

Biofortification of Mungbean for Improved Nutrition

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INTRODUCTION

Mungbean (*Vigna radiata* L.) is an important legume crop cultivated widely in Asia, particularly in India. It is valued for its short duration, nitrogen-fixing ability, and adaptability to diverse agro-climatic conditions. Mungbean seeds are rich in protein (20–25%), carbohydrates, dietary fiber, and essential minerals such as iron (Fe), zinc (Zn), and folate. Despite its nutritional benefits, deficiencies of micronutrients like iron, zinc, and vitamin A remain prevalent among populations relying heavily on cereal-based diets. This condition, known as hidden hunger, leads to anemia, impaired immune function, and reduced cognitive development. Biofortification of mungbean aims to enhance its micronutrient content, thereby improving its nutritional value and contributing to food and nutritional security in a sustainable manner.

2. Concept of Biofortification

Biofortification refers to the process of increasing the concentration and bioavailability of essential nutrients in crops during plant growth rather than through post-harvest fortification.

2.1 Types of Biofortification

1. **Conventional Breeding** – Selection and hybridization of nutrient-rich genotypes
2. **Agronomic Biofortification** – Application of fertilizers (e.g., Zn, Fe)
3. **Genetic Engineering** – Use of biotechnology to introduce nutrient-enhancing genes

3. Importance of Biofortification in Mungbean

Biofortification of mungbean plays a crucial role in addressing micronutrient deficiencies, particularly iron and zinc, which are widespread in developing countries. As a commonly consumed pulse, mungbean serves as an affordable and accessible source of nutrition for rural populations. Enhancing its micronutrient content helps improve dietary quality without requiring significant changes in food habits. Biofortification is also a cost-effective and sustainable approach, as it delivers nutrients

through crops rather than relying on external supplementation or fortification programs. Moreover, the consumption of nutrient-rich mungbean contributes to better public health outcomes by reducing the prevalence of anemia, boosting immunity, and supporting overall growth and development. Given its adaptability to diverse agro-climatic conditions and short duration, mungbean is an ideal candidate for biofortification initiatives aimed at achieving long-term nutritional security.



Source: <https://link.springer.com/>

4. Nutritional Profile of Mungbean

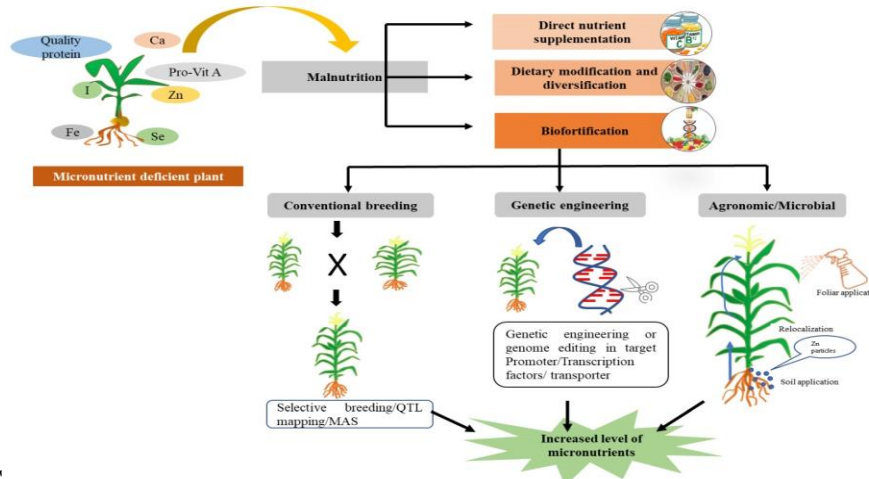
Mungbean seeds are highly nutritious, containing 20–25% protein, making them an excellent plant-based protein source. They are also rich in essential minerals such as iron (6–8 mg/100 g) and zinc (2–3 mg/100 g), along with folate and other vitamins necessary for human health. Additionally, mungbean has low fat content and is easily digestible, making it suitable for all age groups. However, the presence of anti-nutritional factors like phytates can hinder the absorption of minerals. Therefore, biofortification efforts must focus not only on increasing nutrient concentration but also on improving their bioavailability.

5. Approaches to Biofortification of Mungbean

Biofortification of mungbean can be achieved through multiple approaches that complement

each other. **Conventional plant breeding** involves screening diverse germplasm to identify genotypes with higher iron and zinc content. These selected lines are then used in hybridization and selection programs to develop improved, nutrient-rich varieties. The success of this approach largely depends on the availability of genetic variability and the heritability of target traits.

Agronomic biofortification focuses on enhancing nutrient content through external inputs such as micronutrient fertilizers like zinc sulfate ($ZnSO_4$) and iron sulfate ($FeSO_4$). Foliar sprays and improved soil management practices help increase nutrient uptake by plants. While this method provides quick results, it requires repeated application and proper management.



