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Biofortification and Its Role in Malnutrition

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Abstract

Micronutrient malnutrition is a global public health problem, especially in developing countries. Hunger and starvation which are causative agents of malnutrition are occasioned by poor food supply and low-income purchasing power for the expensive animal sources of micronutrient. Access to adequate, safe and nutrition food required for a healthy and active life by all people at all times is limited, resulting in micronutrient food insecurity. The quantity and quality of food available for consumption to people determined their micronutrient. The quantity ana quality of food available for consumption are causative agents for macronutrient and micronutrient deficiencies. Bio-fortification is an emerging method to increase the micronutrient values of crops in order to eradicate hidden hunger in developing countries. This paper therefore describes the contribution of biofortification in fighting micronutrient malnutrition in developing countries.

Key words: Micronutrient, Food Insecurity, Biofortification, Developing Nation.

What is biofortification

Nutritious diet is vital for proper growth and development in humans. Biofortification is a feasible and cost-effective means of delivering micronutrients to populations that may have limited access to diverse diets and other micronutrient interventions. Biofortified crops are bred to fulfil a significant portion of the dietary requirement of iron, zinc, or vitamin A among women and children, based on their usual eating patterns, in populations where these crops are consumed as staples. Biofortified staple crops, when consumed regularly, will generate measurable improvements in human health and nutrition. Plant breeders screen thousands of crop varieties stored in global seed banks to discover varieties with naturally higher amounts of essential micronutrients. Then, through collaborations with various breeding centers of the Consultative Group on International Agricultural Research (CGIAR), and nationalagricultural research systems, these nutrient-rich varieties are used to breed biofortified varieties that are also high-yielding, disease and pest resistant, and climate smart in local agro- ecological conditions. Fortification is the practice of deliberately increasing the content of anessential micronutrient, i.e., vitamins and minerals (including trace elements) in a food, so asto improve the nutritional quality of the food supply and provide a public health benefit withminimal risk to health. Nutrients are added to the food as they are being processed while biofortification focus on making plant food more nutritious as the plant grow.

Biofortification is a process for improving the nutritional value of the edible parts of the plants, through mineral fertilization, conventional breeding, or transgenic approaches. The targeted micronutrient for biofortification in staple crops are iron, zinc and pro vitamin A.

Why we need biofortification

Biofortification is needed because malnutrition become a universal holding back development with unacceptable human consequences.

- The world population is continuously increasing and suffers from lack of food.
- Worldwide 1.5 billion people are estimated overweight by World Health Organization (WHO, 2011).
- Increasingly these two forms of malnutrition, underweight and overweight are occurring simultaneously within different countries. (Gillespie and Haddad 2003; FAO 2006).

Over 2 billion people worldwide suffer from a chronic deficiency of micronutrients, a condition known as hidden hunger. It affects one in three people globally, inhibits children from reaching their full growth and developmental potential and reduces adult health and productivity.

The Global Hunger Index 2018 ranks India at 103 out of 119 countries on the basis of three leading indicators – prevalence of wasting stunting in children under 5 year, child mortality rate and the proportion of undernourished in the population. 194.4 million people are undernourished in India.

Micronutrient deficiency	Effects include	Number of people affected
Iodine	Brain damage in newborns, reduced mental capacity, goiter	~1.8 billion
Iron	Anemia, impaired motor and cognitive development, increased risk of maternal mortality, premature births, low birthweight, low energy	~1.6 billion
Vitamin A	Severe visual impairment, blindness, increased risk of severe illness and death from common infections such as diarrhea and measles in preschool age children; (in pregnant women) night blindness, increased risk of death	190 million preschool age children; 19 million pregnant women
Zinc	Weakened immune system, more frequent infections, stunting	1.2 billion

Sources: Allen (2001); Andersson, Karumbunathan, and Zimmermann (2012); de Benoist et al. (2008); Micronutrient Initiative (2009); Wessels and Brown (2012); and WHO (2009; 2014a).

