

Agronomic Biofortification: Nourishing Communities for a Sustainable Future

Anasuya Boruah¹ and Akash Paul^{1*}

¹M. Sc (Agri.) Scholar, Department of Agronomy, Assam Agricultural University, Jorhat, 785013

ARTICLE ID: 13

Abstract

Green revolution significantly boosted food crop productivity but failed to keep pace with the growing nutritional needs of the global population, leading to rising malnutrition problems, particularly in developing countries. Micronutrient deficiencies, known as hidden hunger, hinder crop and human growth and development. Agronomic biofortification, a cost-effective approach, addresses this challenge by enhancing micronutrient content in crops through methods like integrated nutrient management, foliar sprays, and microbial applications. This method improves crop nutritional quality and when consumed, enhances human nutrition. Organic mineral forms, being more readily absorbed and less toxic, are preferred. Proper timing and dose of nutrient applications, along with soil moisture management, play crucial roles in achieving successful agronomic biofortification. With research and awareness initiatives, this approach can significantly enhance global nutritional well-being.

Introduction:

Malnutrition, often referred to as "hidden hunger," has emerged as a critical global issue, impacting approximately 2 billion people worldwide (Tulchinsky, 2010). This pervasive problem disproportionately affects women and young children in developing countries. Alarming, 151 million children under 5 are categorized as "stunted," and 51 million suffer from "wasting," indicating severe malnutrition. In India, a staggering 79.1% of children aged 3-6 and 56.2% of married women aged 15-49 battle anemia (Krishnaswami, 2009). The primary cause of malnutrition is the lack of a balanced diet, worsened by diminishing micronutrients in soil, which leads to food with reduced vitamins and minerals. Even mild to moderate micronutrient deficiencies can cause health issues like impaired metabolism, weakened immunity, stunted growth, cognitive impairment, and reduced reproductive



capacity. Mitigating malnutrition requires a two-pronged approach: direct (nutrition-specific) and indirect (nutrition-sensitive) interventions. Direct strategies include dietary diversification, micronutrient supplementation, and food fortification. Indirect interventions address the root causes of malnutrition, with biofortification as a key element. Biofortification differs from traditional fortification as it enhances the nutritional content of food crops during growth, focusing on staples like rice, wheat, and legumes. These crops are dietary cornerstones for many, especially those vulnerable to micronutrient deficiencies. This approach ensures that nutrition and food security are attainable for even the most remote and resource-constrained regions, addressing the hidden hunger that plagues our world.

Significance of minerals and vitamins in maintaining human health

Micronutrients such as Iron, Zinc, Selenium, Calcium, and β -carotene play crucial roles in human health. Iron deficiency, prevalent in staple foods like rice, wheat, and maize, leads to anemia, affecting millions globally and resulting in pallor, fatigue, cognitive impairment, and reduced work capacity. Zinc deficiency, widespread in soils, leads to various health issues, from low weight gain and diarrhea in infants to dwarfism and taste sensitivity in older individuals. Selenium's importance in human health is highlighted by its role in DNA repair, immune function, and as an antioxidant, with its deficiency associated with symptoms like fatigue, joint swelling, and increased vulnerability to infections. Calcium is fundamental for bone health, and its deficiency can lead to osteoporosis and an increased risk of fractures. β -carotene, a precursor to vitamin A, is vital, particularly in regions with vitamin A deficiency, as it helps prevent severe visual impairment, illness, and even death in children. Understanding the critical roles of these micronutrients in human health underscores the significance of addressing deficiencies through agricultural and nutritional interventions to ensure the well-being of populations, especially in developing regions where these deficiencies are most prevalent.

Need for biofortification:

The critical need for biofortification arises from the widespread prevalence of micronutrient malnutrition, affecting over 2 billion people and causing more than 20 million annual deaths (Kennedy *et al.*, 2007). Iron and zinc deficiencies, ranking 5th and 6th among global health concerns, primarily persist in low-income countries, with children and women being most vulnerable. Conventional approaches like industrial fortification and



pharmaceutical supplementation face limited reach in impoverished regions due to access and acceptability issues. Biofortification presents an innovative solution by incorporating essential micronutrients and vitamins directly into food crops, ensuring their accessibility to communities that lack access to fortified foods and supplements. To be successful, biofortified crops must meet three key criteria: they should be high-yielding and profitable for farmers, efficacious in reducing micronutrient deficiencies in humans, and acceptable to both farmers and consumers in target regions. This holistic approach offers a sustainable and practical means to combat malnutrition, addressing the critical global concern of hidden hunger at its roots.