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Source: <https://www.mdpi.com/>

Genetic engineering and biotechnology offer advanced tools for improving nutritional quality. Techniques such as gene insertion and CRISPR/Cas9-based gene editing enable targeted enhancement of nutrient accumulation and reduction of anti-nutritional factors, thereby improving bioavailability.

Microbial biofortification utilizes beneficial microorganisms such as biofertilizers that enhance nutrient solubilization and uptake. These microbes not only improve nutrient availability but also contribute to soil health and sustainability.

6. Genetic Basis of Nutrient Enhancement

The effectiveness of biofortification largely depends on the genetic makeup of mungbean. The presence of sufficient genetic variability in germplasm allows breeders to select and improve nutrient-rich traits. Quantitative trait loci (QTLs) play a significant role in controlling micronutrient accumulation, while specific genes regulate nutrient transport and storage within the plant.

Modern breeding techniques such as marker-assisted selection (MAS) help in the precise identification and transfer of desirable traits, thereby accelerating the development of biofortified varieties.

7. Role of Anti-Nutritional Factors

Mungbean, despite being a nutrient-rich pulse, contains certain anti-nutritional factors such as

phytates and tannins that can significantly reduce the bioavailability of essential minerals like iron and zinc. Phytates bind with minerals to form insoluble complexes, making them less absorbable in the human digestive system, while tannins can interfere with protein digestibility and mineral utilization. These compounds, although naturally present, pose a major limitation in achieving the full nutritional potential of mungbean.

Biofortification strategies, therefore, not only focus on increasing the concentration of nutrients but also aim to reduce the levels of these anti-nutritional factors. Approaches such as selective breeding, genetic modification, and processing techniques are used to lower phytate and tannin content. Enhancing nutrient bioavailability ensures that the body can effectively absorb and utilize the minerals present in mungbean, thereby improving its overall nutritional impact.

8. Recent Advances in Mungbean Biofortification

Recent advancements in science and technology have significantly accelerated the biofortification of mungbean. Researchers have successfully developed varieties with higher iron and zinc content through conventional breeding and advanced molecular techniques. The use of genomic tools and molecular markers has enabled precise identification of genes associated with nutrient accumulation.

Integration of omics technologies, including genomics and proteomics, has provided deeper insights into the metabolic pathways and gene functions involved in nutrient enhancement. Furthermore, CRISPR-based gene editing has emerged as a powerful tool for targeted modification of genes, allowing scientists to improve nutrient content and reduce anti-nutritional factors with greater accuracy and efficiency.

9. Impact on Human Health

Biofortified mungbean has a significant positive impact on human health, particularly in regions where micronutrient deficiencies are prevalent. Increased iron content helps in reducing iron deficiency anemia, especially among women and children. Enhanced zinc levels contribute to improved immune function, reducing susceptibility to infections.

Regular consumption of nutrient-rich mungbean supports better growth and cognitive development in children. It also plays an important role in maternal health by providing essential nutrients required during pregnancy and lactation. Overall, biofortified mungbean contributes to improved nutritional status and quality of life.

10. Challenges in Biofortification

Despite its potential, biofortification of mungbean faces several challenges. Limited genetic variability for certain nutrients restricts breeding progress. There is often a trade-off between high yield and nutrient content, making it difficult to develop varieties that excel in both aspects. Environmental factors such as soil type, climate, and management practices also influence nutrient accumulation in crops.

Additionally, lack of awareness among farmers about biofortified varieties hinders their adoption. Policy and market constraints, including inadequate support systems and low consumer awareness, further limit large-scale implementation. Addressing these challenges is essential for the successful promotion and adoption of biofortified mungbean.

11. Strategies for Promotion

Effective promotion of biofortified mungbean requires a multi-dimensional approach.

Strengthening breeding programs is essential to develop high-yielding, nutrient-rich varieties with improved adaptability. Farmer awareness campaigns play a crucial role in educating farmers about the benefits of biofortified crops and encouraging their adoption. Government support through favorable policies, subsidies, and inclusion in agricultural schemes can accelerate dissemination. Additionally, integrating biofortified mungbean into public health programs such as mid-day meals and nutrition missions can enhance its reach and impact on vulnerable populations.

12. Future Prospects

The future of mungbean biofortification is promising with advancements in modern technologies. Integration of genomics and artificial intelligence will enable faster and more precise breeding of nutrient-rich varieties. Development of climate-resilient mungbean varieties will ensure stability under changing environmental conditions. Precision agriculture techniques will further enhance nutrient efficiency and crop management. Moreover, strengthening extension services and digital platforms will help scale up adoption among farmers, ensuring wider impact on nutritional security.

CONCLUSION

Biofortification of mungbean is a promising strategy to combat hidden hunger and improve nutritional security. By combining conventional breeding, agronomic practices, and modern biotechnology, it is possible to develop nutrient-rich mungbean varieties that are both productive and sustainable. Continued research, policy support, and farmer participation are essential to realize the full potential of biofortification in improving human health.

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