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Minerals Biofortification through Microbes: The New Strategy for Enhancement of Nutrients in Food Crops

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Abstract

Minerals are required both plants and humans for normal growth and development. Plants contain most of the essential nutrients but compared with macronutrients, the concentration of micronutrients is substantially minimum. Low concentration in food crops, leads to micronutrient deficiencies in humans. Nutrients deficiency is one of the serious global threats that affect millions of people worldwide. It can cause dangerous health conditions and diseases. So, importance is needed to improve the concentration these micronutrients in food crops. Biofortification through microbes is a new and promising option for the bioavailibity of micronutrients; especially, Fe, Zn and Se in the major food crops. Microbes that promote plant growth are becoming an effective approach to replacing the artificial inorganic fertilizers. It is achieved by using various microbial biofertilizers that solubilize the essential minerals and micronutrient which are present in soil and are made easily available for plants uptake.

Introduction

Over the past 50 years, in developing countries agriculture research has been increased the production and yield of different varieties of staple crop (rice, wheat, maize, pearl millet, and others), which substantially reduces the micronutrient in the crop. The reduction of micronutrient causes "**Micronutrient deficiencies"** or "**Hidden hunger**" in mankind, which is one of the serious global threats, affects more than two million people worldwide. For the well-being of human, mineral elements needed, that can be supplied by appropriate diet. Worldwide 60% of people are deficient in iron (Fe), 30% of deficient in zinc (Zn) and iodine, and 15% are deficient in selenium. Other than these, magnesium (Mg), calcium (Ca), and copper (Cu) deficiencies are also commonly present in many developing and developed countries (Kour *et al.,* 2020).

Deficiencies of micronutrients causes dangerous health conditions and diseases included birth defect, cancer, cardiovascular disease, osteoporosis, neurodegenerative disorders, and many more. Due to mineral malnutrition, people are used to consume different mineral supplements to compete the requirements of the micronutrient. These strategies are not always been successful. For this reason, rising of micronutrient content in the crop (staple crop) is very necessary. Different methods are available to increase the mineral supplements in the crops, included spraying of chemical fertilizers, nanofertilizers, agronomic fortification, or biofortification. Biofortification increases the nutrients of the crops to the sufficient level without polluting the environment. Moreover, it is long-term, cost-effective, and feasible to reach the undeserved, rural population. For this reason, biofortification technique is widely used for uplifting of mineral concentrations in edible crop and also to improve the crop yield on infertile soils.

Micro-Minerals Biofortification Strategies

Worldwide, the fifth major challenge to human health is micronutrient deficiency. Deficiency of iron and zinc is widespread common problems and affects most of the people the society. Mostly children below five years and pregnant women are being suffering from severe malnutrition. Deficiencies of vitamin A, zinc, iron, and iodine in crops are the main attributes for causing about 20% death of children under the age of five. Onto alleviate the micronutrient and minerals deficiencies, bio fortification of the staple and cereal crops are considered to be an economic solution to solve micronutrients deficiency. **"biofortification**" referred as, increase the bioavailability of micronutrients and mineral content of food crops.

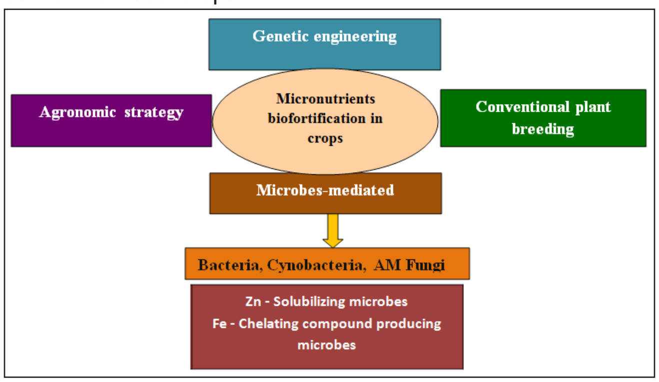

Figure 1: Different strategies for micronutrients biofortification in food crops

Microbes-mediated biofortification, agronomic biofortification, conventional plant breeding, and genetic engineering are the four main strategies of biofortification which are been widely used for improving the nutritional content of food crops. Biofortification through microbes is achieved by using various microbial biofertilizers that solubilize the essential minerals and micronutrient that are present in soil and made easily available for uptake of plants (Kour *et al.,* 2020).