Approaches for biofortification:

Biofortification, aimed at producing nutritious and sustainable foods, employs three primary approaches: transgenic, conventional breeding, and agronomic strategies. These approaches target staple crops such as rice, wheat, maize, sorghum, and various others. The transgenic approach is essential when limited genetic variation hampers nutrient content variation, allowing for the transfer of desirable genes across species, as exemplified by 'Golden Rice.' However, regulatory challenges and intellectual property constraints have hindered its widespread adoption. Conventional breeding leverages available genetic diversity in the primary, secondary, or tertiary gene pools to develop nutrient-enriched varieties through cross-breeding. Agronomic methods temporarily enhance crop nutrition by applying nutrients directly, contributing to improved human nutritional status. The choice of biofortification approach depends on the crop, nutrient, and genetic diversity. Biofortification plays a pivotal role in addressing malnutrition and enhancing food security, offering a multifaceted approach to improving the health and well-being of communities worldwide.

Agronomic biofortification techniques:

Agronomic biofortification is a potent strategy for enhancing the nutrient content of crops through the application of proper agronomic practices. It is an effective means of supplementing micronutrient powders and improving dietary diversity, addressing the critical issue of malnutrition. Some of the key techniques are as follows:

- a. Application of fertilizer:** This approach primarily relies on the judicious use of mineral fertilizers to increase nutrient concentrations in edible plant parts. However, its success is contingent on the intricate interplay of several factors along the pathway from soil to human consumption. Soil characteristics, crop variety, and plant-root interactions influence the

bioavailability of micronutrients from soil to crops. Crop-to-food transfer depends on the crop variety, food processing, and the allocation of nutrients in edible parts. The bioavailability of micronutrients in the food for human consumption is influenced by dietary intake, nutrient form, food processing, and host-related factors. Agronomic techniques can be further enhanced when combined with NPK fertilization and integrated soil fertility management, which optimize nutrient use efficiency and improve soil conditions. These strategies underscore the need for a holistic approach to address malnutrition, encompassing not only agronomic practices but also the selection of improved crop varieties. Understanding the complex web of factors that influence nutrient bioavailability is crucial for the success of agronomic biofortification, which holds great promise in improving human health and nutrition by increasing the micronutrient content of crops at the source.

- b. Application of microbes:** The application of microbes, particularly Plant Growth-Promoting Rhizobacteria (PGPR), Arbuscular Mycorrhizal Fungi (AMF), Cyanobacteria, and Actinomycetes, holds great potential in agronomic biofortification by enhancing nutrient availability and plant health in the rhizosphere. PGPR release growth-promoting compounds, solubilize minerals, and modify root morphology to increase nutrient uptake. AMF create an extensive hyphal network, exploring the soil more efficiently than plant roots alone, while some ecto-mycorrhizal fungi produce organic acids that mobilize nutrients. Cyanobacteria counteract pathogenic activity, stabilize the soil with allelochemicals, and sequester nutrients for plant uptake. Actinomycetes contribute by dissolving primary minerals and acting as nucleation sites for secondary minerals, facilitating nutrient absorption by plants. These microbial strategies offer a promising avenue for enhancing the nutrient concentration in crops and promoting sustainable agriculture, ultimately addressing malnutrition and hidden hunger.
- c. Application of organic matter:** Soil organic matter significantly influences soil physical, chemical, and biological properties. It enhances soil structure, porosity, and stability, making it vital for overall soil health. Organic matter not only acts as a reclamation agent for alkaline and saline soils but also plays a crucial role in nutrient supply to plants. It enhances the solubility and availability of essential minerals like iron (Fe) and zinc (Zn). Additionally, the addition of organic matter boosts microbial activity, nutrient cycling, and



ultimately results in crops with higher nutrient content, including minerals and vitamins, particularly in organic farming practices.