To tackle hidden hunger strategies such as dietary diversification, supplementation, commercial fortification and biofortification can be adopted. Supplantation is short term intervention to improve nutritional health, involving the distribution of pills or mineral solution for immediate consumption. The biofortification strategy seeks to put the micronutrient-dense trait in those varieties that already have preferred agronomic and consumption traits, such as high yield. Marketed surplus of these crops may make their way into retail outlet reaching consumers first in rural areas then urban areas, in contrast to complementary interventions, such as fortification and supplementation, that begin in urban areas.

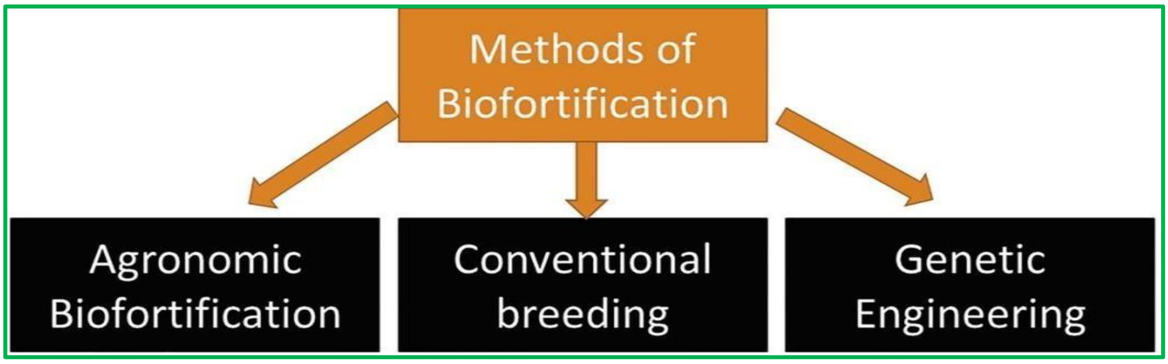
The goal of Biofortification

- The goal of bio fortification is contributed to reducing the high prevalence of specific nutritional deficiencies.
- This is to be achieved by improving the micronutrient density of staple food crops.
- Bio fortification is intended to contribute to the prevention of micronutrient deficiencies by reaching all household members.

Harvest Plus

Harvest plus was launched in 2004 with funding from the Bill and Melinda Gates Foundation the UK Department for International Development (DFID) and others. Harvest Plus is focusing on increasing levels of Zinc, and beta- carotene in seven staple crops, grown in areas of high subsistence farming, namely sweet potato, bean, pearl millet, cassava, maize, rice and wheat. Harvest plus targets different crop in different countries.

Method of Biofortification



1. **Conventional Breeding:** Conventional breeding of food crops for desired characters via controlled breeding of crop plants making them acquire or absorb and retain more nutrients. In selective breeding, scientists use

❖ Seed banks - collection of seeds usually collected in the past, which may have greater genetic variation than current varieties.
❖ Mutagenesis – a chemical or physical induction of genetic mutation used to generate new variation.
❖ Wide crosses – inter – breeding between a cultivated species and another, normally closely – related species.

Wheat is an example of sufficient variability for grain micronutrient is not available in the cultivated germplasm but wild species show a range. Wild species showed wide variation forFe and Zn. Triticum boeoticom, T. monococcum, Aegilops taushii, A. speltoides have wider range of micronutrient density.

Quality Protein Maize: High lysine mutant gene has been isolated in maize which are opaque-2, opaque-7, opaque- 16 and fluory-2. The opaque- 2 has high lysine and tryptophan contents as compared to normal maize. This is used to develop several varieties and hybrids of maize that have high quality protein. This is known as quality protein maize (Korinek et al, 2007). During the 1980s, CIMMYT took initiative to convert a number of non-QPM genotype to QPM genotype they followed a modified backcrossing-cum -recurrent selection. Two scientists Dr. S.K. Vasal and Dr. Evangelina Villages develop high quality protein maize with hard kernel, good taste and other consumer favoring characteristics.
Development of QPM genotype take place through conventional breeding and marker assisted selection. Vivek QPM was developed by transferring the opaque-2 gene into the parental inbreeds of the single cross maize hybrid, Vivek Maize Hybrid-9.

