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Biofortification: A Sustainable Solution To Malnutrition

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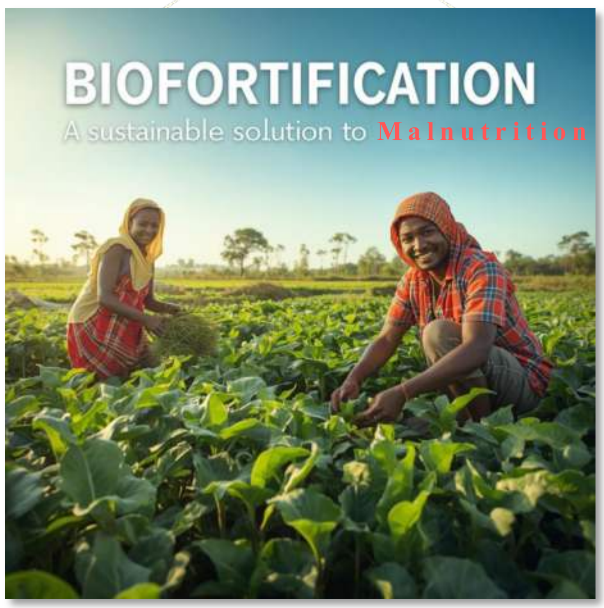
Introduction: The Global Challenge of Hidden Hunger

Malnutrition continues to be a significant global public health concern, especially micronutrient deficiencies, or "hidden hunger." It is thought to impact almost 2 billion people globally and cause over 800,000 deaths annually, with developing nations bearing the brunt of the burden due to limited access to a variety of nutrient-rich foods. Staple cereals make up to 60% of daily caloric consumption in many of these areas, but they frequently lack important vitamins and minerals like iron, zinc, and vitamin A, which can result in deficiencies that affect immunity, growth, cognitive development, and general health. Biofortification, which increases the micronutrient content of staple crops through plant breeding, agronomic techniques, or biotechnology, has emerged as a sustainable and economical solution to this problem. Biofortification provides a long-term solution to eliminate hidden hunger and promote nutritional security, especially among vulnerable populations in developing nations, by enhancing the nutrient profile of regularly consumed foods (Vanguri *et al.*,2025).



What Is Biofortification? Concept and Methods

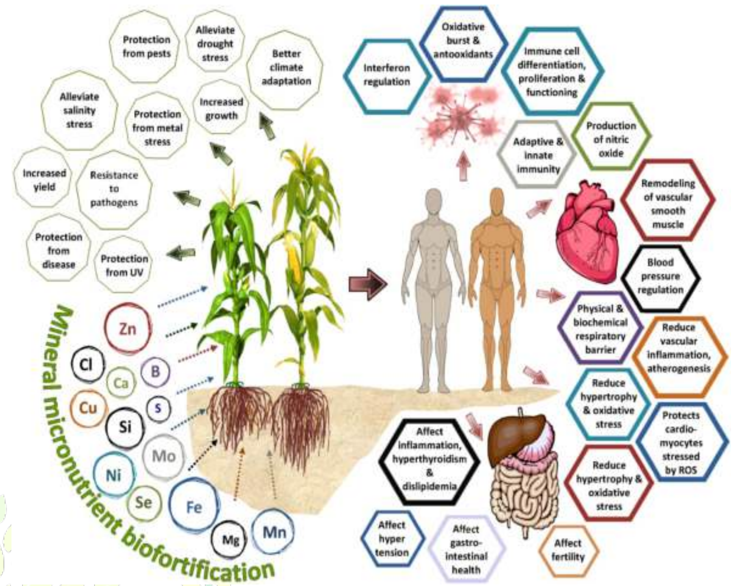
Biofortification is a long-term method for improving the nutritional content of staple crops by increasing levels of important vitamins and minerals. This can be accomplished via three primary techniques: conventional breeding, which taps into natural genetic diversity from wild relatives and landraces (e.g., wild emmer wheat exhibits iron concentrations of 15-109 mg/kg, and the 'Lal Gotal' landrace achieves 100.45 ppm); agronomic biofortification, which involves mineral fertilizer applications that pose environmental concerns and limit long-term viability; and advanced biotechnological tools like transgenics, marker-assis