- d. Seed treatment:** In addressing the challenges of soil fertilization, biofortification through seed treatment offers a practical alternative. Seed treatment, involving seed priming and seed coating, proves to be a simple, cost-effective method to increase micronutrient concentration in grains. The effectiveness of seed coating depends on factors like the nutrient used, coating material, soil conditions, and nutrient-seed ratio. This approach provides a pragmatic solution to enhance crop micronutrient content, making it a valuable tool in combating malnutrition and hidden hunger.
- e. Through irrigation water management:** Since the primary mode of nutrient uptake is through mass flow and diffusion, soil moisture plays a pivotal role in influencing nutrient concentrations in crop yields. Adequate moisture levels promote robust root development and enhance nutrient solubility, making them more accessible to plants. Conversely, both water excess and deficit conditions can diminish nutrient concentration, either through leaching or restricted mobilization in the root zone. Therefore, precise irrigation management practices, when coupled with optimal soil nutrient content and physical conditions, can potentially boost the concentration of specific nutrients in the grains of certain crops.

Advantages:

Agronomic biofortification offers significant advantages, including:

1. It is applicable to crop varieties already in cultivation by farmers, known for their high consumer acceptance of the produce.
2. The potential to achieve increased micronutrient concentration in both grains and other crop parts within the same growing season.
3. Minimal micronutrient quantities are required, especially with foliar application.
4. No necessity for investing in new seed varieties.
5. Agronomic biofortification consistently presents a mutually beneficial approach for developing nations.

Constraints:

Agronomic biofortification, while holding great promise for enhancing crop nutritional quality, confronts several formidable challenges that must be addressed to realize its full



potential. One of the major hurdles is the erratic availability of micronutrient fertilizers to farmers, often resulting in the neglect of necessary applications and widespread deficiencies. Additionally, the low nutrient use efficiency for micronutrients, like iron, zinc, and copper, presents a critical limitation to their uptake by plants, underscoring the need for more efficient delivery methods. Genetic constraints further complicate matters, particularly the negative correlation between protein content and agronomic biofortification. The hidden nature of iron and zinc deficiencies, which lack readily apparent external symptoms, necessitates a concerted effort in raising public awareness about their adverse health effects. Moreover, substantial knowledge gaps persist in understanding the complex mechanisms governing mineral translocation from soil to plant, and safety concerns associated with biofortified crops require meticulous examination before their introduction to the market. Furthermore, post-harvest processing losses, particularly during the selective removal of outer tissues, remain insufficiently investigated for most crops, warranting closer scrutiny to mitigate nutrient loss. Tackling these multifaceted constraints is essential to harness agronomic biofortification's potential in addressing global micronutrient deficiencies and advancing food security.

Future Prospect

The future of agronomic biofortification holds great promise, but it requires concerted efforts across various sectors. Public institutions must take the lead in implementing policies and promotional campaigns to raise awareness and foster acceptance of biofortified crops. Offering premium prices for these products in the market can incentivize farmers to embrace biofortification practices. Awareness generation is vital, and demonstration trials on farmers' fields can help dispel misconceptions about yield losses compared to conventional methods. Strong linkages with agro-processing industries and effective extension activities, such as field demonstrations and media campaigns, can inform farmers, industries, and consumers about the benefits of biofortified crops. Policy support is equally essential, including the provision of subsidized micronutrient fertilizers, bio-inoculants, and fair market prices for biofortified grains. Integration of biofortified crops into government-sponsored programs and expanding research into nano-fertilizers can further accelerate the adoption and dissemination of fortified crops, addressing nutritional deficiencies and enhancing food security.

ConclusionIn conclusion, agronomic approaches offer a relatively rapid solution to address nutrient deficiencies in crops. Proper management practices have demonstrated significant



improvements in nutrient concentrations, especially with the fertilization of both micro and macronutrients. Organic amendments like leaf compost and farmyard manure have shown promise in enhancing micronutrient content in edible crop parts. Additionally, combining soil and foliar applications of specific nutrients has proven effective. Microbial inoculants and seed treatments also hold potential for biofortification. Overall, agronomic biofortification, complemented by various cultivation practices, presents a practical and promising strategy for enhancing the nutritional quality of crops.

References:

- Kennedy, G.L., Pedro, M.R., Seghieri, C., Nantel, G., Brouwer, I. (2007). Dietary diversity score is a useful indicator of micronutrient intake in non-breastfeeding Filipino children. *The Journal of Nutrition*. 137: 472-477.
- Krishnaswamy, K. (2009). The problem and consequences of the double burden-A brief overview. Programme and abstracts. In *Symposium on Nutritional Security for India-Issues and Way Forward, Indian National Science Academy*, New Delhi. (pp. 3-4).
- Tulchinsky, T. (2010). Micronutrient deficiency conditions-Global health issues. *Public Health Reviews*. 32: 243-255.