Iron pearl millet: Pearl millet is a regionally important staple in the Indian states of Maharashtra, Rajasthan, Gujarat, and Uttar Pradesh, the target area for biofortified pearl millet. Lack of Iron impairs mental development and learning capacity, and increases weakness and fatigue. Under the biofortification program, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Mahatma Phule Krishi Vidyapeeth jointly developed an open pollinated high- iron variety of pearl millet, called Dhana Shakti, which was released in 2012 in Maharashtra and later in 2013 across India, making it the first mineral biofortified product of any crop cultivar released in India. Dhana shakti has 71 mg/kg iron and 40 mg/kg zinc. It was rapidly adopted by farmers, reaching 65,000 farmers by 2015.

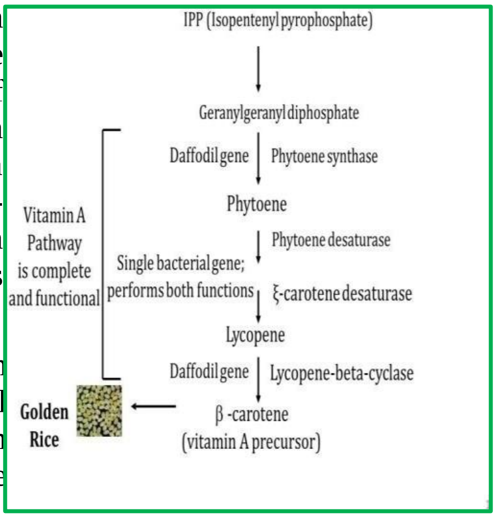
2. **Genetic Engineering:** A rapid way to introduce desirable traits into elite varieties. Transgenic strategies differ from other approaches in that novel genetic information is introduced directly into the plant's genome. Genetic engineering is the artificial

manipulation, modification, and recombination of DNA or other nucleic acid molecules in order to modify an organism or population of organisms.

Golden Rice: Golden rice was developed in Europe in 2001 by Ingo Potrykus, it is intended to use be used to reduce the vitamin A deficiency. Golden Rice technology is based on the simple principle that rice plants possess the whole machinery to synthesis of β-carotene, and while this machinery is fully active in leaves, parts of it are turned off in the grain endosperm. It is a genetically modified food crop of rice which contains β- carotene synthesis pathway is activated in the rice endosperm that's gives the characteristic golden colour.

Golden rice was developed with introducing three genes encoding the enzymes phytoene synthase, carotene desaturase and lycopene β- cyclase. Phytoene synthase (psy) gene derived from daffodils (Narcissus pseudonarcissus). Psy is a transferase enzyme involved in the biosynthesis of carotenoids. It catalysis the conversion of Geranylgeranyl diphosphate to phytoene. Carotene desaturase and Lycopene cyclase (crt1) gene isolated from soil bacteria Erwiana uredovora, produce enzymes and catalysts for the synthesis of carotenoids in the endosperm of rice.

β -Carotene Pathway Genes Added: Original Golden Rice (GR1) does not produce enough ß-carotene (Provitamin A). it produces only 1.6 µg/gm of carotenoids. Unexpected effect seen due to the insertion genes. It was supposed to produce lycopene (as in tomatoes) and so be bright red; instead, it produced ß-carotene due to unexpected metabolic pathway. Health and Environmental risks regarding GM crops. Due to this reason, there is low acceptance in public.



