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Nourishing India: Biofortification for a Sustainable Agricultural Future

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Abstract: India is a developing country, green revolution increased the agricultural yield but not sufficient for the increasing demand of the growing population. Govt. is doing its best to deal with hunger, but the nutrient value is not sufficient to live a healthy life. Hunger is often associated with an empty stomach, but hidden hunger reveals a less visible yet critical issue. Hidden hunger is micronutrient deficiency, where individuals consume sufficient calories and may still lack essential vitamins and minerals. It is crucial to shift focus towards enhancing the nutrient value of food, beyond just meeting caloric needs, to promote better public health. However, nutrient-rich foods often come with a higher price tag, making them inaccessible to many. Biofortification offers a promising solution – a farming approach that boosts the natural nutrient content of crops, making nutritious food more accessible without requiring significant changes to people's diets. Biofortification is a sustainable and targeted approach to improve the nutritional value of staple foods by increasing essential micronutrients such as iron, zinc, vitamin A, and others through selective breeding, improved agricultural practices and biotechnology.
Keywords: Biofortification, Micronutrient deficiency, Hidden hunger, Nutrient-rich food, Malnutrition

I. INTRODUCTION

Malnutrition is a serious global challenge, impacting individuals across their lifespan. It arises from an imbalanced diet, manifesting in various forms such as undernutrition, stunting, micronutrient deficiencies, being underweight, or obesity. The wide-ranging effects of malnutrition necessitate a thorough and focused nutritional strategy to support optimum health and wellbeing. 3 billion people, all over the world cannot afford the minimum price of healthy diets recommended by national governments (Herforth *et al*., 2020), and around two billion people are insufficiently supplied with the essential trace elements (Andersson *et al*., 2012). Global Hunger Index (GHI) of India is 27.5 in 2022, which is serious, and 15.3% of our population did not have sufficient food to eat. Infant mortality rate in India is 35.2 per 1000 child births, and 59.1% of Indian women (15-19 years) are anemic (National Family Health Survey 5). Enhancing micronutrients in the diet boosts immunity and is important for building resilience in times of crisis(Heck *et al.*, 2020). Our health is impacted by hidden hunger, which is not felt in the stomach. Biofortification of staple food crops is a practical way to ensure nutritional security in developing nations. (Zulfiqar *et al*, 2020).

The nutrient quality of food is decreasing, as the soil, which provides the plants with their vital nutrients, is either depleted of it or the microflora is so severely affected that the nutrients are not available for the plants to absorb. Although food fortification can be done during food processing or supplementation through pills but biofortification works at the agricultural level, embedding nutrition into the food right at its source (IFPRI, 2020). So, improving micronutrients in grains of important crop varieties can sustainably help to improve malnutrition in the people. Biofortification of staple crops improve vitamins and mineral density, benefiting over 40 million smallholder families in developing countries (HarvestPlus, 2020). Biofortification is significantly important for rural populations in low- and middle-income countries who depend heavily on staple foods like rice, wheat, or maize and have limited access to diverse or fortified diets. Biofortification supports the two sustainable development goals i.e. hunger and health. As global agriculture faces growing challenges from climate change and resource scarcity, biofortification provides a low-cost, sustainable, and farmer-friendly solution to strengthen both food systems and public health (CGIAR, 2019). Several crops, which are consumed by most of the population worldwide as staple foods, such as wheat, rice, cassava, beans, sweet potatoes, maize, mustard, and gourd, are biofortified with different nutrients and minerals to help improve overall public health. Biofortified crops are not only sustainable solutions but are cost-effective compared to dietary supplements.

Globally, 100 crores people suffer from selenium deficiency due to inadequate dietary intake. As wheat is a staple crop for many, biofortification can enhance selenium levels in wheat grains, although variations exist depending on wheat varieties (Ismail, 2024). Staple crops like wheat and rice are ideal for micronutrient fortification, offering a promising approach to address dietary deficiencies. Being rich in vitamin A, Golden rice should be integrated into consumer diets (De Steur, 2022).

As per the press release on 8th Dec, 2023 by Shri Kailash Chaudhary, Minister of state for Agriculture & Farmer's welfare, more than 10-million-hectare land is used for biofortified varieties of significant crops such as wheat, rice, mustard and pearl millet in India and 37,425.7 quintal seeds of biofortified crops are produced and supplied to public and private agencies for multiplication & distribution to farmers for economically weaker sections.

A. Danger and Potential Consequences of Hidden Hunger

Globally, hidden hunger affects over two billion people and causes serious consequences, especially for women and children (HarvestPlus, 2022). Micronutrients (Vitamin A, Fe, Cu, Zn, Se, Mo, Ni, etc.) influence physical and mental health as many of them act as cofactors of different enzymes, which control our metabolism (Gillespie *et al.*, 2016). Anemia reduces energy and mental concentration, and the main cause of anemia is iron deficiency. Deficiency of Vitamin A can cause blindness and weaken the immune system, especially in children. Zinc deficiency increases sensitivity to infections and slows growth. In addition to affecting individuals health, these vitamin and mineral deficiencies also impede social development by reducing learning capacity, expanding medical costs, and lowering productivity (WHO, 2021).