Biotechnology has led to developments such as Golden Rice, supplemented with β-carotene to alleviate vitamin A deficiencies, and maize variants with provitamin A concentration ranging from 0.24 to 8.80 µg per gram. These techniques have successfully increased zinc in wheat (up to 118 mg/kg in wild Triticum dicoccoides), iron in rice (6.2-71.6 ppm in brown rice lines), and provitamin A in sorghum and maize. Combining these measures boosts the nutrient density of ordinary crops, giving an affordable, long-term solution to hidden hunger, particularly in rural regions without access to supplements or fortified items (Sen *et al*.,2024).

Biofortified Crops and Their Nutritional Benefits

Biofortified crops are intended to supplement basic foods with vital vitamins and minerals, thereby alleviating hidden hunger and micronutrient shortages. Pearl millet biofortified with iron and zinc has shown remarkable improvements. The combined application of $ZnSO_4$ @ 25 kg/ha (soil) and $FeSO_4$ foliar spray (0.5% at tillering stage) produced the tallest plants (192.92 cm), highest grain yield (2422.25 kg/ha), stover yield (6669.26 kg/ha), and biological yield (9091.51 kg/ha), as well as maximum net returns (₹54,707.5/ha) and a benefit-cost ratio of 1.65. Similarly, zinc-rich wheat lines have been reported with grain Zn levels up to 118 mg/kg, and vitamin A-rich sweet potato and Golden Rice enriched with β-carotene supply important nutrients to people lacking access to supplementation. These biofortified crops not only boost growth and production but also improve human health by reducing iron-deficiency anaemia, zinc-related stunting and vitamin A deficiency, making them a long-term and cost-effective solution to malnutrition (Yadav *et al*.,2025).

Influence of Micronutrient Biofortification on Human Health and Immunity



(Sen et al.,2024)

Advantages of Biofortification for Sustainable Agriculture

Biofortification offers considerable benefits for sustainable farming as an economical, long-term solution to hidden hunger, particularly in countries with high zinc and iron deficits, such as India, where 47% of soils are zinc-deficient, and 13% are iron-deficient. In contrast to supplemental or artificial food fortification, it improves dietary nutrition effortlessly since staple foods such as rice, wheat, maize, and pearl millet naturally absorb extra micronutrients during cultivation without affecting consumer habits. Bacteria such as Bacillus altitudinis and Pseudomonas putida increase nutrient solubilization, siderophore production, and root absorption, resulting in elevated Fe and Zn levels in grains. This strategy benefits farmers by increasing yields and soil health, consumers by addressing micronutrient shortages that affect over two billion people worldwide, and food security by making calorie-dense staples nutritionally balanced. Biofortification improves agricultural resilience and addresses malnutrition by reducing reliance on synthetic fertilisers and utilising microbial mechanisms (Nazma *et al*.,2025).

Conclusion: Biofortification For A Healthier Future

Biofortification is a long-term, cost-effective solution to "hidden hunger," which affects more than 2 billion people worldwide due to iron, zinc, and vitamin A deficiencies. Rice, the major food for more than half of the world's population, loses significant amounts of iron and zinc during milling, emphasising the need for biofortified strains to improve nutritional quality. To date, 37 such rice cultivars enriched with iron, zinc, protein, or provitamin A have been released globally (16 in India and 21 elsewhere), meeting national standards of more than 10 mg/kg iron, 24 mg/kg zinc, and 10% protein in polished grains. These types contribute to the prevention of anaemia, the reduction of child mortality, and the protection of maternal health, all while promoting the Sustainable Development Goals. However, widespread use necessitates increased consumer education, continued research on nutritional genetics and bioavailability, and strong regulations to integrate them into conventional agriculture. Addressing the shortfall, where ordinary rice, such as Swarna, provides only 2-3 mg iron and 7-8 mg zinc daily, vs the recommended 15 mg each, biofortification improves healthful eating and long-term health for vulnerable people (Vanguri *et al*.,2025).

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