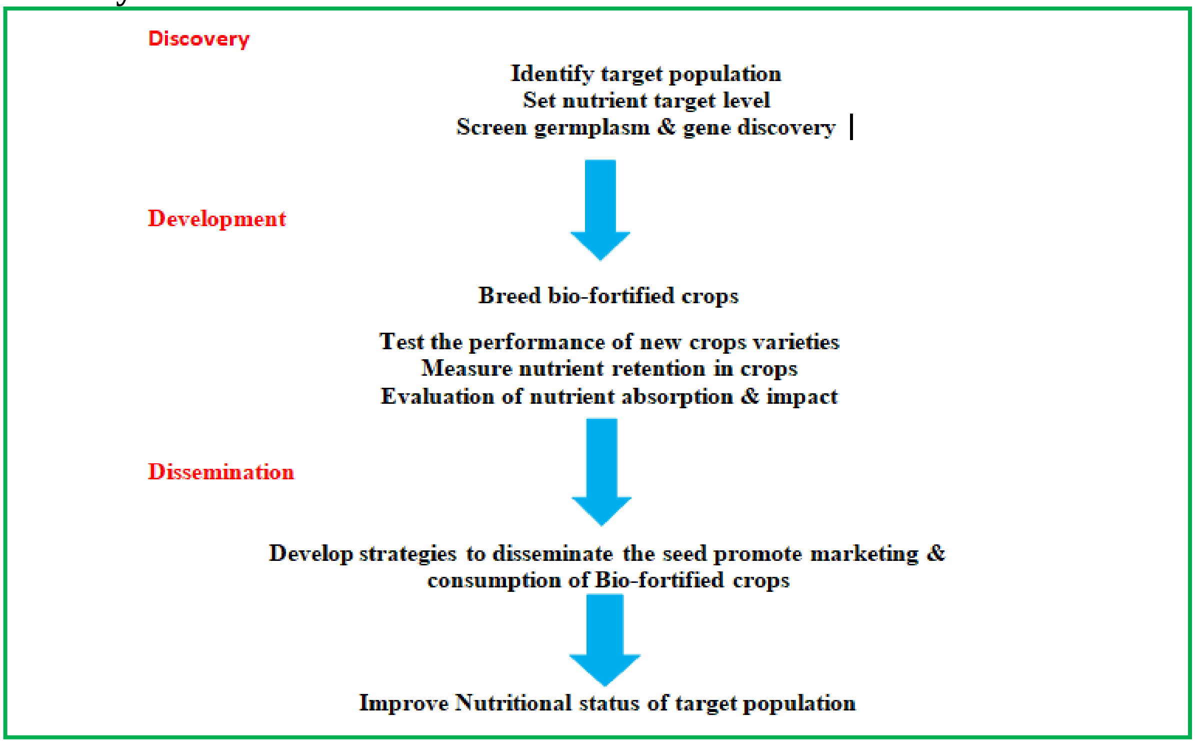
GOLDEN RICE -2: In 2005 Syngenta, produced golden rice -2. Evaluation of phytoene synthase from several plant sources led to the identification of the psy gene from maize as the most efficacious source, resulting in the greatest accumulation of total carotenoids and β- carotene. They combined, the phytoene synthetase gene (psy) from maize and the carotene desaturase gene (crtl) from Erwinia uredovora were inserted into rice. Produced up to 23 times more carotenoids than golden rice (up to 37 µg/g), and preferentially accumulates beta- carotene (up to 31 µg/g of the 37 µg/g of carotenoids).

3. **Agronomic Biofortification:** Agronomic biofortification involves fertilizer application of required nutrients for enrichment purpose. Approaches for agronomic biofortification includes adequate fertilization, method of fertilization, time of application, FYM application, crop rotation, intercropping. This strategy only works if the mineral deficiency in the grain or other edible part reflects the absence of that mineral in the soil and if the mineral fertilizer contains that mineral that are rapidly and easily mobilized.

How Biofortification: Using conventional breeding. Researchers develop new varieties with high yields and greater nutrient density, then transfer them to countries agricultural research services. Crop improvement activities for biofortification focus, first, on exploring the available genetic diversity for iron, zinc, and provitamin A carotenoids. At the same time or during subsequentscreening, agronomic and end-use features are characterized. The objectives when exploringthe available genetic diversity are to identify parental genotypes that can be used in crosses, genetic studies, molecular-marker development, and parent-building. If variation is present in the strategic gene pool (only in unadopted sources), pre-breeding is necessary prior to using the trait in final product development; if variation is present in the adapted gene pool, the materials can be used directly to develop competitive varieties. Most breeding programs simultaneously conduct pre-breeding and product enhancement activities to develop germplasm combining high levels of one or more micronutrients.

Testing in different terrain, climates; release of best varieties by varietal release committees. The next breeding steps involve developing and testing micronutrient-dense germplasm, conducting genetic studies, and developing molecular markers to facilitate breeding. Genotype x environment interaction (GxE) – the influence of the growing environment on micronutrient expression – is then determined at experiment stations and in farmers' fields in the target countries. Then it is delivered to farmers.

