) of nano-iron oxide (2 and 4 g/l), iron chelate and iron sulphate (4 and 8 g/L) on grain yield of wheat cv. Pishtaz. The highest 1000-grain weight, harvest index, grain and grain carbohydrate yields were produced by application of 8 g/l iron sulphate followed by application of 2 g/l of nano-iron oxide. Application of 2 g/l of nano-iron oxide produced the highest grain protein (62%) and iron contents (42%) and grain protein yield (104%) and iron yields (78%) followed by application of 8 g/l iron sulphate. Thus, nano-iron source and lower rate could be utilized for enrichment of iron in wheat seed.

Rico *et al*. (2013) studied the quality of rice (Three varieties: Cheniere, Neptune and 10AY004 with high, medium and low amylase, respectively) grains harvested (135 DAT) from soil treated with $nCeO_2$ at 0 and 500 mg/kg soil amended. The result showed that MA variety with K, Na, Fe, and Al concentrations in the treated plants were markedly higher than in untreated plants (20.7, 7.6, 425, and 174.2% higher, respectively). The overall treatment increased the protein content in albumin (7.3%), but decreased that in prolamin (17.4%), compared to the control. Also, treatment did not change the sugar contents but adversely affected the starch concentration. Meanwhile, it is interesting to note that $nCeO_2$ caused changes in the FTIR intensity of grain powder. These, results indicated that $nCeO_2$ could be enhancing micronutrient but compromise the other nutritional value of rice.

Conclusion

The seed priming with Iron oxide NPs represents an innovative and user-friendly approach for wheat biofortification which triggers iron acquisition and accumulation in grains. Although, the negative correlation between Ce and starch concentrations suggests that $nCeO_2$ have a negative impact on the nutritional value of rice. On the contrary, it improved and enhanced storage of important nutrients in barley grains which may be concluded as effect varies among different species. However, the nanoparticulate delivery of Zn through ZnO NPs could be effective and was beneficial to enhance the growth, Zn accumulation in grains, yield and yield attributes of maize crop. Biosynthesized Zn NPs can be used as an effective nanofertilizer to enhance crop production and zinc concentration in cereals as showed positive effect in pearl millet. Lower rate of nFe_2O_3 could be utilized for iron biofortification in cereal crops as its shown similar effects in wheat grain.

Future Thrust

Due to the unavailable form of bulk nutrition and particles in nutrient management practices, the cereals crops have some physiological hindrances in fortifications. The nano-dimensional form of nutrient application will facilitate nutritional uptake even through selective permeability of the root cortex region. Thus, the nanoparticles will be a new paradigm to cope with the challenges of fortification without changes in the genetic makeup of a particular plant.

Conflict of Interest: None

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