Microbes are the invisible engineers of soil and maintain several biogeochemicals of the environment. There are various soil microbes that are beneficial for the uptake of micronutrient and improve the plant growth, including bacteria, fungi, cyanobacteria, actinomycetes, and mycorrhiza. These plant growth-promoting microbes undergo various mechanisms to make available nutrients of the plant uptake such as solubilizing the nutrients fixed in the soil matrix, production of phytochormones, and atmospheric nitrogen fixation. Also, microbes influence the availability of nutrients by numerous characteristics such as solubilization, oxidation or reduction, and chelation. Microbes-mediated biofortification of crops is attained by using microns in the form of biofertilizers (Kour *et al.*, 2020). Microbial biofertilizers are selected live microbial cultures, which are applied on the plant surfaces, seeds, or soil of the crops. These biofertilizers colonize in the interior of the plant and helping in plant growth by increasing availability, supply, and uptake of micronutrients from the soil. One of the remarkable advantages of using biofertilizers is to reduce the pollution of the environment and more accessible to small and marginal farmers as they are cheap and easily produced.

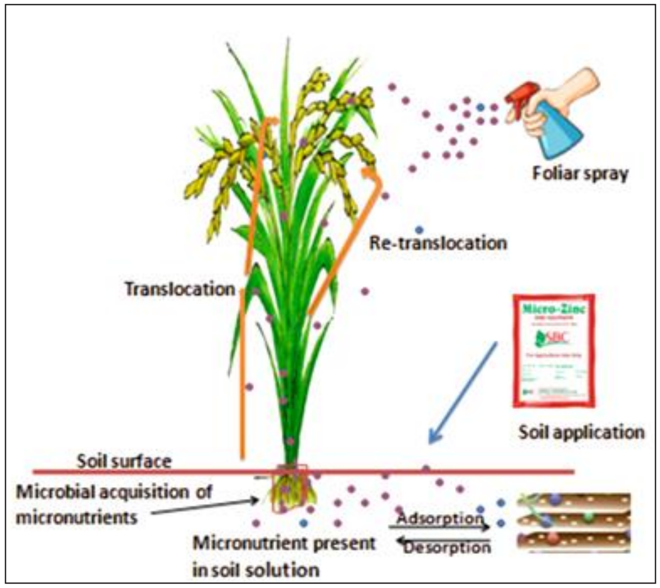

Figure 2: Agronomic biofortification

Microbes-Mediated Biofortification of Micronutrient

a) Iron (Fe) Biofortification

Iron is the most abundant element on earth's surface, which is unavailable to the plants because it is present in the insoluble form (iron oxyhydroxide polymers). Deficiency of iron causes lower hemoglobin or anemia. Worldwide, about one billion populations are deficient in iron and it is mostly common among infants, children, and women in the developing countries. Biofortification of iron in plant is necessary to overcome this issue. Microbes and plants are involved in a particular mechanism, *i.e.*, to chelate the insoluble iron that is present in the soil by producing low molecular weight iron-binding molecules called siderophore which satisfy the iron. Siderophores are produced by various microorganisms under iron limiting conditions to enhance bioavailability of the element in environment. It chelates the insoluble iron (Fe^{3+}) in different pH conditions and makes iron available for plants' uptake (Sharma *et al.,* 2003).

E.g., Arbuscular mycorrhizal fungus (AMF), *Glomus intraradices, Pseudomonas fluorescens, Pseudomonas putida, P. chlororaphis, Brevibacterium antiquum, Bacillus* *pichinotyi, Chryseobacterium* sp., *Enterobacter ludwigii* and *Providencia* sp.