People in low-income households usually consume only a couple of basic foods that satisfy hunger. Although it is impractical for the poor, it is ideal to increase nutrition by adding more foods to the diet; in other words, diversified diets are a better option. So, dealing with hidden hunger through biofortified versions of these very staples offers an efficient, economical and permanent solution (IFPRI, 2020).

B. Methods of Biofortification

1) Traditional Plant Breeding: Conventional plant breeding methods, i.e., controlled mating and selection of desired traits, are used. High-yielding crop varieties are crossed with varieties, which are naturally rich in nutrients. Over 5-7 growing seasons, breeders select and improve plant lines that have good farming traits with better nutrition. By this method, iron-rich beans and vitamin A-rich maize have been developed and are now being grown in several countries (CGIAR, 2019).
2) Fertigation and Agronomic Biofortification: Using fertilisers, soil amendments, and microbe interaction, this technique raises the amount of nutrients in crops. Fertigation is faster than plant breeding; further, it can also help where soils are deprived of such nutrients. Iron deficiency in cereals can be effectively improved by agronomic biofortification without sacrificing yield (Zulfiqar *et al*, 2020). Zinc levels in wheat can be raised by applying Zn enriched fertilizers to wheat fields.
3) Genetic Engineering and Biotechnology: Sometimes the desired level of nutrients cannot be achieved by traditional breeding or agronomic practices, then plants are genetically modified by diverse methods such as transgenesis, genome editing, and integrated omics (Shahbaj *et al*, 2024). Biotechnology can introduce traits more quickly and precisely, and new tools like CRISPR are making this more efficient and acceptable in some countries (Tang *et al.*, 2009). It modifies the metabolic pathway to redistribute micronutrients, improve bioavailability, and decrease anti-nutrients in crops. Golden Rice, which contains provitamin A, is a well-known example.

C. Enhance Bioavailability

It is not only the quantity of nutrients, but absorption of nutrients is also very important. Some antinutrients are naturally present in plants and impact the nutrient absorption and digestion. Through Genetic engineering or plant breeding, scientists either reduce these anti-nutrients or add substances that improve the nutrients in the body (HarvestPlus, 2022).

D. Impact and Benefits

Biofortified crops have shown significant improvements in health, especially in communities where food diversity is low. Orange-fleshed sweet potato increases vitamin A levels in children and iron-rich pearl millet improves memory and attention in adolescents (Low *et al.*, 2007). Iron deficiency causes anemia in a large portion of the Indian population, particularly in women and children. This global issue can be solved by enhancing iron in edible plant parts as well as by improving its bioavailability (Connorton and Balk, 2019). Foliar spray can increase the amount of iodine in pome fruit peels, which is a key component of the thyroxine hormone. These pome fruits can be consumed without peeling (Budke *et al*, 2021). Most of the population all over the world is iodine deficient, and being volatile after microbial interaction, foliar spray is more efficient than soil application (Budke *et al.*, 2020b). Catmak *et al*, 2020 mentioned that Iodine is sufficiently present in biofortified plants.

Farmers can easily opt these biofortified seeds as there is no special agronomic trait change; further, they may give good market value to the farmers, once it is popularized (IFPRI, 2020).

Biofortification, helps to improve the nutrient content in the crop, when it is still in the farm. When a country's agricultural and food nutrition plans are coordinated, it will benefit its citizens' health and well-being as well as its economy because not only will the healthcare system be less burdened, but healthy people will also perform better. Since women in India are the primary victims of malnutrition, biofortification will truly empower women.

E. Challenges

Although biofortification is in progress, not to that extent due to some barriers:

1) Low Awareness. Although people are interested in buying healthy foods, our farmers and people are not fully aware of such biofortified foods, even many of them are negligent of the existence of such crops and their immense health benefits, hence these crops are not in much demand. (Foti *et al*, 2021). Awareness campaigns are needed to increase the interest of people and farmers in these crops.
2) Regulatory policy for Genetically Modified Crops: Globally, GMO crops are not getting public acceptance, even after scientific health verification and have to undergo a long process of approval from the government, which slows down or even stops their growth (Tang *et al.*, 2009).
3) Inefficient Seed Supply Systems: Generally, farmers are unaware of such crops and even if they know about these crops and wish to cultivate them in their fields, they do not have easy access to their seeds. To fill this gap, a strong public-private association is required, which will help to make it feasible to develop a supply chain that reaches every farmer in the rural areas.
4) Taste and Appearance Liking: Generally, people are used to what they are eating and do not want to change the texture, taste, aroma and even look of the regular meal they are having, and if biofortified foods don’t match these expectations, adoption remains low. Breeding must consider local preferences, and community involvement is essential in testing and adapting new varieties (Low *et al.*, 2007).

