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Biofortification- Leading Edge Technology for Enhanced Micronutrient Accumulation in Field Crops towards Food Security

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Due to a growing population, there is a global threat to nutritional security. This shows that the global food system needs to use strategies that are both practical and cost-effective. Fe and Zn are two important micronutrients around the world and micronutrient deficiency in soil has also been reported in different tracts of the world. This makes it harder for plants and, eventually, for people to get the nutrients they need. These micronutrients are very important to the way the body works, so not getting enough of them has very bad effects on the body.

Status of Micronutrients in Soil

Most of the deficiencies are caused by using too much fertilizer on high-yield crop varieties and not adding enough micronutrients to the soil. In important parts of the world's soil, the highest amount of Zn and B deficiencies were found to be 49% and 31%, respectively. Most of India's soil has enough micronutrients, but they aren't easy for plants to take up. This means that soils in many parts of India aren't good enough. Indian soils have different amounts of boron deficiencies, ranging from 68% in the red soils of Bihar to 2% in the alluvial soils of Gujarat. Maximum B deficiency (54–86%) was observed in Alfisol soils of West Bengal and Assam, due to high rainfall that leads to a decrease in water-soluble B. Indo-Gangetic plains with saline soil exhibited a higher concentration of B, whereas the moderate level of B was recorded in Rajasthan and Madhya Pradesh. Copper deficient soil was observed in Kerala, Himalayan Tarai zone, Bihar, Uttar Pradesh and north Madhya Pradesh.

Biofortification through the Mode of Minerals Fertilization

Biofortification is the process of improving the nutritional value of a crop by increasing the number of micronutrients in edible parts without sacrificing agronomic traits like resistance to pests, yield, and drought.

Ferti-Fortification

There are many reasons why correcting deficiencies by applying micronutrients to the soil is the most flexible and efficient approach. It has been found that Zn soil application increases wheat and rice crop production and Zn content. The treatment of zinc to the soil has also been shown to influence the yield and nutritional value of cowpea and chickpea.

Foliar Feeding

Spraying a single or mixture of micronutrient solutions in combination with the target salt onto the leaves allows for their absorption through the stomata and epidermis. Foliar feeding was more effective than soil treatments for maximizing nitrogen uptake and avoiding visual deficiency and soil deficiency issues in the near future.

Seed Priming

Seed priming is a process in which seeds are hydrated in a controllable manner, which lets them do their pre-germination metabolic activities without bursting open. Bread wheat benefited more of seed priming with Zn + Pseudomonas sp. MN12 than from any other method of application.

Seed Coating

In addition to the inert sticky substance, nutrients are applied to the seed surface in the form of finely ground powder during the coating process. This method modifies the soil-seed contact, which in turn changes the uptake of soil-applied and coated nutrients. The effectiveness of micronutrients is affected by many things, such as the ratio of nutrients to seeds, the soil characteristics, the soil quality, the soil moisture, and the coating material. Zn seed coating has been used a lot to improve the yield of many different field crops. Using $ZnSO_4$ and $ZnCl_2$ to coat the seeds with Zn increased the amount of Zn in the tissue, helped the seeds germinate, and helped the seedlings grow faster than when the seeds were not coated.

Application of Lime

Coating seeds with zinc has been widely used to boost yields across a wide range of agricultural products. Covering seeds with $ZnSO_4$ and $ZnCl_2$ increased wheat's Zinc content in tissue, germination rates, and seedling growth compared to not coating the seeds. Several analyses have looked at what happens when lime is applied alongside P fertilization. P has been found to have deleterious interactions with Zn and to reduce the availability of Zn in nearly all soils, worsening plant Zn shortage and resulting in lower grain Zn concentrations.

Application of Elemental Sulfur

However, solitary Zn application to soil may cause nutritional disturbance due to the antagonistic impact of Fe and Zn, and the literature reports that S and Zn significantly increase grain Zn content. Biochar provides a conducive environment for the microbial communities that produce Fe-chelating chemicals and control the metal's movement in and around the grain. When S is applied alongside Fe and organic input (biochar manure/poultry manure), the mineral composition and nutritive values of rice grain are significantly increased in comparison to when S is not applied.

Application of Gypsum

Gypsum facilitates the removal of excess exchangeable Na with Ca from the soil cation-exchange complex and bicarbonate from the soil solution. Soil bicarbonate removal raises accessible plant nutrients such as zinc, iron, copper, manganese, and cobalt. This pattern can be explained by the fact that increasing amounts of gypsum have been applied to soils, thereby lowering their pH and enhancing their physical qualities.

Application of Biochar

Incorporating biochar into acidic soils has the potential to improve soil fertility and crop quality by increasing the availability of micronutrients and promoting plant development. The combined application of biochar and zerovalent iron (BZVI) improved rice's Zn and Fe concentrations while decreasing Cd levels. ZnO application in the root zone and subsequent increases in biomass may have led to competitive Zn uptake, resulting in lower Cd concentrations. Biochar reduces the bioavailability of Cd and other metals in the soil by lowering the pH of the soil.

Application of Biosolids

Biosolids contain essential nutrients including N and P as well as soil organic matter. Sewage sludge is also a source of numerous metals, particularly Zn, at varying concentrations, depending on the source.

Transgenic Technology/Biotechnological Approach

Because of these and other limitations, the transgenic technique must be used in biofortification. the lack of a high-quality, species-wide population sample for the required feature (e.g., provitamin A in rice), or incongruous varieties for conventional breeding (due to a lack of sexuality; e.g., banana), long time period required to introduce single or multiple traits (pyramiding traits) into locally adapted elite varieties, inability to target nutritional traits to specific organs and inadequate knowledge of QTL × environmental interactions. Grain mineral content is inversely related to grain production, hence conventional breeding can only go so far. This necessitates the development of novel gene-editing tools, such as transcription activator-like effector nucleases, and the widespread availability of fully sequenced genomes of food staple crops. The transgenic strategy comprises the production of transgenes that cause the re-translocation of micronutrients between tissues and increase their bioavailability, hence enhancing their efficacy and reconstructing biochemical pathways.

Biofortification through Nano-Technology

Through their high surface area, enhanced penetrability, controlled release, and targeted delivery of the desired nutrient to the plant system, engineered nanomaterials (ENMs) have given a viable alternative to conventional agricultural methods. In addition to the direct application of ENMs to plants, traditional fertilisers and pesticides have included ENMs for their role in plant development, disease suppression, nutritional and yield increase.

The importance of micronutrients has been acknowledged for both people and livestock, where micronutrient deficiencies can result in negative health effects. In emerging and poor nations, the primary cause of micronutrient insufficiency is the population's reliance on cereal-based foods. To overcome micronutrient insufficiency in the human population, agronomic biofortification by fertilization appears sustainable and cost-effective. Management strategies like as organic or inorganic inputs may operate as direct nutrient sources or contribute to boosting the bioavailability of micronutrients by altering soil characteristics. However, due to the increasing usage of fertilizers, a complementary method is urgently required. Transgenic biofortification is an adaptable method for enhancing the micronutrient content of crops; however, little research is undertaken on fodder crops. The enrichment of plant nutrients with nano-fertilizers is a burgeoning topic of study, necessitating extensive research into the toxicity issue.

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