b) Zinc (Zn) Biofortification

Zinc is an essential transition metal required for the growth and metabolic activities for human and plants. In plants crop growth, yield, maturity, vigor, and many physiological functions depend upon zinc. Whereas, in human zinc plays a significant role on the synthesis of DNA, RNA, and metabolic homeostasis. The main reason for zinc deficiency is the low availability of assessable zinc in the soil, which is not readily available for the plant's uptake. The low bioavailability of zinc in the soil affects zinc concentration in grains and human health directly. Microbial biofortification overcome the deficiency of zinc by enhancement of micronutrient. Zinc solubilization can be achieved by various mechanisms such as chelation soil pH reduction or by improving root growth and root absorptive area (Verma *et al.,* 2017). Chelating compounds produced by microbes form a complex on binding with zinc and they release zinc chelated compounds at the root surface which ultimately enhances the bioavailability of zinc in plants. Several microbes including bacteria and fungi species (Arbuscular mycorrhizae, *Bacillus*, *Enterobacter*, *Pseudomonas* and *Microbacterium*) improve the bioavailability of zinc in soil system and plant tissues by using different mechanisms.

E.g., *Burkholderia* sp., *Sphingomonas* sp., *Variovorax* sp., *Enterobacter* sp., AMF *Funneliformis mosseae*, *Rhizophagus irregularis, Bacillus aryabhattai, Acinetobacter, Pseudomonas fragi, Pantoea dispersa, Pantoea agglomerans, E. cloacae, Rhizobium* sp., *Pseudomonas aeruginosa, Ralstonia pickettii, Burkholderia cepacia* and *Klebsiella pneumonia*.

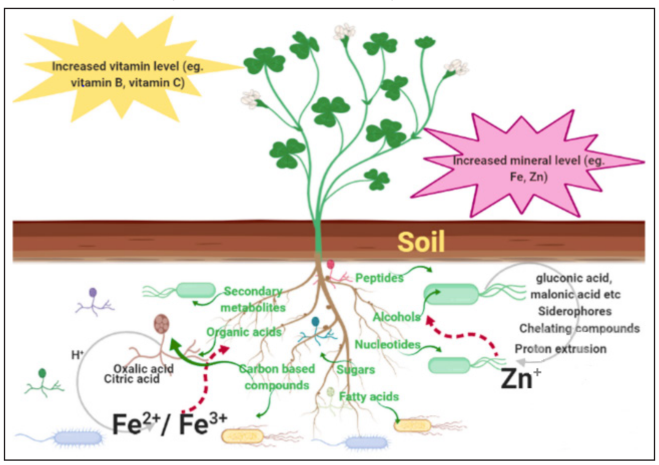

Figure 3: Iron and Zinc bioavailability through direct and indirect mechanism of action (Prasanna *et al*., 2013)

c) Selenium (Se) Biofortification

Selenium (Se) is an essential micronutrient and a vital trace element for humans and plants. Despite being an essential element, it is also a potential toxic element to natural ecosystems due to its bioaccumulation potentiality. In human and animals, selenium performs a wide range of functions, whereas for mankind anticancerous and antioxidants properties are the primary concern. Deficiency of the metalloid in the diet of human can cause retardation of growth, impaired bone metabolism, thyroid function abnormalities and risk of oxidative damage. In general, world's soil has low quantity of Selenium therefore; biofortification of selenium is the major need. To overcome the selenium deficiency, various microbes have been screened for the biofortification of Se.

E.g., *Stenotrophomonas* sp., *Bacillus* sp., *Enterobacter* sp., *Pseudomonas* sp., *Glomus claroideum, Paenibacillus, Klebsiella, Rhizophagus intraradices* and *Acinetobacter* sp.

Conclusion and Future Opportunities

Biofortification through microbes is a better strategy to enrich micronutrients and also helps in achieving sustainable agriculture. To overcome the deficiencies of micronutrient, one of the important strategies is biofortification. Several biofortification strategies were implemented in the past for the biofortification of crops such as agronomic, conventional breeding, microbes-mediated, *etc*. Microbes are the invisible engineers of the soil and maintain several biogeochemical of the environment. Plant Growth Promoting Microbes are used as biofertilizers helping in the plant growth by increasing availability, supply, and uptake of micronutrients from the soil. One of the remarkable advantages of using microbial biofertilizers is that it reduces the pollution of the environment and is more accessible to small and marginal farmers as it is affordable and easily produced. Microbes-mediated biofortification in future possesses manifold benefits which can fight against the problem of hidden hunger in humans. This biofortification can also support green revolution and achieve sustainable environment.

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