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Zinc Biofortification in Rice as a Modern Era Strategy to Relieve the Zinc Deficiency in Human Health and Fitness

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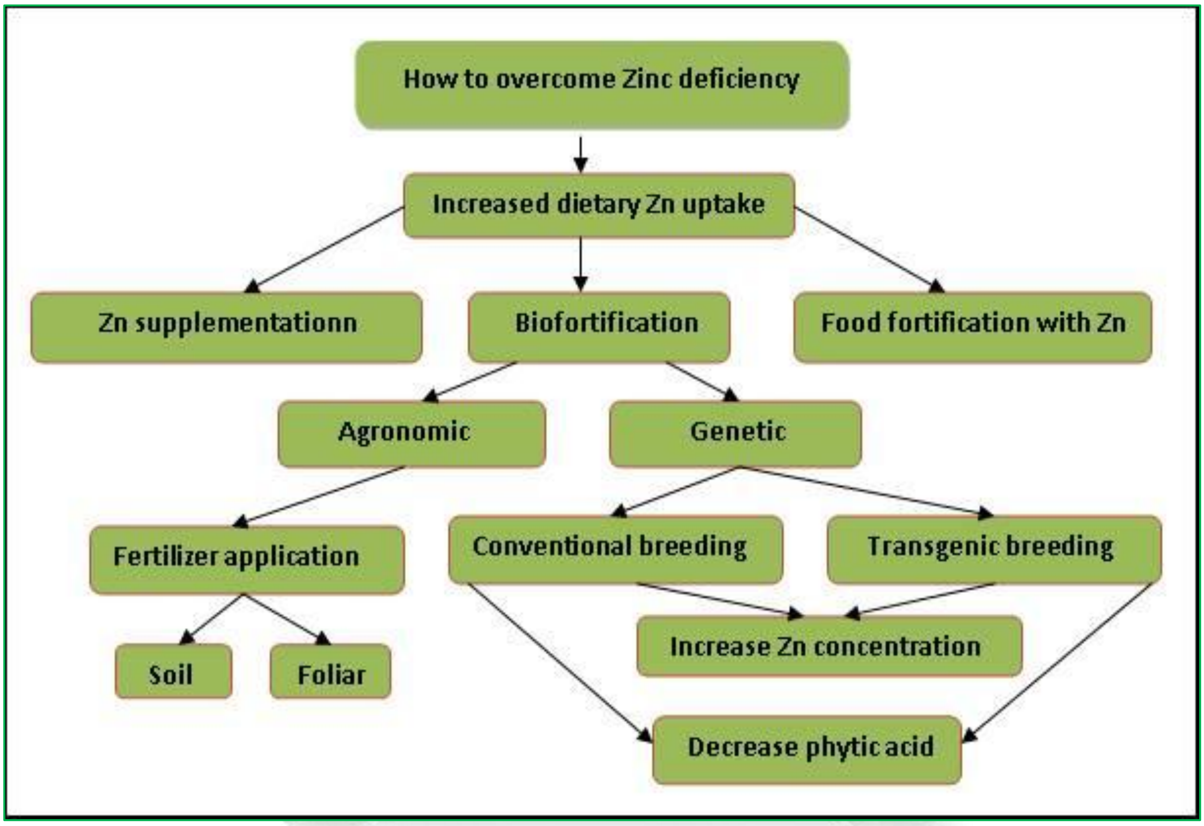
The lack of adequate dietary intake of zinc still causes a huge health problem in developing countries. Although green revolutions have dramatically increased productivity and solved the food security problems of developing nations like India, still they are far behind the developed nations regarding dietary diversity. The reason for this problem is high intake of cereal-based foods with low concentration and low bioavailability of Zn. FAO reported that 2 billion people worldwide suffering from micronutrient deficiencies. Zinc concentration in modern cultivars of cereals are very low and therefore cannot meet the human needs for Zn. Zinc is deficient in more than 30% of the world's soils. Crops, humans, and animals are at high risk for Zn deficiency. When it comes to the grain yield and nutritional quality, cereals, specifically rice, is more susceptible to Zn deficiency than legumes. Every year, nearly 0.8 million people and nearly 0.45 million children in the world die from zinc deficiencies. It is believed that this acute shortage issue arose due to crop production on infertile land or increased consumption of rice which is naturally low in Zn. There have been reports that deficiencies in Zn can lead to serious health complications (defective immune system, delays in growth, stunted growth, poor learning abilities, infections, DNA damage, and cancer). An individual suffering from a zinc deficiency is susceptible to mental lethargy, acrodermatitis, and infertility. As in rice, In order to avoid micronutrient loss, it is recommended to parboil food grains before milling to prevent Zn loss. Food diversity, supplementation, and fortification can help us combat these deficiencies, but rural communities have limited access to these three strategies. Biofortification offers a cost-effective solution to escalating deficiencies of micronutrients (Zn) in the population, particularly for the poor.

Through biofortification, food crops can be developed that are rich in nutrients using conventional breeding practices and modern biotechnology, without sacrificing agronomic performance or significant consumer preferences. Zn biofortification can be done in two ways: (a) agronomic and (b) genetic biofortification. Agronomic biofortification involves enriching cereal grains with nutrients like zinc during crop growth. While, in genetic biofortification, crops are bred to be more nutritious. This can be accomplished through conventional selective breeding or genetic engineering. Among these methods, plant breeding strategy (e.g., genetic biofortification) appears to be the most effective and sustainable way of increasing Zn concentrations in grain. However, breeding method takes a long time and involves considerable effort and resources. Breeding for biofortified food crops with Zn depends heavily on soil Zn pools available to plants. However, soils in most parts of the cereal growing areas have a variety of chemical and physical problems that dramatically reduce Zn availability to plants. Due to this, the new (biofortified) cultivars might not have the genetic capability to absorb sufficient amounts of Zn from the soil and accumulate it in the grain. In order to improve Zn concentration in cereal grains, it is essential to have a short-term solution. Zinc fertilizers or zinc-enriched NPK fertilizers (e.g., agronomic biofortification) is an effective solution to this problem. Zinc can be applied to soil, seeds, and leaves in agronomic biofortification or by dipping seedlings in fertilizer solutions. Inorganic salts, primarily zinc sulphate ($ZnSO_4$) are typically used to treat zinc insufficiency. Due to its changes into other chemical forms, however, the recovery of applied Zn is relatively limited. Zn chelated source, such as Zn ethylene diamine tetra-acetic acid (Zn-EDTA), in which the central metal ion (Zn^{2+}) is surrounded by chelate ligands, which supplies a significant amount of Zn to the plant without interacting with soil components and improve zinc use efficiency.



Pictures of Zinc fortification in Rice with foliar spray of (a) Zinc sulphate ($ZnSO_4$), (b) Zn-EDTA at Research Farm, SKUAST-Jammu

Foliar application of Zn-EDTA is far more effective than soil application in terms of grain Zn accumulation. Soil application, on the other hand, is more efficient in increasing the grain yields. As a result, zinc biofortification has been identified as the most effective way to advance global welfare and reduce Zn deficiency in humans. The rice grain is deficient in zinc by nature, as are the people who eat it. Addressing the zinc deficiency in rice grain will directly address the malnutrition problem in those populations. To establish a long-term solution to this challenge, agronomic biofortification should be used as a complementary tactics along with breeding approaches.