II. CONCLUSION

To get the benefits of fortified crops fully, people must be aware of these crops. Awareness will increase the public interest and its consumption. Our plant breeders and policymakers should consider the fortified traits in the plant breeding programs. (Bouis and Saltzman, 2017). Biofortification offers a powerful, field-level response to hidden hunger. By improving the nutritional value of staple crops, people who are most in need can benefit for a long time without having to make significant dietary changes or incur additional costs. As food systems face growing pressure from climate change and economic inequality, biofortification presents a solution that is both resilient and inclusive. By introducing vital nutrients into the agricultural system, biofortification provides an economical, environmentally responsible, and sustainable way to improve nutrition. Capital investments in farmer access, supportive legislation, and public awareness are essential to achieve its full potential. Additionally, including biofortification in regional development plans guarantees both practical usefulness and cultural value. With focused assistance, biofortification can help communities flourish and pave the way for a time when hidden malnutrition is rare.

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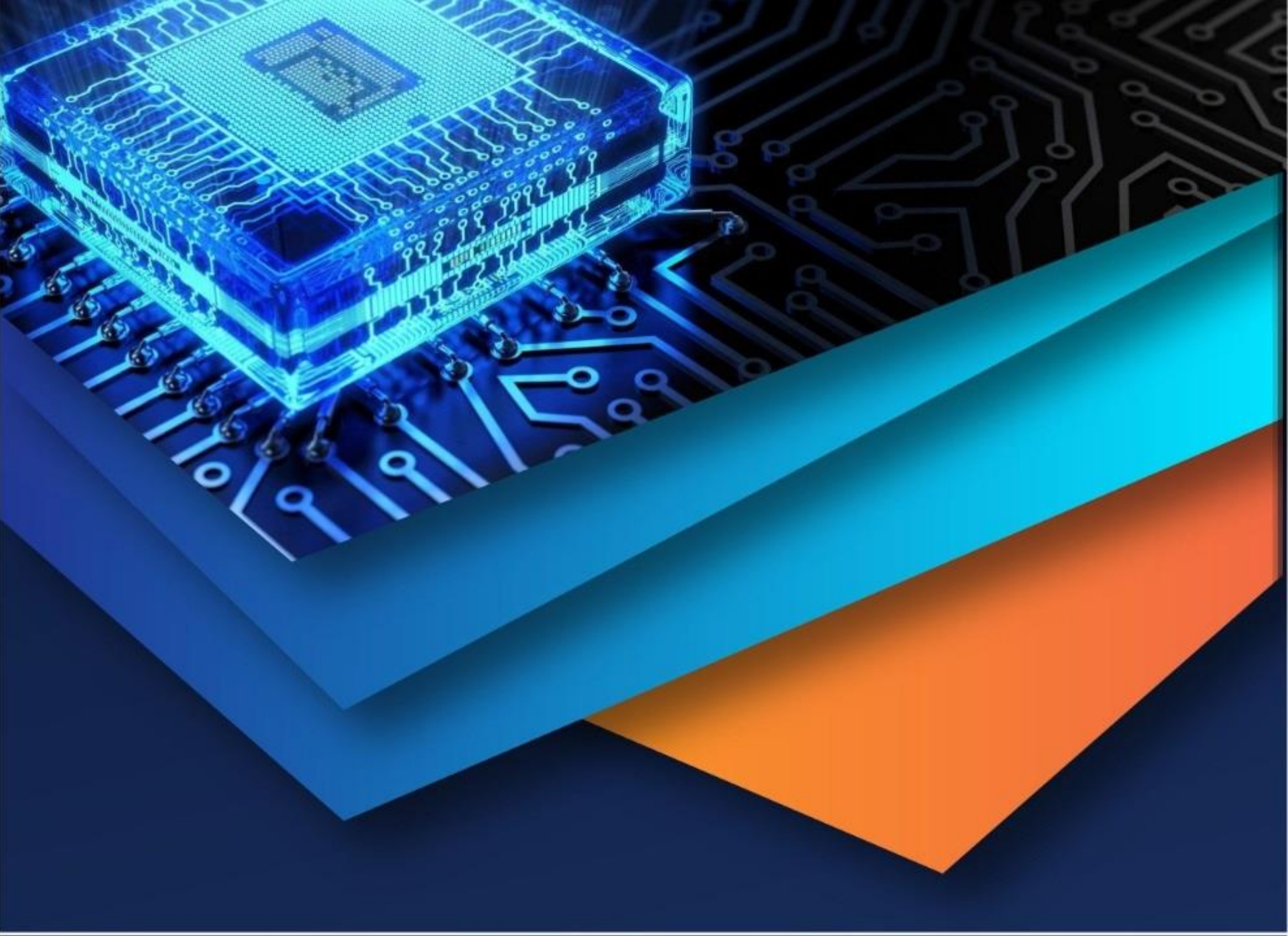

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