



Popular Article

Domain: **Agriculture Science**

Vol 5 Issue 2, Feb 2026, 158-161

Breeding for Biofortified Crops: Addressing Micronutrient Deficiencies

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[DOI:10.5281/trendsinaagriculture.18508587](https://doi.org/10.5281/trendsinaagriculture.18508587)

Abstract

More than two billion people worldwide suffer from micronutrient deficiencies, including iron, zinc, and vitamin A, which cause anemia, reduced immunity, stunted development, and cognitive impairments. Biofortification, which involves boosting key micronutrient levels in crops through plant breeding and biotechnology, is a sustainable and cost-effective technique for improving human nutrition. This article describes how biofortified crops are developed using various breeding methodologies, such as traditional breeding, molecular breeding, and contemporary genomic technologies. The main success stories, benefits, problems, and future potential for breeding initiatives are presented. Strengthening breeding efforts for biofortified crops will help eliminate hidden hunger and improve global nutritional security.

Keywords: Biofortification, breeding, micronutrient deficiencies, conventional breeding, molecular breeding, nutrition security

Introduction

Despite advances in food production, micronutrient deficiencies—also known as "hidden hunger"—remain common, particularly in underdeveloped nations. People may consume adequate calories yet lack essential micronutrients like as iron, zinc, iodine, and vitamin A (FAO, 2020). These deficits have substantial health implications, particularly for youngsters and pregnant women. Conventional therapies, including as supplements and dietary fortification, are helpful but can be expensive and difficult to maintain in resource-constrained environments.

Biofortification is an agricultural method that improves crop micronutrient content using plant breeding, genetic engineering, or agronomy. Unlike post-harvest fortification,

biofortification incorporates nutritional richness into the crop, reaching both rural and urban people through daily meals. Because grains, legumes, and vegetables are extensively consumed, breeding them for better micronutrient content is an effective strategy to enhance nutrition on a long-term basis.

➤ **Micronutrients of Concern**

The most prevalent micronutrient deficiencies include:

- Iron deficiency, leading to anemia and reduced physical and cognitive performance
- Vitamin A deficiency, causing vision impairment and weakened immunity
- Zinc deficiency, impacting growth, immune function, and reproductive health

These deficiencies are global public health issues. For example, iron deficiency anemia affects an estimated 1.6 billion people worldwide (WHO, 2021).

➤ **Breeding Approaches for Biofortified Crops**

1. Conventional Breeding

Conventional (conventional) breeding is the process of choosing parent plants with naturally high micronutrient content and crossing them to create varieties with desired features such as nutrient density, yield, and adaptability.

Steps of Conventional Breeding for Biofortification:

1. Germplasm screening to identify individuals with high micronutrient levels.
2. Crossing and selection for nutritional characteristics and agronomic performance.
3. Field examination to determine nutritional content, yield, and stability.
4. The release and distribution of new kinds to farmers.

This technique has been effective in numerous crops with adequate natural genetic diversity.

2. Molecular Marker-Assisted Breeding

Marker-assisted selection (MAS) employs DNA markers linked to nutrient-related features to speed up breeding. Rather than directly testing nutrient content, which may be expensive and time-consuming, breeders screen seedlings for genetic markers linked with high micronutrient levels.

Example: A marker associated with high grain zinc can be utilized to select breeding lines early in the breeding cycle, saving significant time and resources.

MAS improves precision and speed for generating biofortified varieties, particularly for **complex features regulated by several genes.**

3. Genomic Selection and Modern Genomics

Genomic selection employs genome-wide data to forecast breeding values for nutritional characteristics. This approach enables for the simultaneous selection of nutrient density, yield, disease resistance, and abiotic stress tolerance.

Genome editing technologies (such as CRISPR/Cas9) offer precise options to change or improve genes involved in micronutrient production or accumulation, particularly when natural variation is restricted.

- **Examples of Biofortified Crops Developed Through Breeding**

Iron-Biofortified Beans with Pearl Millet

Iron-rich beans have been discovered in Latin America and Africa, and frequent consumption has been shown to significantly increase dietary iron intake (Bouis & Saltzman, 2017). Similarly, pearl millet cultivars with high zinc and iron content have been released in South Asia.

Vitamin A-Biofortified Sweet Potato

Orange-fleshed sweet potato (OFSP) contains β -carotene, a key provitamin A molecule. The adoption of OFSP cultivars in East Africa has resulted in significant improvements in vitamin A status among children and women (Low et al., 2007).

Zinc-enriched wheat and rice.

Efforts in South Asia and Africa have produced wheat and rice lines with higher zinc levels. These types assist to treat zinc deficiency in areas where grains are the primary source of nutrition.

➤ **Benefits of Breeding Biofortified Crops**

1. Cost-Effectiveness

Once nutrient-rich varieties are released and adopted, seeds can be saved, and nutrition benefits continue without recurring costs to consumers or governments.

2. Wide Reach

Biofortification benefits rural and urban populations alike, especially in areas where industrial food fortification is impractical or costly.

3. Sustainable Nutrition Improvement

Biofortified crops improve micronutrient intake through everyday diets, reducing the need for supplements or fortified foods.

4. Integration with Existing Farm Practices

Biofortified varieties are bred for yield, stress tolerance, and disease resistance, making them compatible with farmers' existing management practices.

➤ **Integrating Biofortification into Policy and Practice**

To maximize impact, biofortification should be part of multisectoral nutrition and agriculture strategies. Actions include:

- Linking breeding programs with national nutrition goals
- Strengthening seed systems to ensure access to biofortified seeds

- Nutrition education to promote consumption of nutrient-rich foods
- Public-private partnerships to scale adoption and market access

Future Prospects

Advances in genomics, phenomics, and digital breeding technologies are accelerating the creation of biofortified crops. Integrating precision agriculture and climate-smart methods will increase productivity while boosting nutrition.

Emerging technologies, such as high-throughput screening, bioinformatics, and participatory breeding, are decreasing the obstacles to breeding nutrient-dense crops that are tailored to local conditions.

Conclusion

Breeding for biofortified crops is a practical, science-based approach to solving worldwide micronutrient deficits. Biofortification complements other nutrition initiatives by raising necessary vitamin and mineral levels in staple and horticultural crops, providing a long-term solution to hidden hunger. Significant work has been made in creating iron, zinc, and vitamin A-rich cultivars, which have both nutritional and agronomic advantages. However, attaining the full potential of biofortification necessitates powerful breeding programs, supporting legislation, enhanced seed systems, and public awareness campaigns. Biofortification, by combining agricultural, nutrition, and health goals, has the potential to alter nutritional security and improve the well-being of disadvantaged communities across the world.

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