Pathway of Biofortification



Biofortification: The Evidence

Conventional crop breeding increase nutrient levels without reducing yield. More than 180 varieties of eleven crops, including vitamin A sweet potato, vitamin A cassava, vitamin A orange maize, iron beans, iron pearl millet, zinc rice and wheat have been officially released in 30 countries and are being tested and grown in over 30 or more. Economists are leading studies to inform delivery and marketing strategies that will maximize adoption and consumption of biofortified crops. Farmers' willingness to grow biofortified crops is investigated through farmer field day evaluations, adoption studies, as well as impact evaluation studies. These studies showed that farmers liked the various agronomic and consumption attributes of biofortified crops, and—in all cases studied—the rates of adoption and diffusion of biofortified varieties were significant and sustained. Farmers are growing and eating bio fortified crops, and consumers are buying them. Consumer acceptance study of bhakri iron pearl millet in rural Maharashtra revealed that even in absence of information about the nutrient's benefits, consumers liked the sensory attributes of iron pearl millet grain and the bhakri made from it as much as, if not more than, conventional pearl millet grain and bhakri. When nutrition information was provided, consumer acceptance and willingness to pay was even greater. Bio fortification is cost-effective centralized investment (Harvest plus, 2018).

Biofortification: Indian Scenario for Crop Improvement

The National Nutrition Strategy was launched on September 5, 2017 by NITI Aayog. Four proximate determinants of nutrition are considered viz. drinking water, food, income and livelihood and health service. The nutrition strategy envisages a **Kuposhan Mukt Bharat.**

On World Food Day 2020, during ceremony of 75th anniversary of United Nation Food and Agriculture Organization (FAO), the Prime Minister noted that common varieties of some crop lack key micronutrient that are essential for good health and thus biofortified varieties were developed to overcome these shortcomings. He also dedicated 17 recently developed biofortified varieties to the nation. The biofortified varieties mentioned by the Prime Minister include:

- zinc rice CR Dhan 315;
- wheat varieties HI 1633 rich in protein, iron and zinc, HD 3298 rich in protein and iron, and DBW 303 and DDW 48 rich in protein;
- Ladhowal Quality Protein Maize Hybrid 1, 2 and 3 rich in lysine and tryptophan;
- CFMV1 and 2 of finger millet rich in calcium, iron and zinc;
- CLMV1 of little Millet rich in iron and zinc;
- Pusha Mustard 32 with low erucic acid;
- Griner 4 and 5 of groundnut with enhanced oleic acid;
- yam variety Sri Neelima and DA 340 with enhanced zinc, iron and anthocyanin content.

These crops are rich in essential nutrients like iron, zinc, calcium, protein, lysine, tryptophan, vitamin A and C, anthocyanin, oleic acid and linoleic acid. These varieties have been developed by utilizing the local landraces and farmer varieties.

Benefits of Biofortification

- ❖ Reaching rural communities without access to pharmaceutical supplements or fortified food and improving life- time nutritional status.
- ❖ Less susceptible to social and economic changes than short term interventions.
- ❖ The potential to impact a large number of people at low cost per person

Conclusion

- ❖ Bio fortification is a cost-effective, feasible means of reaching populations who mayhave limited availability and access to diverse diets, supplements, or commercially fortified foods.
- ❖ Because bio fortification combines increased micronutrient content with preferred agronomic, quality and market traits, bio fortified varieties match or out perform theusual varieties that farmers grow and consume.
- ❖ A onetime investment in plant breeding yields micronutrient- rich varieties forfarmers to grow for years to come.
- ❖ Bio fortification is one solution among many that are needed to solve the complex problem of micronutrient deficiency.

Future Challenges

- ❖ Building consumer preference.
- ❖ To integrate biofortification into public and private policies, programmes, andinvestments.
- ❖ Production of crops for human nutrition which increased iron concentration.
- ❖ Improving the efficiency with which minerals are mobilized in the soil.
- ❖ Enhancing the mineral uptake efficiency of the important crops.

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